DESIGN & FABRICATION OF 3-PHASE PWM RECTIFIER FOR IMPROVEMENT OF POWER FACTOR

Major Project Review

Submitted in partial fulfillment of the requirements

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IN

ELECTRICAL ENGINEERING

(Power Electronics, Machines and Drives)

By

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I, **Jwal M. Trivedi**, Roll No. **12MEEP40**, give undertaking that the Major Project entitled **"Design and fabrication of three phase PWM rectifier for improvement of power factor."** 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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Certificate

This is to certify that the Major Project Report (Part-II) entitled **" Design and fabrication of three-phase PWM rectifier for improvement of power factor"** submitted by **Jwal M. Trivedi (Roll No:12MEEP40)** towards the partial fulfillment of the requirements for semester-IV of 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 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

Today, when the world is heading towards the acme of technology, power electronics field is seemed to be of great significance. Seeing to it power electronics converters are to be designed due to the booming requirement. Here in the below dessertation three phase ac to dc PWM(Pulse Width Modulation) rectifier is designed for achieving unity power factor in utility line current and voltage and simultaneously achieving constant dc at the output side. For achieving this task, simulation is developed by designing two control loops. One is innercurrent loop which deals with ac qauntity and maintains unity powerfactor at the input and outer voltage loop which deals with dc quntity and maintains constant dc. The technique for the PWM(Pulse Width Modulation) pulses which are to be implemented for the swiching device is SPWM(Sine Triangular Pulse Width Modulation) technique. With that fabrication work is to be carried out for achieving the above aim. For generating the SPWM(Sine Triangular Pulse Width Modulation) pulses for the hardware set up PIC(Peripheral Interface Controller) microcontroller is used. SPWM pulses are obtained through PIC controller. Here the SPWM(Sine Triangular Pulse Width Modulation) pulses should be developed and implemented through PIC(Peripheral Interface Controller) such that unity power factor and constant dc at the output are achieved. This converter provides with fast dynamic response and low

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Abbreviation

SPWM .... Sine Triangular Pulse Width Modulation

PWM .... Pulse Width Modulation

PIC .... Peripheral Interface Controller

SMPS .... Switched Mode Power Supplies

ADS .... Adjustable Speed Drives

UPS .... Uninterrupted Power Supplies

BESS .... Battery Energy Storage Systems

IGBT .... Insulated Gate Bipolar Transistor

MOSFET .... Metal Oxides Field Effect Transistor

GTO .... Gate Turn Off Thyristor

SMRs .... Switched Mode Rectifiers

PFC .... Power Factor Rectifiers

AF .... Active Filters

THD .... Total Harmonic Distortion

ADC .... Analog To Digital Converter

Chapter 1

Introduction

1.1 Introduction and Overview

There are several conventional methods by which the output dc voltage can be controlled, e.g. a diode bridge with a tap changing transformer or an auto-transformer, as shown in fig.1.1. Although this method is simple but suffers from the demerits due to size, weight and cost of transformer. This type of control scheme was used to control dc voltage hence speed of dc motors used in electric traction of Indian Railways. In case of an ac-to-dc phase controlled switching, the phase controller works as an ordinary contactor switch. For a certain period of time, the switch is closed (on), thus the input supply reaches to load and the output voltage can be obtained. Similarly, for the certain period of time the switch is open (off), thus the input voltage does not reach the load. Thus, instead of the complete input voltage reaching the load, the switch (phase controlled converter) slices the input voltage and only its part reaches the load. In this arrangement no transformer is required. Thus, the size, weight and cost reduce and efficiency is high.

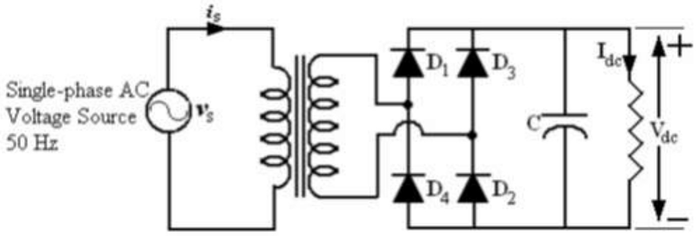


Figure 1.1: Diode bridge type ac-to-dc converter

Above shown is the figure for diode bridge rectifier for the single phase system. Here the output dc is obtained across the capacitor.

1.2 Classification of Converters

The converters can be classified according to supply system, devices used in the circuits and as per application. The general classification of ac-to-dc converter is shownin fig.1.2. The simulation of the single phase diode bridge rectifier is performed by considering various parameters according to the parameters of proposed front-end converter. The simulink model, waveforms for dc link voltage, source voltage and line current and the result for the THD of the line current for diode bridge type ac-to-dc converter are shown in fig.1.3, 1.4 and 1.5 respectively. AC-to-DC Converters

a. Single-Phase Type

b. Three-phase Type

Single-phase Type

a. Uncontrolled converter

b. Controlled converter

Uncontrolled Converter

a. Half wave

b. Full wave

Controlled Converter

a. Half wave

b. Full wave

Half wave uncontrolled converter

a. Half wave without Df

b. Half wave with Df

Half wave controlled converter

a. Half wave full converter without Df

b. Half wave semi converter with Df

Full wave controlled converter

a. Full wave full converter without Df

b. Full wave semi converter with Df

Specifications of single phase diode bridge rectifier are:

a. Input Voltage = 1432 Volts

b. Output Voltage = 2000 Volts

c. Supply Frequency = 60 Hz

d. DC Link Capacitor = 10000 μF

e. Load Resistance = 40 Ω

Simulink model and waveforms of single phase diode bridge rectifier:

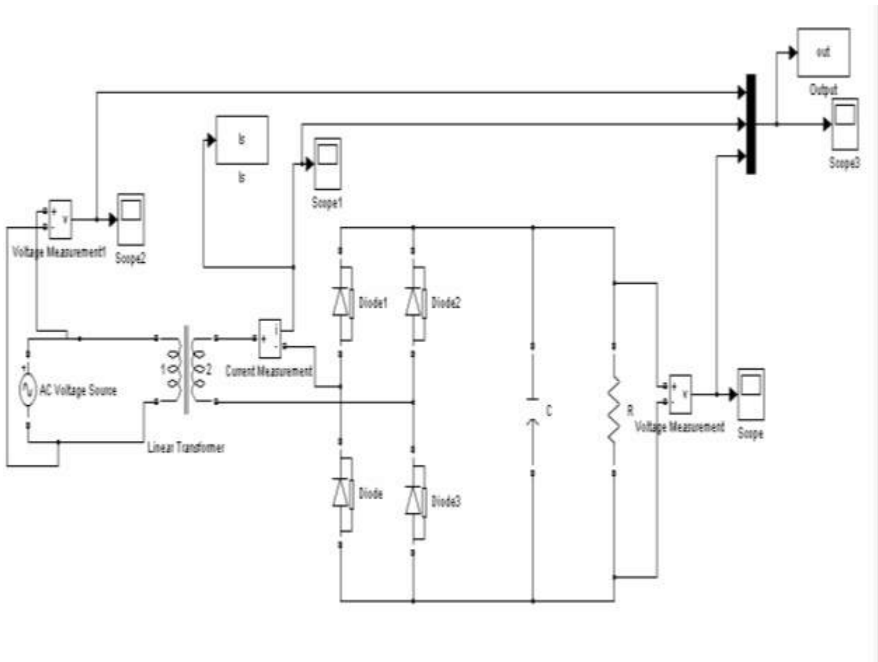


Figure 1.2: Simulink model of diode bridge rectifier

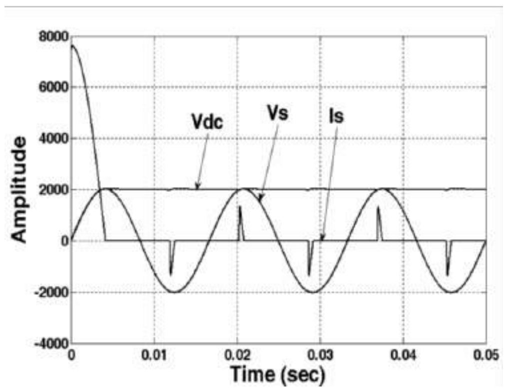


Figure 1.3: Waveforms for V_s, V_{dc} and I_s of single phase diode bridge rectifier

Waveforms for the voltage and current are shown above in the figure. There are high charge current spikes are obtained.

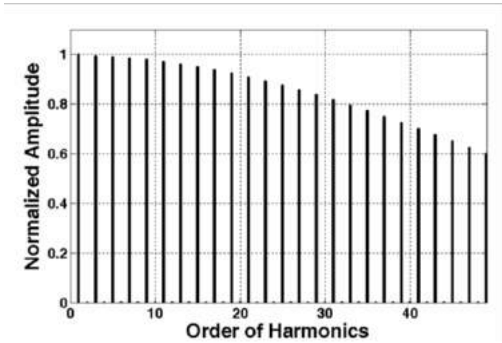


Figure 1.4: Normalized harmonic spectrum of line current for single phase diode bridge rectifier

The harmonics for the diode bridge rectifier are obtained and are around 328.5% which are very high.

1.3 Literature Review

Solid state acdc conversion of electric power [2] is widely used in adjustable-speed drives (ASDs), switch-mode power supplies (SMPSs), uninterrupted power supplies (UPSs), and utility interface with non conventional energy sources such as solar PV, etc., battery energy storage systems (BESSs), in process technology such as electroplating, welding units, etc., battery charging for electric vehicles, and power supplies for telecommunication systems, measurement and test equipments. Conventionally, acdc converters, which are also called rectifiers, are developed using diodes and thyristors to provide controlled and uncontrolled dc power with unidirectional and bidirectional power flow. They have the demerits of poor power quality in terms of injected current harmonics, caused voltage distortion and poor power factor at input ac mains and slow varying rippled dc output at load end, low efficiency and large size of ac and dc filters. In light of their increased applications, a new breed of rectifiers has been developed using new solid state self commutating devices such as MOSFETs, insulated gate bipolar transistors (IGBTs), gate turn-off thyristors (GTO), etc., even some of which have either not been thought or not possible to be developed earlier using diodes and thyristors. Such pieces of equipment are generally known as converters, but specifically named as switch mode rectifiers (SMRs), power-factor correctors (PFCs), pulse width-modulation (PWM) rectifiers, multilevel rectifiers, etc. Because of strict requirement of power quality at input ac mains several standards have been developed and are being enforced on the consumers. Because of severity of power quality problems some other options such as passive filters, active filters (AFs), and hybrid filters along with conventional rectifiers, have been extensively developed especially in high power rating and already existing installations. However, these filters are quite costly, heavy, and bulky and have reasonable losses which reduce overall efficiency of the complete system. Even in some cases the rating of converter used in AF is almost close to the rating of the load. Under these observations, it is considered better option to include such converters as an inherent part of the system of acdc conversion, which provides reduced size, higher efficiency, and well controlled and regulated dc to provide comfortable and flexible operation of the system.

a. Thiyagarajah, K., Ranganathan, V.T., Iyengar, B.S.R.
   In the paper titled A high switching frequency IGBT PWM rectifier/ inverter system for AC motor drives operating from single phase supply authors have explained a PWM rectifier/ inverter system using insulated gate- bipolar-transistors (IBGTs), capable of switching at 20 kH_z is reported. The base drive circuit for the IGBT, incorporating short circuit protection is presented. The inverter uses Undeland snubber together with a simple energy recovery circuit, which ensures reliable and efficient operation even for 20 kH_z switching. The front-end for the system is a regenerative single phase full-bridge IGBT inverter along with an ac reactor. Steady-state design considerations are explained and control techniques, for unity power factor operation and fast current control of the front-end converter, in a rotating as well as a stationary reference frame, are discussed.

b. P.N. Tekwani, Dhaval Patel

   In the paper titled Design and Simulation of a PWM Regenerative Front-End

Converter authors presented the simulation results of a new control scheme for a pulse width modulation (PWM) rectifier which provides unity power factor as well as very low percentage of total harmonic distortion (THD) in ac supply side current. The design considerations for the proposed control scheme and the method of obtaining the PI controller tuning parameters are discussed. For the proposed control scheme, simulation results are obtained for various levels of loading, observing the output dc voltage ripple, unity power factor condition and harmonic content in ac side supply current. Both motoring (forward power flow) as well as regenerative (reverse power flow) mode of operation of the rectifier have been considered.

c. Swami H.

In the paper titled Harmonic resistance emulator technique for single phase unity power factor correction author suggested a new technique (to be called as Harmonic Resistance Emulator) for single-phase power factor correction using the typical full-bridge active front-end converter is proposed. Unlike conventional single-phase power factor correction circuits, which make use of a single switch boost converter, this technique employs the full bridge converter to be operated in sine-triangle PWM (pulse width modulation) mode. Two schemes of the proposed technique are discussed. One is the input-current sensor less scheme and the other is input-voltage-sensor less scheme.

d. Ya-Gang Wang, Hui-He Shao

In the paper titled Automatic tuning of optimal PI controllers authors explains that the PI controller is unquestionably the most commonly used control algorithm in the process control industry. PI controllers have traditionally been tuned empirically, e.g. by the method described in Ziegler and Nichols. This method has the great advantage of requiring very little information about the process. There is, however, a significant disadvantage because the method inherently gives very poor damping. Hang modified Ziegler-Nichols tuning formula, which improve the performance of PI controllers. A method for auto tuning optimal PI controllers is proposed. The PI auto tuner first introduce relay feedback experiments to identify a second-order plus dead time mode1, PI controller is then designed based on the proposed robustness specification and integrated error optimum. Simulation examples show that the proposed PI auto tuner gives satisfactory performance for different types of processes.

Chapter 2

Front End Converter

2.1 Introduction of Front End Converter

Here in this chapter dealing with the converter section is done, its design, control strategy used, switching pattern and switch used and also required calculation done. Topology used is front end converter, and for this topology is switch is IGBT. An IGBT is a voltage controlled device similar to that of power MOSFET. It has lower switching and conduction losses. In addition to this, it has some features of MOSFET like ease of gate drive, peak current, capability and ruggedness. An IGBT combines the advantages of BJTs and MOSFETs. And IGBT has high input impedance like MOSFETs and low on-state conduction losses like BJTs. An IGBT is inherently faster than BJT, but its switching speed is inferior to that of MOSFET. But still it is preferred because current rating of single IGBT can be up to 1200V, 400A and its switching frequency can be upto 20 kH_z. High switching frequency inverters are desirable for ac motor drives, as they permit the operation of the drive with practically sinusoidal stator current and fast current control for high dynamic performance. In addition the audible noises can be reduced at switching frequencies of the order of 20 kH_z. In comparison to conventional open loop voltage PWM converters, the current-controlled PWM (CC PWM) converters have the following advantages:

a. Control of instantaneous current waveform and high accuracy

b. Peak current protection

c. Extremely good dynamics

d. Compensation of effects due to load parameter changes (resistance and reactance)

e. Compensation of the semiconductor voltage drop and dead times of the converter

f. Compensation of the dc-link and ac-side voltage changes.

Hence, this project pertains to a designing of a current controller for a general Power Electronics Converter that may be either an inverter or rectifier. The front end converter is reported here, which operates at unity power factor at all loads. It also exhibits forward and reverse power flow. This proposed converter consists of two converters connected in parallel across the load. This is done so as to suppress the harmonic currents in the mains and reduce ripple content at the dc link. The front end converter was implemented in single phase and three phase system and simulations results were obtained. And, it was found that it was able to maintain constant voltage and unity power factor with less THD (Total Harmonic Distortion) in input current at all load condition as compared to diode bridge rectifier. The power circuit of the Front End Converter, its control loop design and implementation of control loop with power circuit is reported in further sections.

2.2 Rectifier System and modulation techniques

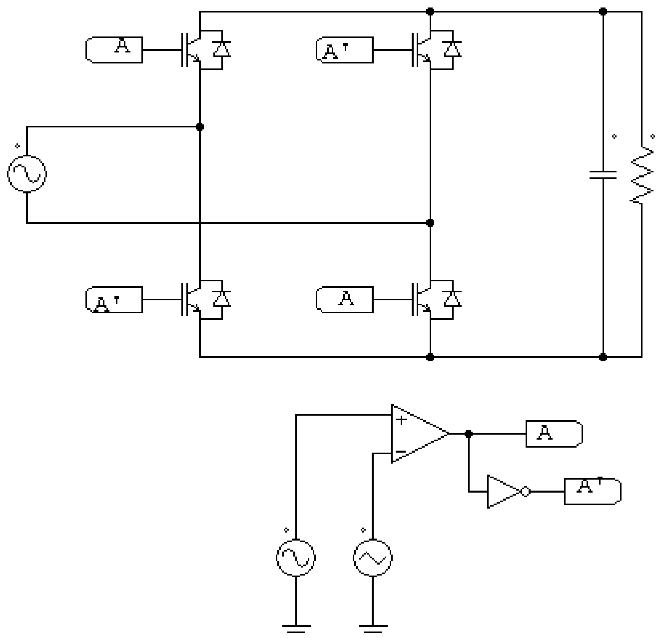


Figure 2.1: Single phase rectifier system

Above shown is the single phase rectifier system. Here there are four IGBTs used for generating dc output. Basically a converter is used to convert an input signal to proportionately another form of output signal. Hence it is called converter. If the converter is rectifier, then it will convert from ac to dc, whereas if the converter is inverter then it will convert from dc to ac. For this it uses two kinds of modulation techniques namely bipolar and unipolar modulation scheme. Each scheme has its own gating sequence and consequently advantages and disadvantages.

Bipolar modulation

In bipolar modulation scheme, the reference sine wave (V_m) is compared with triangular carrier wave (V_{cr}). When $V_m > V_{cr}$, IGBT 1 is turned ON and when $V_m < V_{cr}$, IGBT 3 is turned ON. Here, IGBTs of the same leg act in a complimentary manner, i.e. when IGBT 1 is ON then IGBT 2 should be OFF and vice-versa. Same is the case with leg-B. For simulation purpose, the NOT gate was used to implement the complementary action for the IGBTs of the same leg. Modulation index is taken to be 0.8. And the carrier wave frequency was taken to be 550Hz (50 *11 = 550 H_z).

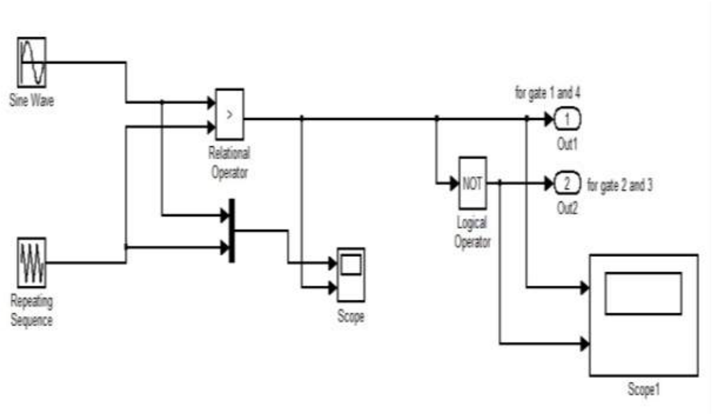


Figure 2.2: Circuit for bipolar modulation scheme

Circuit for the bipolar modulation is shown where the comparison of sine and triangular signals is done and accordingly pulses are obtained.

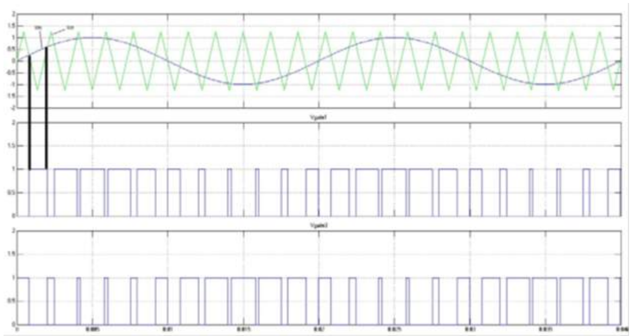


Figure 2.3: Waveforms of bipolar modulation scheme

From the bipolar modulation technique, pulses for the gate are obtained which are bipolar in nature.

Hence as shown, the voltages V_{an} and V_{bn} appear as gate pulses 1 and 3 appear respectively. And the resultant voltage is V_{ab}=V_{an}-V_{bn}. Since the output voltageV_{ab}, is switching between $+V_d and - V_d$, hence this scheme is called bipolar modulation.

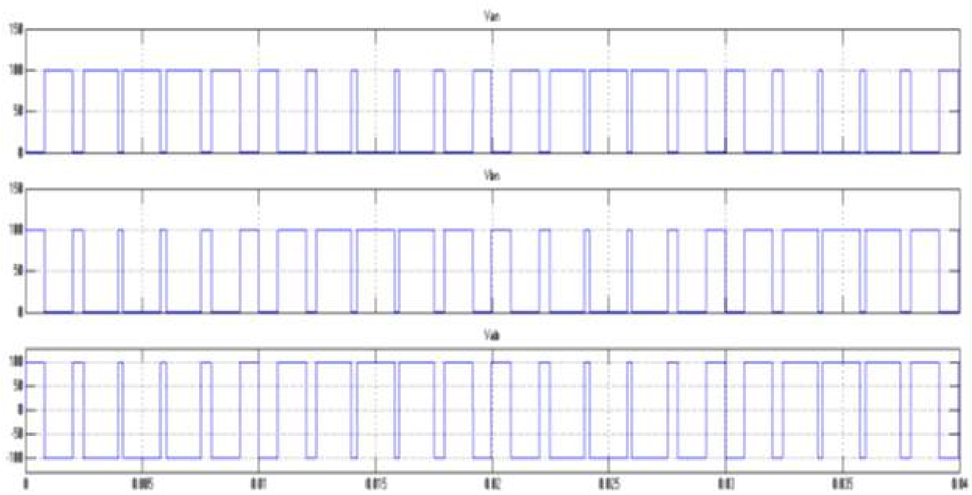


Figure 2.4: Waveforms of bipolar modulation scheme with phase voltage

Here waveforms for the bipolar modulation schemes are obtained with respect to the phase voltages.

Unipolar Modulation

Unipolar modulation can be obtained in two ways- either by using two 180degree phase shifted sine waves or two 180degree phase shifted triangular waves. For the latter one, switch S_1 (IGBT-1) will be turned ON when $V_m > V_{cr}1$ and switch S_3 (IGBT-3) will be turned ON when $V_m < V_{cr2}$, where V_{cr1} and V_{cr2} are the triangular waves 180degree phase shifted and V_m is the reference sine wave. Similarly, for the former one where two sine waves are used, switch S_1 is turned ON when $V_{m1} > V_{cr}$ and switch S_3 is turned ON when $V_{m2} > V_{cr}$, where V_{m1} and V_{m2} are the sine waves 180degree phase shifted. But in both the cases, each switch acts in complimentary manner of other of the same leg i.e. when S_1 is ON, S_2 will be OFF and vice-versa. Same applies to the other leg also. Here the gate pulse for S_1 and S_3 is only shown, since it is understood that S_2 and S_4 will be complimentary of S_1 and S_3 respectively.

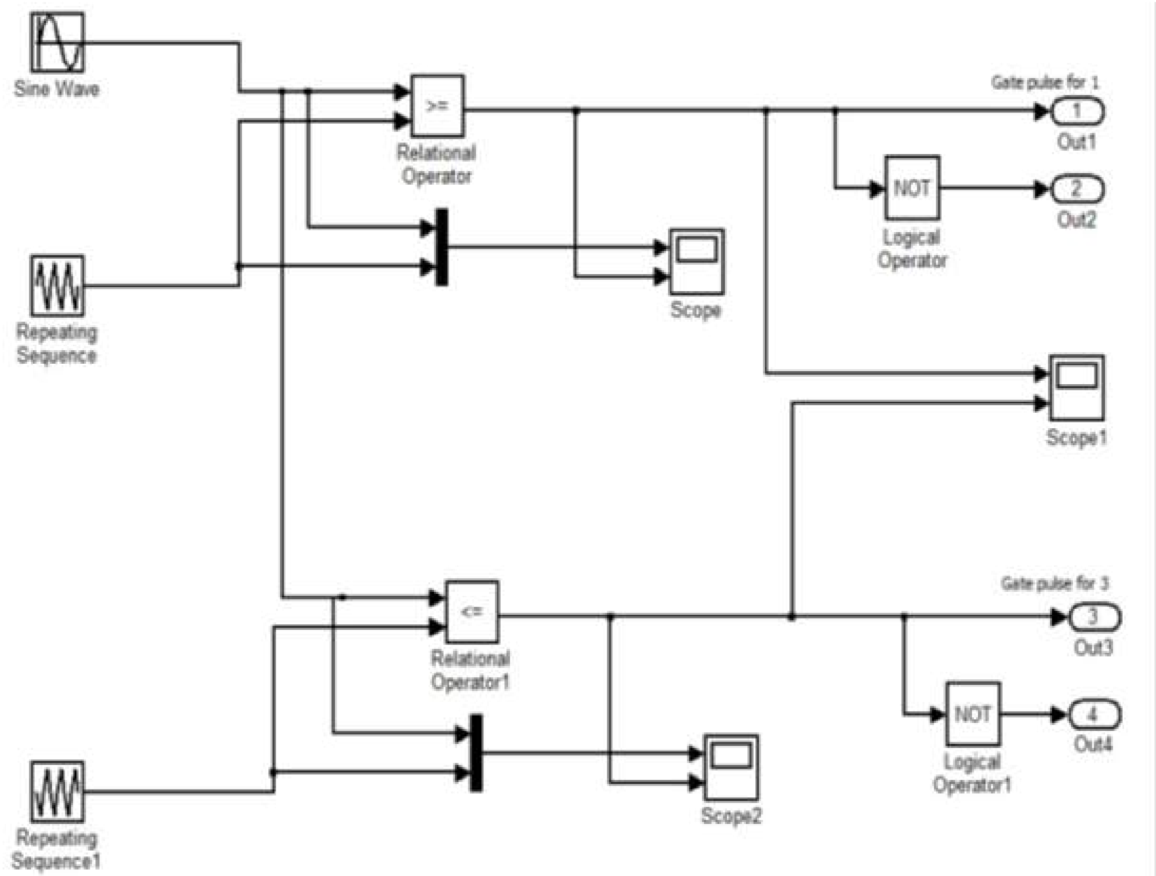


Figure 2.5: Circuit for Unipolar scheme using two Triangular waves

VoltagesV_{an} and V_{bn} appear as the gate pulse 1 and 3 appear respectively. The waveforms of output voltages are shown, the resultant output voltage V_{ab}=V_{an}-V_{bn}. Since the output voltages transit between 0 to V_d or 0 to $-V_d$, hence this scheme is called unipolar modulation scheme.

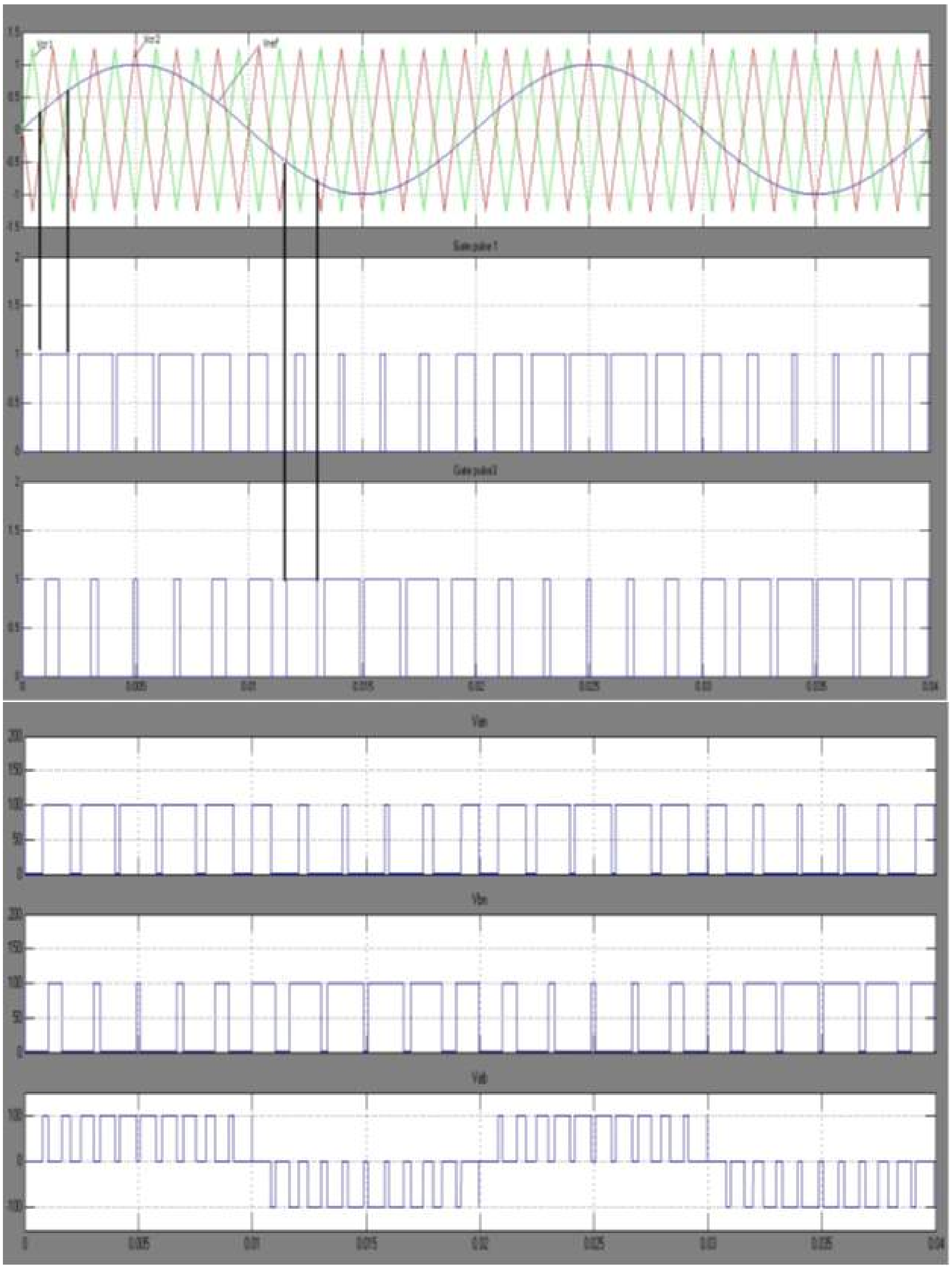


Figure 2.6: Waveforms for the unipolar modulation scheme.

Similarly this unipolar technique can used by applying two sine ways and one triangular waves and their comparison is obtained.

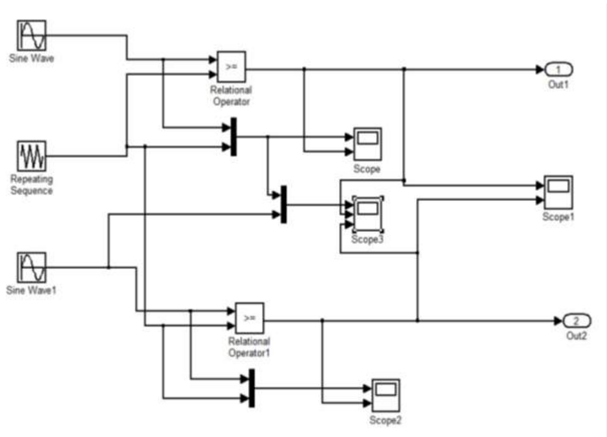


Figure 2.7: Circuit for unipolar modulation using two sine waves

Above shown is the circuit for unipolar modulation technique is shown and where two different sine waves and triangular waves is done.

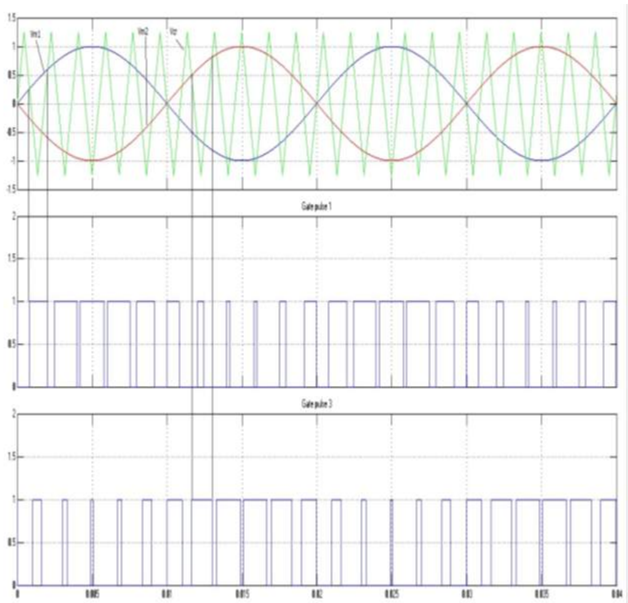
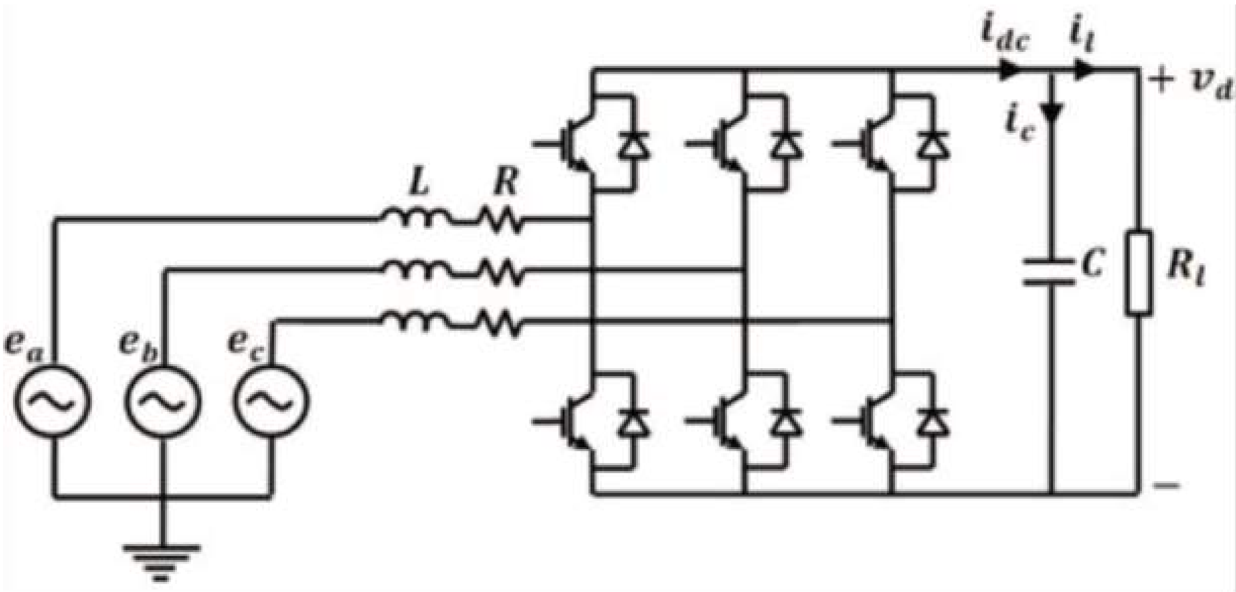


Figure 2.8: Gate pulses of Unipolar scheme using two Sine waves

Now using unipolar modulation technique can be used for providing gate pulses to the IGBT for maintaining constant dc at the output. Here the topology for the front end converter system used is explained in with complete description.

2.3 Front End Converter Topology description

In front end converter topology we are converting ac signal to dc signal. For maintaining constant dc at the output and simultaneously achieving unity power factor at the input side. Here SPWM technique is implicated for providing gate pulses to the six IGBTs. There should be comparison made of three sine waves and one triangular wave. Figure for the topology is shown below.



Front End Converter Topology

In the above topology inductor is used for the boosting of the voltage provided to the converter. And at the output side capacitor is used to maintain constant dc at the output. Resistive load is connected at the output. Here converter input voltage is formed by equating supply voltage and supply current.

$$V_r = \sqrt[2]{Vs^2 + (I_s X_s^2)} \tag{2.1}$$

$$V_{rfl} = \sqrt[2]{(1 + X_{pu}^2)} \tag{2.2}$$

$$X_{pu} = \frac{Is_{(FL)} X_s}{V_s} \tag{2.3}$$

The above equation implies that Vr is greater than Vs by a factor $(1 + X_{pu}^2)^{1/2}$, which is known as boost factor. Hence the range of Vr can be given as $V_s < V_r < V_s\ (1 + X_{pu}^2)^{1/2}$ This maximum value of V_r is decided by the maximum value of phase separation δ, which occurs under full load condition. The minimum value of modulation index is decided by the fact that the minimum value of V_r is equal to V_s.

Here in this control scheme also the first and fourth IGBTs are complimentary to each other. They require dead band to each other so that simultaneous trigger dont take place because if such situation take place than failure of IGBTs occur. Same is the case with the rest of the two phases. There would be two close loops for the present topology. One is current control loop and other is voltage control loop. Inner loop would be current loop for maintaining unity power factor and outer loop would be voltage loop which maintains constant dc at the output. The description would be provided below for the two loops. The output dc voltage is controlled by comparing input power from the converter to the output power demanded by the load, while maintaining unity power factor at all loads. For this, two control loops-voltage control loop and current control loop (faster loop) were proposed. The outer voltage loop is working on dc quantities whereas the inner current loop is working on ac quantities.

Current Control Loop Design

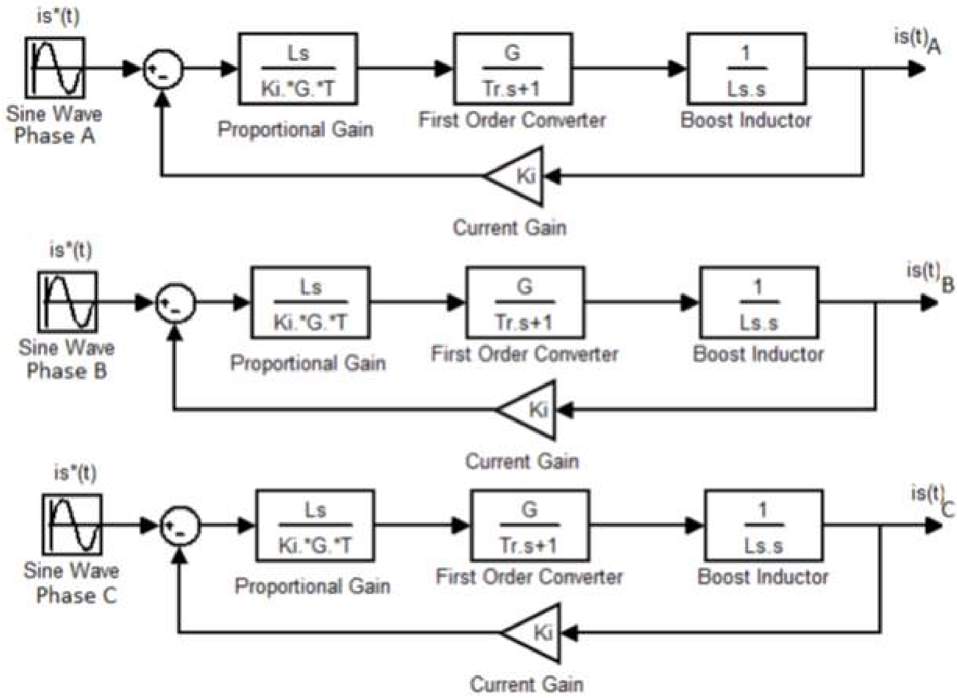


Figure 2.9: Current loop design

Current control loop is inner control loop amd completely deals with the ac quantities and works fast compared to voltage control loop.

$$V_r(t) = V_s(t)G - L_s * k_i * GT[i_s(t) - i_s(t) * k_i] \tag{2.4}$$

Here G is the gain of the converter.

- $G = m * Vdc$
- $K_i = 1/ratedpeakcurrent$
- $V_s = supplyvoltage.$
- $T = triangularcarrierperiod$

Here in this control loop the reference current is compare with the actual current and then the output of the comparison is given to the proportional block. Proportional block is provided to the first order converter which is rectifier system itself. And from the output of the first order system again the current gain is taken as the feedback and the loop works again. As inner current loop should be operating faster (i.e., respond to change in $I_s(t)$), $V_s(t)/G$ should be a feed forward component in the current control loop. Feed forward components are used to reduce burden on other controllers, so the dynamic response does not become sluggish.

Voltage Control Loop Design

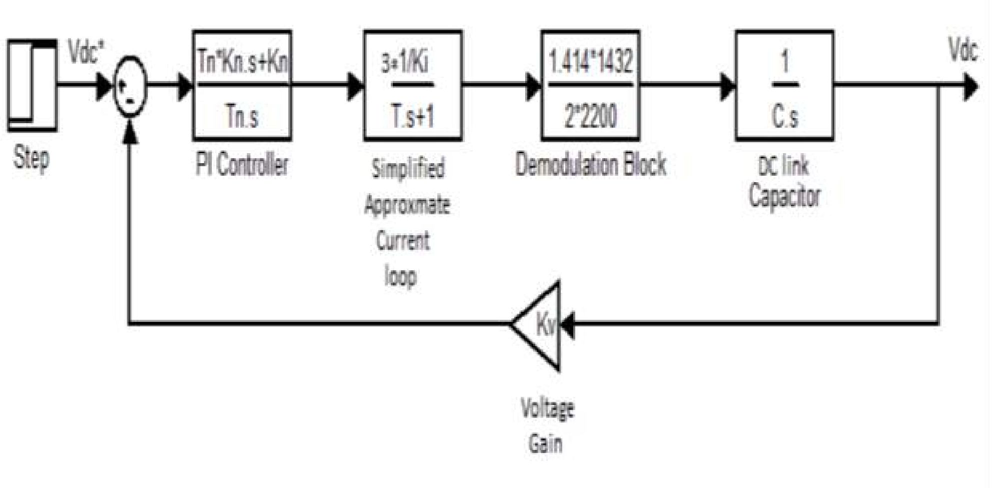


Figure 2.10: Voltage Control Loop

Above shown is the voltage control loop which is outer control loop and deals with dc quantities and is slow compared to inner current loop.

Here above shown is the voltage control loop. Actual dc voltage is compared with the reference dc voltage. And the error obtained is given to minimise the error and that output obtained is given to the current control loop shown above. Then from the output obtained from the current loop is given to the demodulation block which converts ac quantity into dc quantity.

And dc quantity obtained from the demodulation block is given to the dc link capacitor. Again from the dc link capacitor voltage gain is obtained and the system works accordingly. By this we can minimise the error between the actual and reference and can maintain constant dc link. at the output.

- $Kv = Voltagegain = 1/referencevoltage$
- $K_n = (K_i * V_{dc}C)/3 * (2)1/2 * K_v * V_s * T$
- $T_n = 8T_r$

Chapter 3

Design and Simulation of Front End Converter

3.1 Design of Front End Coverter

Now here the simulation design and its output waveforms are observed. The topology for the front end converter is formed below. There would be six IGBTs used and accordingly triggering would be done.

Here above shown is the front end converter circuit. There are inductors connected at the input side of the converter which is boost inductor. Sine triangle PWM pulses are given to the IGBTs for maintaining unity power factor at the input side and constant dc at the output.

Calculations:

- $V_s = SupplyVoltage$ =30V
- $Vs_{rms} = V_r(p_k)/1.414$ =21.21V
- $I_s(pk) = 1.3A$
- $I_s(rms) = Rated(rms)i/pCurrent$ = (P/Vs)*Efficiency =1.06A
- $(L)^2 = ({V_r}^2 - {V_s}^2)/(w)^2 * (Is_{pk})^2\ 10 - 6 = (V_r^2 - 900)/(98596)(1.5)^2$

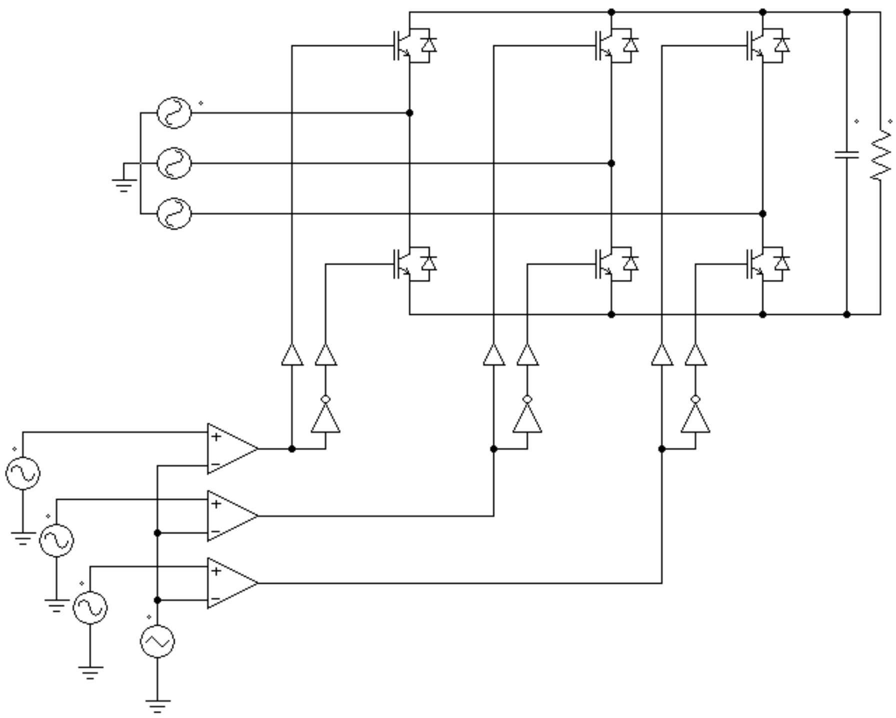


Figure 3.1: Circuit of Front end Converter

- $Vr_{(pk)=m*V_{dc}}$ = 30V
- $Vr_{(1phase)} = ((3) * (3)1/2/2)(30) = 77.94$
- $V_{dc} = 97.42$
- $L_s/(K_i * G * T) = (10^-3)/(1/15) * (30)(2 * -1.818 * 10^-3)$ =0.01375
- $K_v = 1/97.42$
- $K_i = 1/15$
- $K_n = (4 * K_i * V_dc * C)/(3 * 21/2 * K_v * V_s * T_n)$
  $K_n = 4*0.67*97.42*5000*106/(3*21/2*(0.01026)*(21.21)*(8*1.818*10-3))$
  $K_n = 97.21$

3.2 Simulation Results

Waveforms of Gate pulses results for the IGBTs:

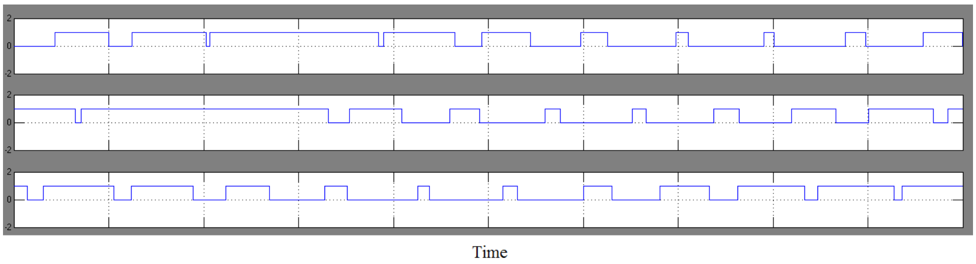


Figure 3.2: Waveforms of IGBT gate pulses

Gate pulses for the IGBT are obtained and are shown in the above waveforms. These gate pulses are obtained through comparison of the sine and triangulare signals. These pulses are to be given to the IGBT which are generated by the SPWM technique by unipolar or bipolar modulation scheme. The gate pulses which are generated will trigger the IGBT and hence unity power factor and constant dc at the output are obtained.

- Inner Current Loop

Here below shown is the circuit for the inner current loop. This circuit deals with ac quantity and is fast loop in working compared to the outer loop. Through this loop, unity power factor at the input side and system becomes efficient. The calculation for this loop is shown above.

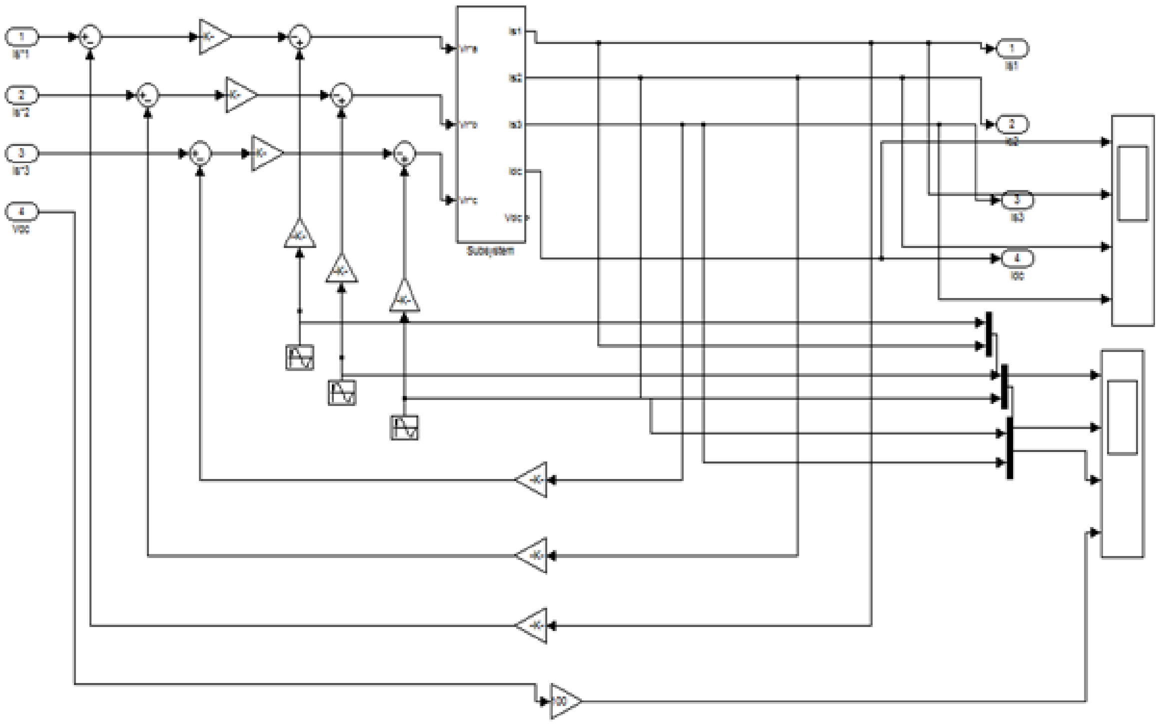


Figure 3.3: Circuit of Inner Current Loop

Block representation of the inner current loop is shown whcih deals in the ac quanitities and maintains unity power factor at the input side for the system

Here above shown is the circuit diadram of inner current loop. Here it deals with the ac quantity and is considerably fast. There is boost inductor and complete rectifier system in it. Through this we get ac voltage which can be given to the triangular quantity and through their comparison SPWM pulses can be generated and given to the gate of IGBT. Current gain loop is also given as the feedback by sensing the actual current. So it is an inner current loop. It works on maintaining unity power factor for the system.

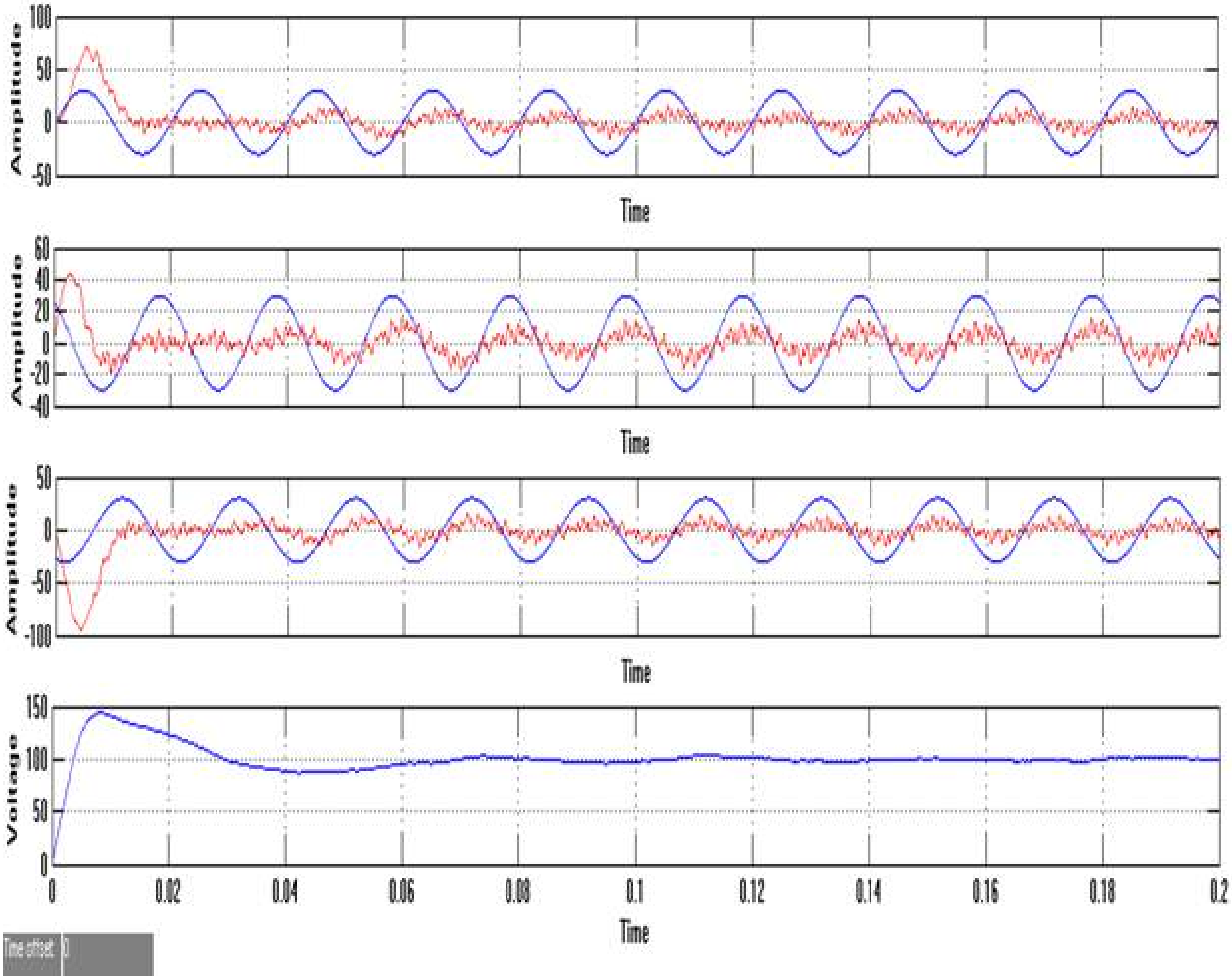


Figure 3.4: Waveforms for the Inner Current Loop for 7A system

Above shown are the waveforms for the lower rating of the system for inner current loop which maintains unity power factor. From the waveforms it is seen that unity powerfactor for all the phases is obtained. But these waveforms are for low rating of 7A. And from the waveforms we can see unity power factor are obtained with the working of inner current loop which is formed by boost inductor and inner rectifier system.

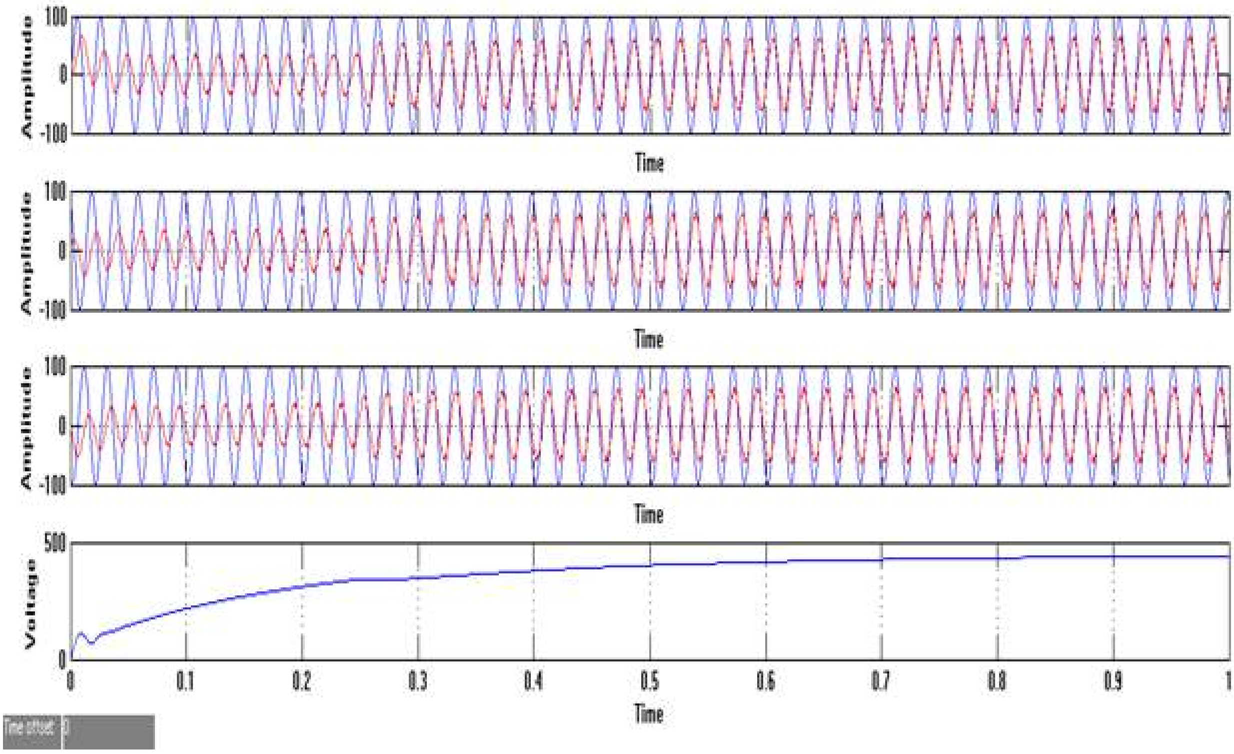


Figure 3.5: Waveforms for the Inner Current Loop for 64A system

Above shown are the waveforms for the higher rating of the system for inner current loop which maintains unity power factor. From the waveforms it is seen that unity powerfactor for all the phases is obtained. But these waveforms are for high rating of 64A. And from the waveforms we can see unity power factor are obtained with the working of inner current loop which is formed by boost inductor and inner rectifier system.

- Outer voltage loop

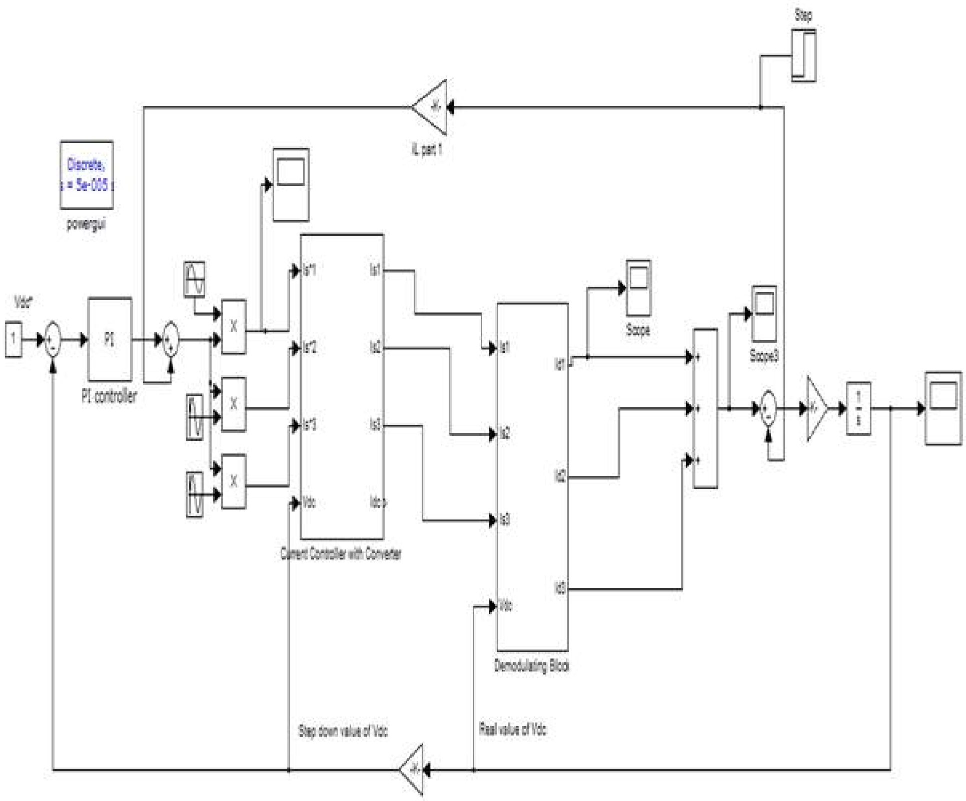


Figure 3.6: Circuit of Voltage Control loop

Above shown is the circuit for voltage control loop. It is an outer loop and maintains constant dc at the output. It is not as fast as current loop and it deals with dc quantity. Here actual voltage is compared with the reference voltage and the error is minimized in the PI controller. Then the quantity is dc which is multiplied with the sine quantity and that obtained is current which is given to the current loop. As the load changes there is change in the actual voltage and accordingly the loop rotates.

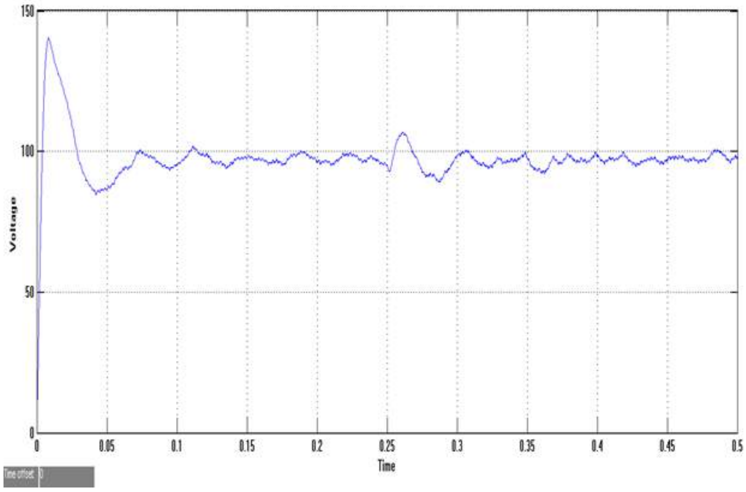


Figure 3.7: Waveforms for the voltage control loop for 100V

Above shown is the waveforms for the constant dc with low rating of 100V. Here it can be seen that constant dc is obtained with outer voltage loop.

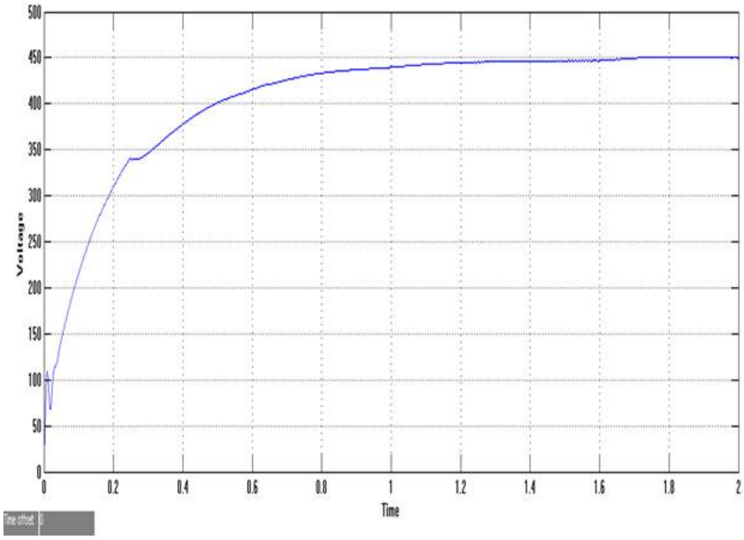


Figure 3.8: Waveforms for the voltage control loop for 450V

Above shown is the waveforms for the constant dc with high ratingof 450V. Here it can be seen that constant dc is obtained with outer voltage loop.

Chapter 4

Hardware Results

Here hardware results are obtained for the converter topology. Dead band circuit waveforms, TLP250 driver circuit waveforms and PIC controller waveforms.

4.1 TLP 250

a. Input Threshold Current : IF=5mA(MAX)

b. Supply Current(ICC) : 11mA(MAX)

c. Supply Voltage(VCC) : 10 35V

d. Output Current(IO) : 2.0A(MAX)

e. Switching Time(tpLH/tpHL) : 0.5s(MAX)

f. Isolation Voltage : 2500Vrms

TLP250(INV) consists of a GaAlAs light emitting diode and an integrated photodetector. This unit is 8-lead DIP. TLP250(INV) is suitable for gate driving circuit of IGBT or power MOS FET.

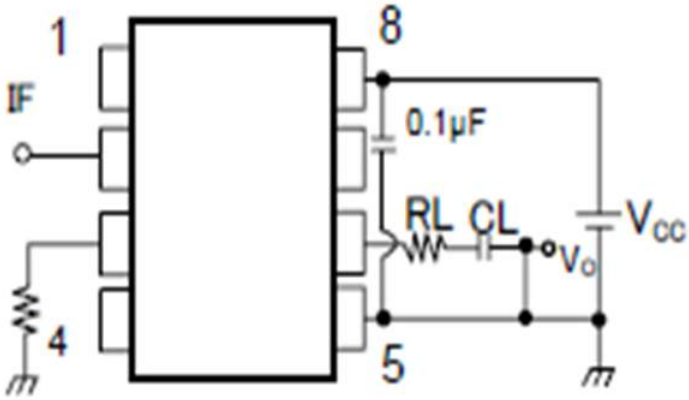


Figure 4.1: Circuit Diagram of TLP 250

The circuit diagram which is fabricated for providing pulses to the IGBTs.

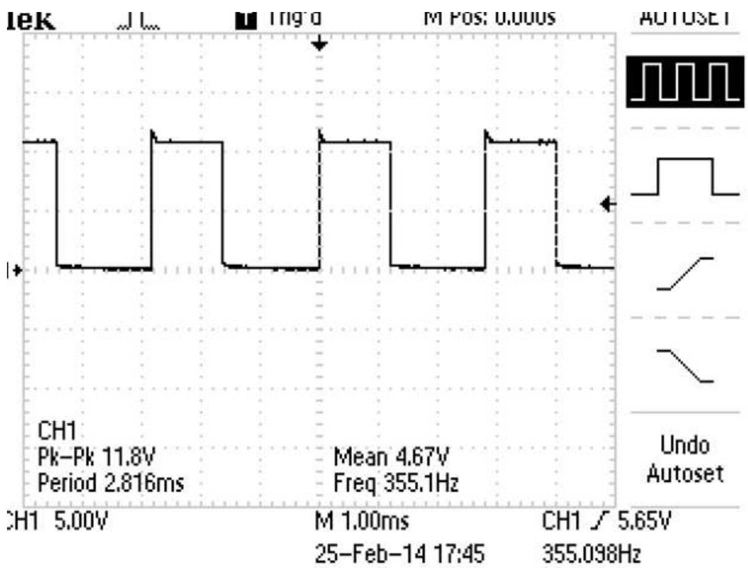


Figure 4.2: Driver IC waveforms 12V pulse

Here from the figure it is known that pulses required for the turning of IGBT can be generated by using TLP 250 IC.

4.2 Dead Band Waveforms

Now to provide dead band between the two IGBT so that there is no simultaneous triggering and hence no IGBT is damaged. Dead band can be generated from the controller and also with using IC 4093 and IC 4050. Here 4050 is buffer IC and having 16 pins. While 4093 is nand gate IC and has 14 pins. Dead band circuit build to provide dead time between the switching of complementary pair of IGBT. The short circuit protection of the inverter IGBT leg is provided by dead band circuit. NOT and NAND gate IC are require to build Dead band circuit. Connecting two not IC in series which react like buffer IC. PWM pulse fed parallel to NAND gate pin-1 and same to buffer IC. Resistor and capacitor RC pair are connected in parallel to buffer IC which gives specifies delay time required for dead band circuit. This signal is fed to NAND gate pin-2. According NAND gate logic output pulse at pin-3 received. For complementary same PWM pulse is fed to NOT gate and whole circuitry repeats for delay time required for dead band circuit. Then it is fed to driver circuit to drive IGBT. 3 phase circuit require 3 pulses gives to dead band circuit content 3 lags of NOT and NAND IC from which 6 complementary pulses carried out with specified dead time.

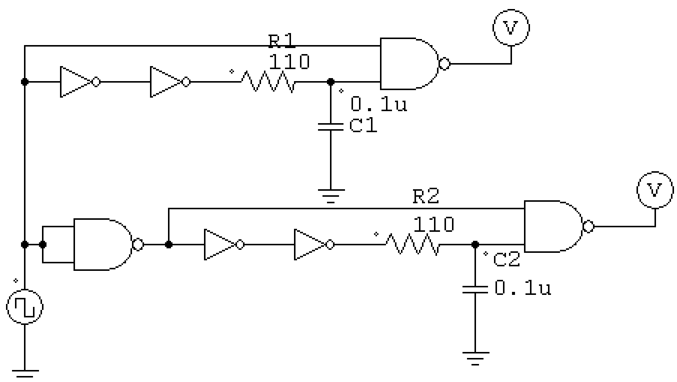


Figure 4.3: Dead Band Circuit

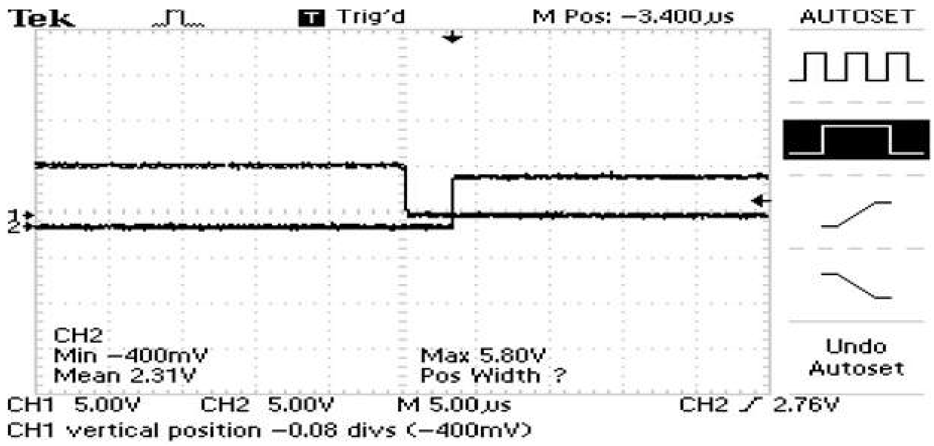


Figure 4.4: Waveforms for Dead Band of 3 micro seconds

Above shown is the dead band waveforms with 3 microsecond of the inverting IGBT of the first leg.

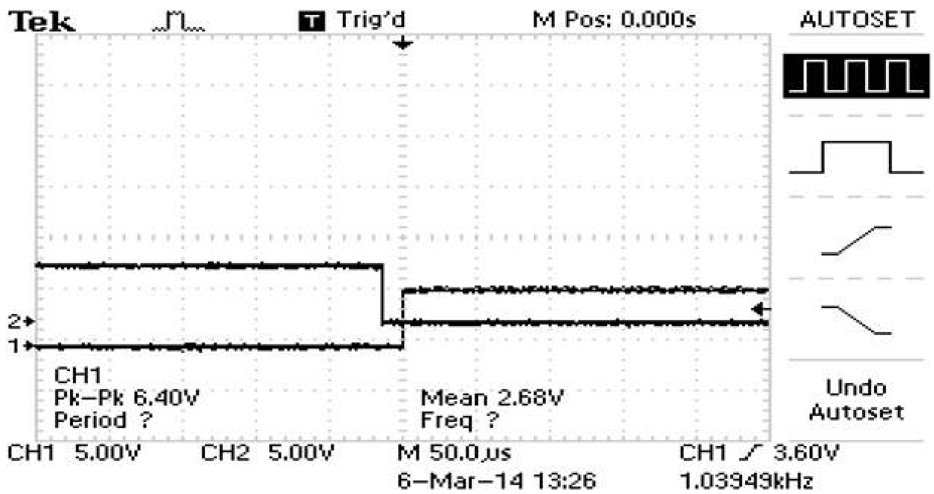


Figure 4.5: Waveforms for Dead Band of 2 micro seconds

Above shown is the dead band waveforms with 2 microsecond of the inverting IGBT of the first leg.

4.3 PIC Controller

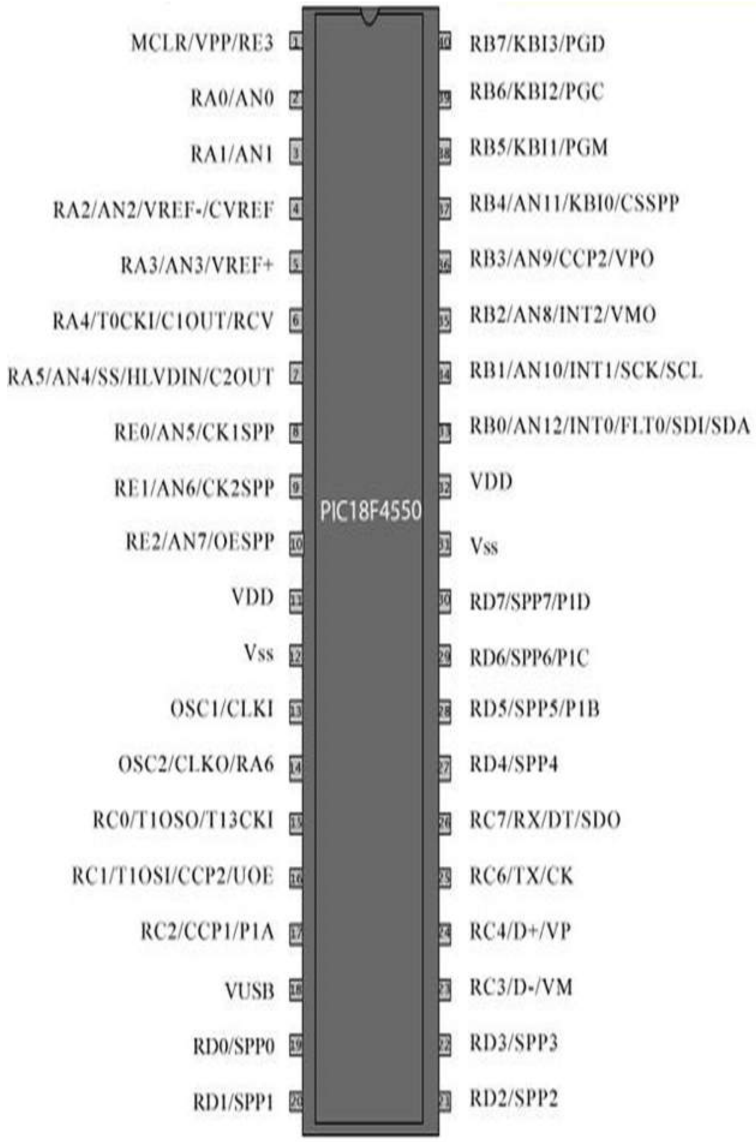


Figure 4.6: Pin diagram of PIC18F4550

Above shown is the pin configuration of PIC IC 18f4550. Here there would three sine signals and one triangular signal is given externally to the PIC IC through ADC channel and internally comparison of the signals through code is done to generate SPWM pulses. The pulses obtained are in complimentary pairs with required dead time and delay provided inbuilt. And hence the pulses obtained are given to the IGBT accordingly.

Flow Chart of Control Logic

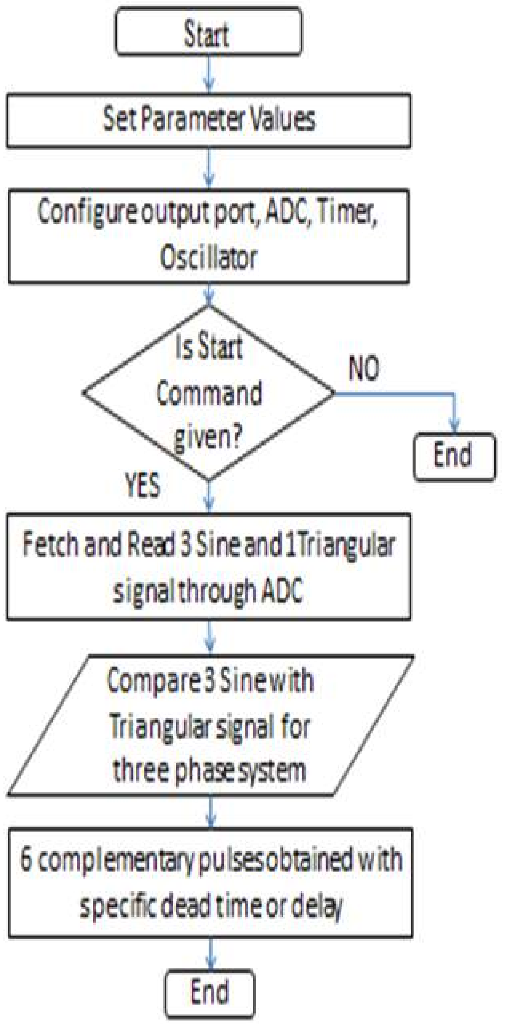


Figure 4.7: Flow Chart of Control Logic of SPWM

Firstly the controller should be started the externally sine and triangular signals are to be given to the ADC channel. Here ADC sensing time should be kept minimum so that sensing of the signals is done fast and accordingly comparison of the signal is done fast.
Now after control logic is developed and made run internally SPWM pulses are generated, these pulses are to be obtained and given to the output port. There would be 6 complimentary pulses obtained and also proper delay time would be provided between each complimentary pair of pulses so that simultaneous triggering does not take place. As these pulses are obtained at the output port then are given at the gate of the IGBT switches to trigger them.

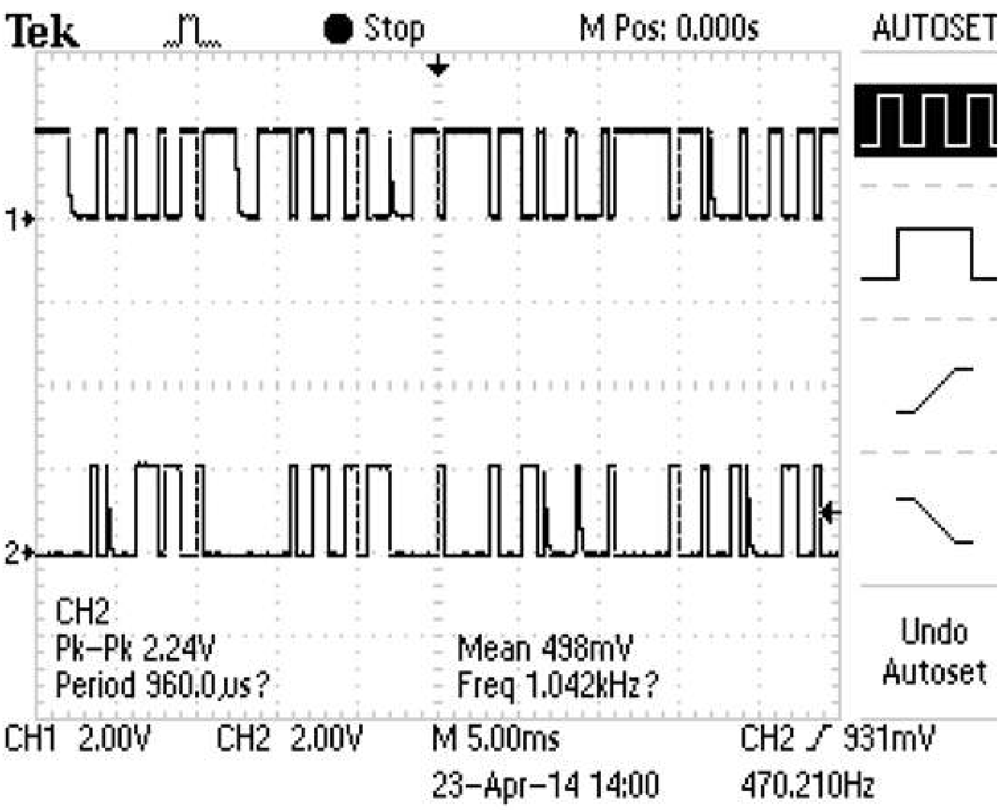


Figure 4.8: SPWM pulses at 5ms time

Here SPWM pulses through the PIC controller are obtained through externally sensing the ADC signlas of sin and triangular signals for 5ms.

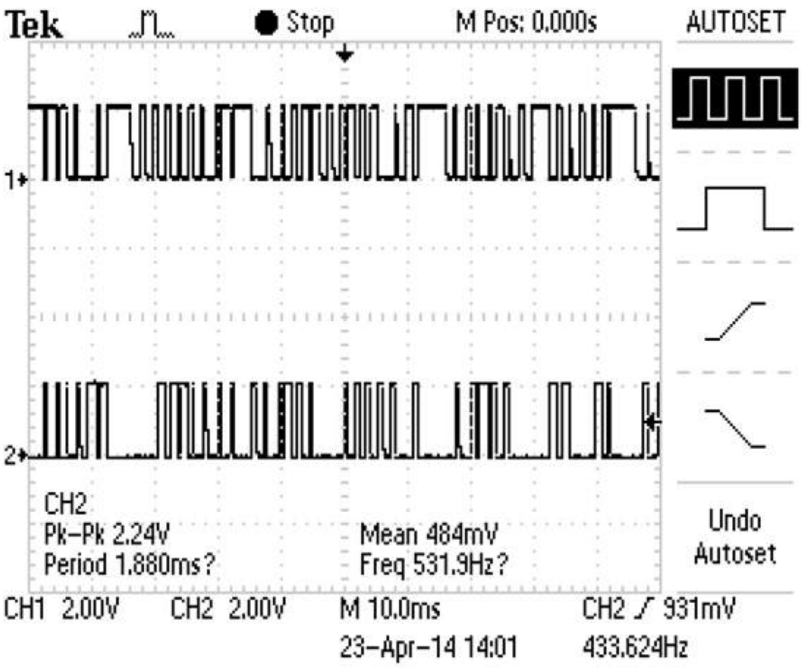


Figure 4.9: SPWM pulses at 10ms time

Here SPWM pulses through the PIC controller are obtained through externally sensing the ADC signlas of sin and triangular signals for 10ms.

4.4 Inbuilt SPWM

In order to accomplish these major tasks PIC16f877 needs to be con

gured, monitor input signal, control and synchronize various internal modules such as oscillator and clock generator and con

guration bits, ADC, PWM Unit, TIMER and I/O ports. The major tasks of the power controller are listed below.

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

For SPWM generation press start button.

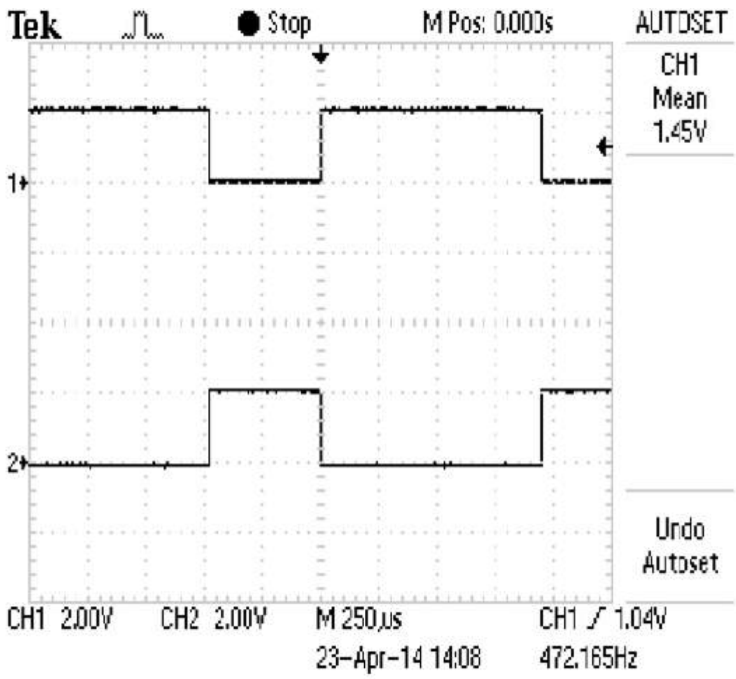


Figure 4.10: SPWM pulses at 250us time

Here SPWM pulses through the PIC controller are obtained through externally sensing the ADC signlas of sin and triangular signals for 250us.

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

Fetch and read value from ADC pin to calculate parameters.

Calculate modulation index and amplitude scaling factor for triangle wave

Fetch and read sine wave look up table for desire frequency.

Value read and shifted to obtain 3 phase sine wave from one sine look up table.

Read triangular wave look up table and multiply with amplitude scaling factor.

Compare 3 phase sine with triangular wave to obtain adjustable output voltage of SPWM inverter

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

These 6 pulses are used to trigger IGBT through TLP250 driver Ic.

Stop PWM generation in case of Fault signal or stop button. endenumerate The

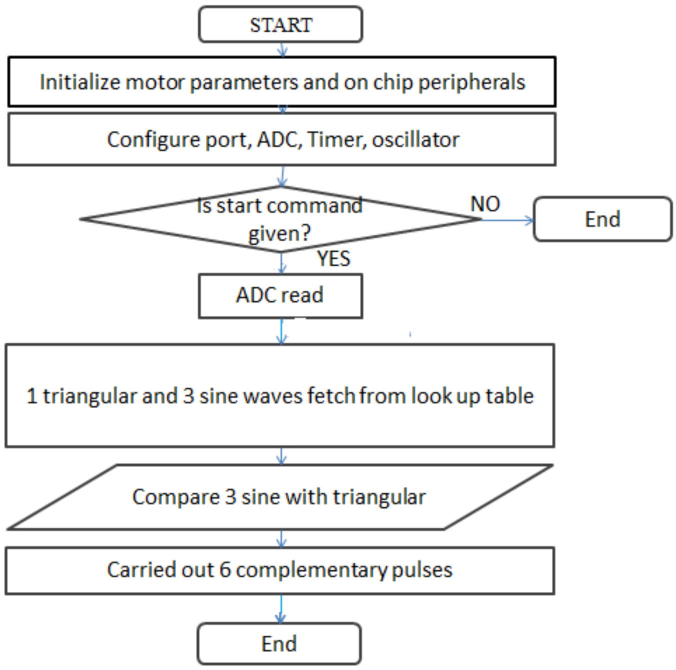


Figure 4.11: Flow chart for PIC16f877 for inbuilt SPWM

Analog to Digital(A/D) Converter module has eight inputs for the 40/44-pin devices. PIC 16f877 micro controller have in built 10 bit ADC port. 10 bit ADC means value store up to 1023 or 210. 0-5V input at ADC pin it can be digitalize or convert to number. This values are further use for calculation of count timer, frequency input. The A/D module has four registers. A/D Result High Register (ADRESH) A/D Result Low Register (ADRESL) A/D Control Register 0 (ADCON0) A/D Control Register 1 (ADCON1) 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 to other 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/Dmodule gives the exibility to left or right justify the 10-bit result in the 16-bit result register. From the input frequency the inverter output voltage,

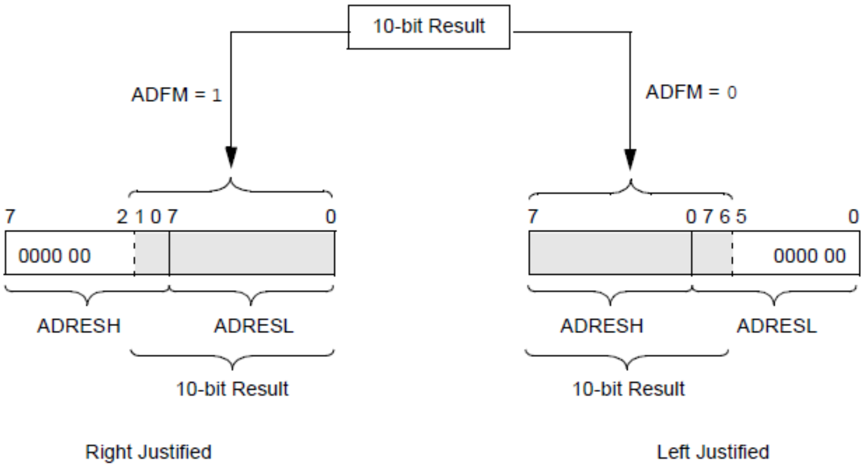


Figure 4.12: Flow chart for PIC16f877 pin configuration

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 rad,write and erase the programme hex file in PIC IC through general pic loader use for loading hex file. 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. Any frequency can be represent by taking

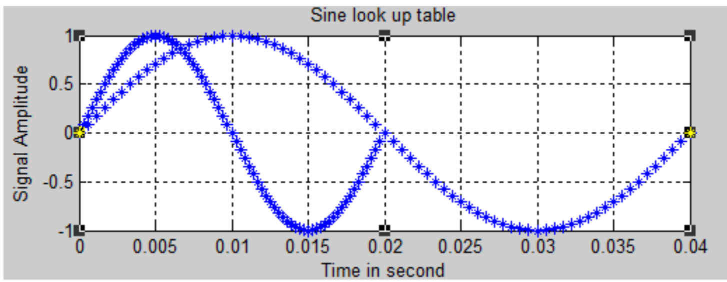


Figure 4.13: Sine waveform by look up table

samples of sine values with specfied time interval which is shown in figure. Values are same for 50Hz sine wave and 25Hz sine wave with equal samples per cycle. This specfic time interval use for generating desire sine frequency operation of SPWM inverter. Making triangular wave look up table means storing triangular values in

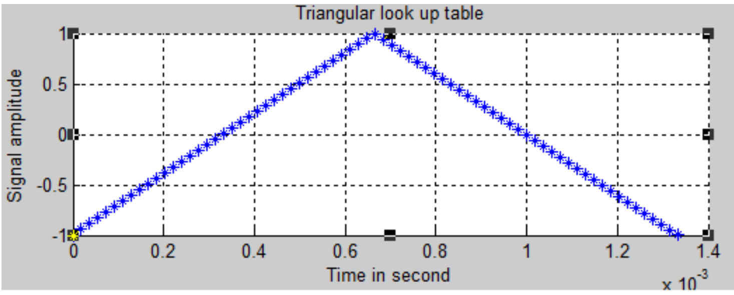


Figure 4.14: Triangular waveform by look up table

array in program memory by taking samples per cycle.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.

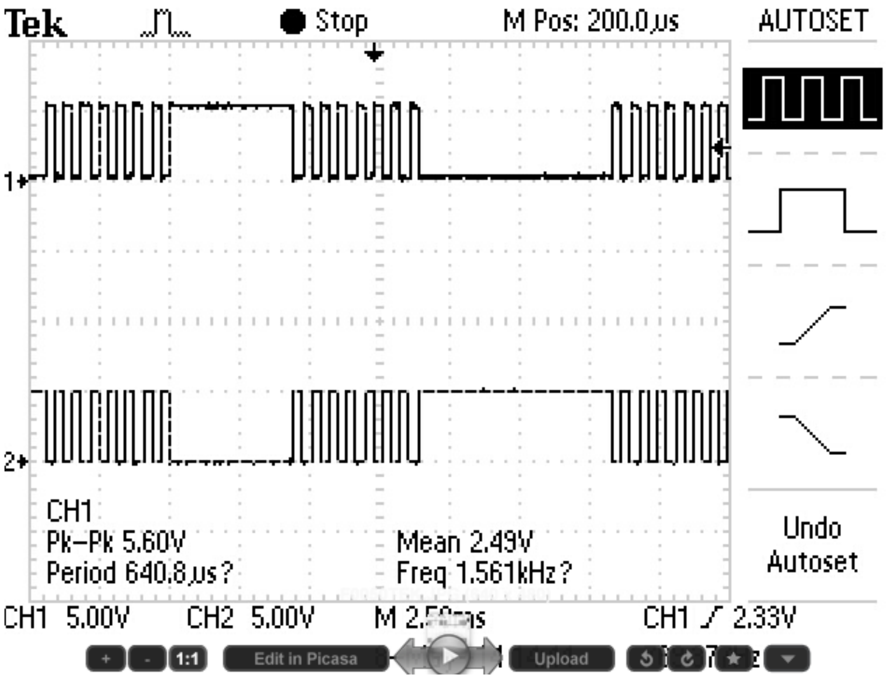


Figure 4.15: Inbuilt SPWM pulses with modulation index 0.8

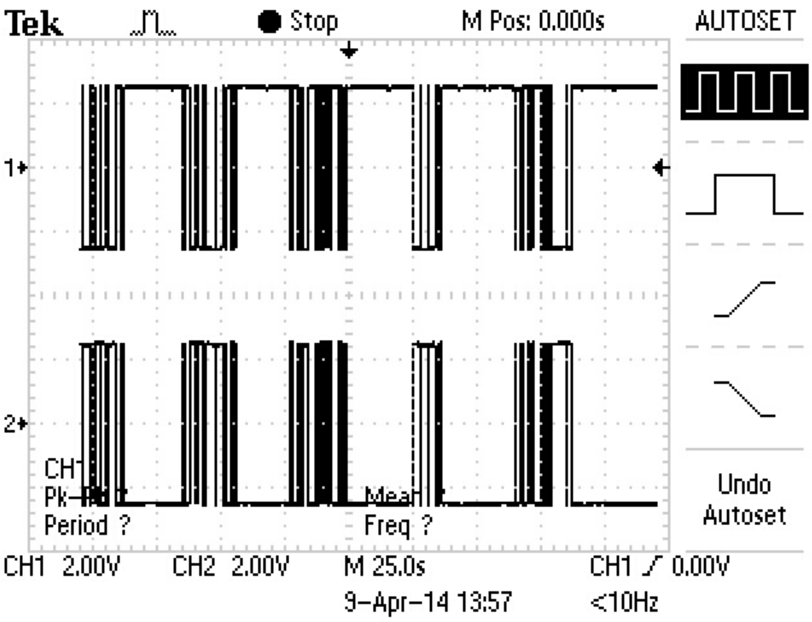


Figure 4.16: Inbuilt SPWM pulses with 25 ms time

4.5 Offset Waveforms

Here the offset circuit is designed using IC LM741, which is 8 pin IC. This circuit is designed to provide offset to the sine and triangular signals because PIC controller understands positive DC signal and from 0 to 5V. So signals from the voltage sensors are given to the offset circuit to give an offset to these signals or else controller would get damage and would fail to work. The waveforms for the offset circuit are shown below

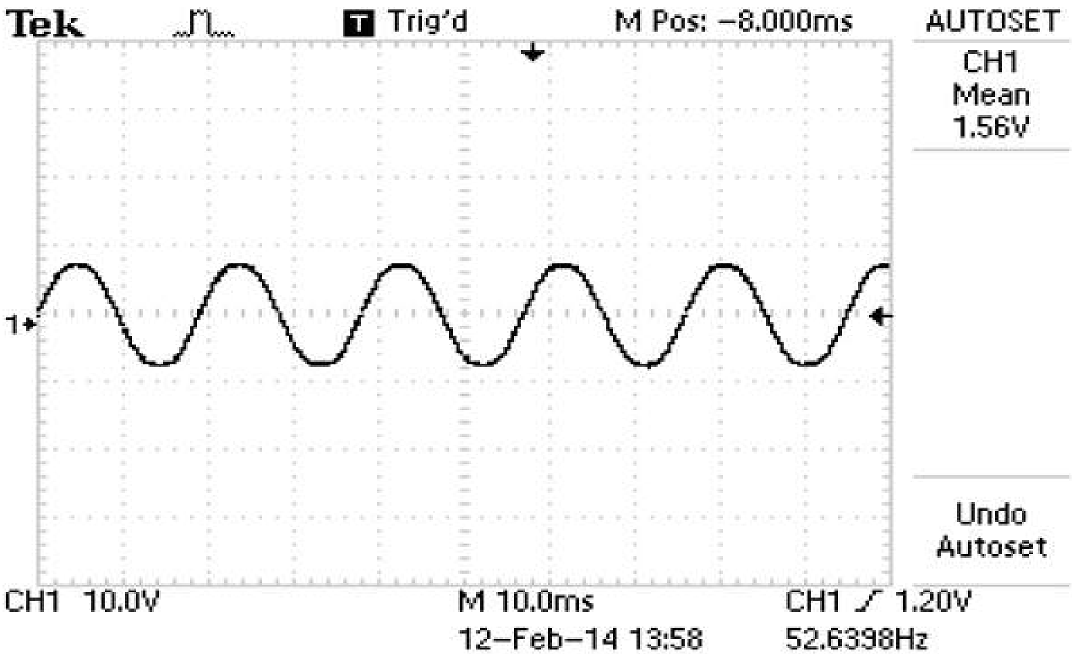


Figure 4.17: Signal without offset

Here in the above figure sine signal is sensed without giving an offset so it cannot be given to the controller as requires positive offset signal.

Here from the waveforms it can be seen that proper offset signal are achieved through IC LM741.

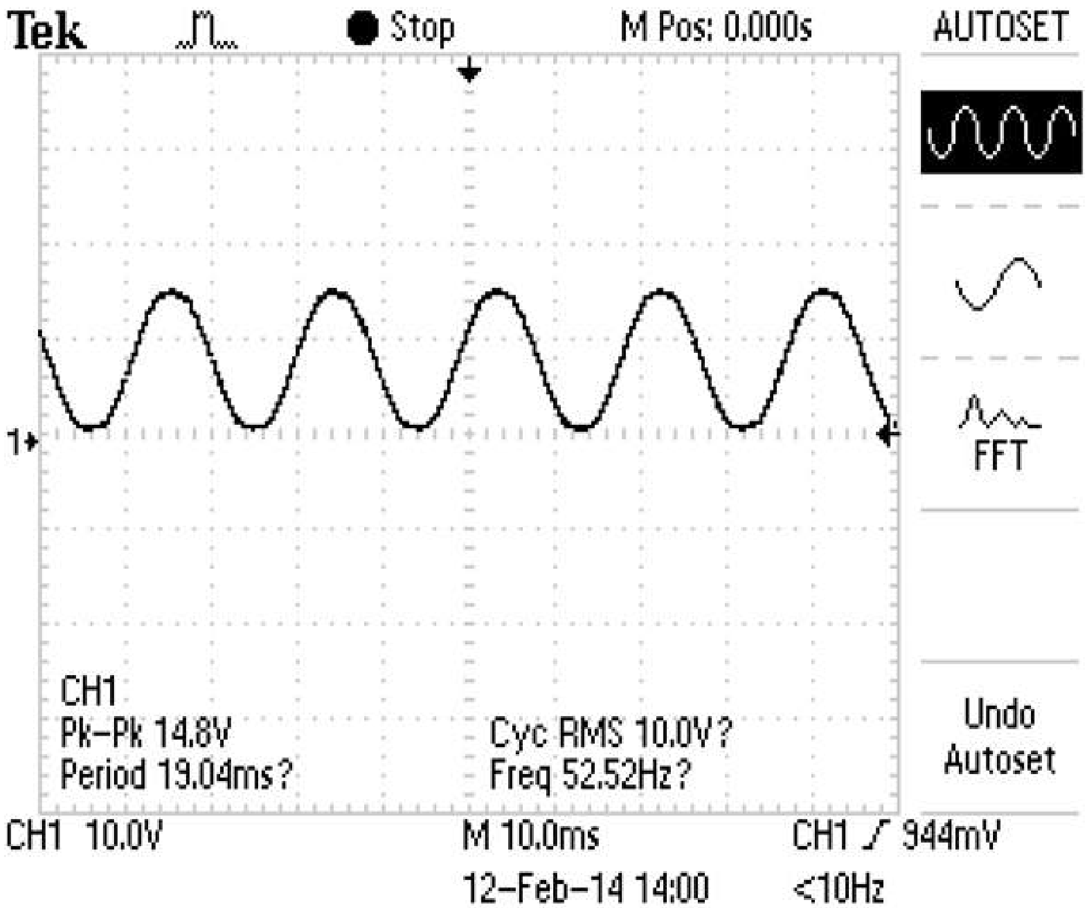


Figure 4.18: Signal with offset

Now here the offset is given to the sine signal and thus the signal can be given to the PIC controller as it has positive offset.

4.6 Fabricated Circuits

Figure 4.19: Supply Circuit

Here above shown is the figure for supply circuit for the driver card which has 15V supply using IC7815.

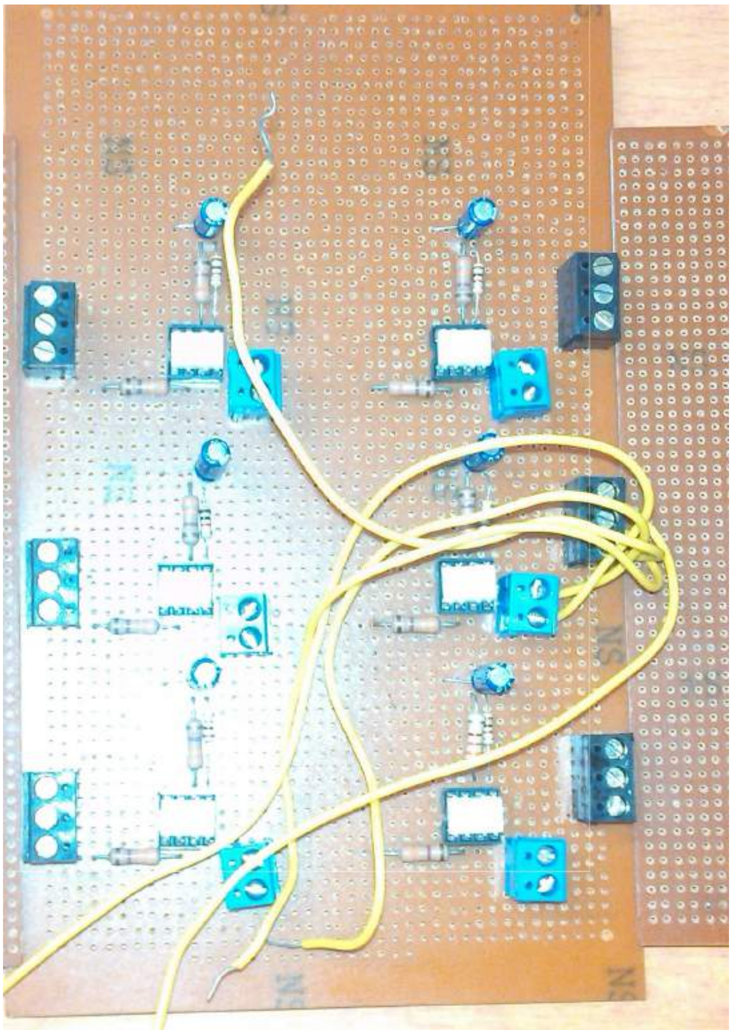


Figure 4.20: Driver Circuit

Driver circuit shown above is developed using TLP250 IC which is used to give gating pulse to the IGBT module.

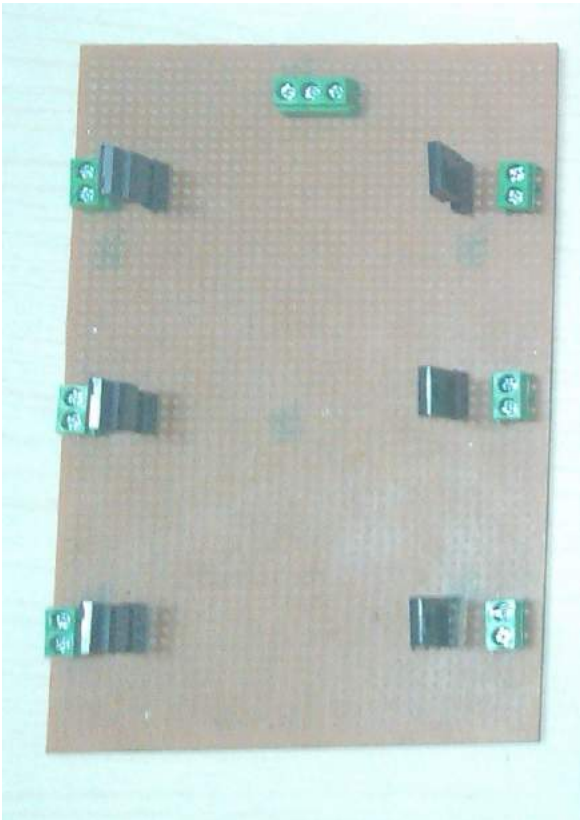


Figure 4.21: IGBT module

IGBT used here is having rating of 600V and 5A capacity.

Chapter 5

Conclusion and Future Work

5.1 Conclusion

Thus from the above report it can be concluded that simulation results are obtained for the three phase rectifier system by maintaining unity power factor at the supply ac side and maintaining DC voltage constant at the output. Simultaneously fabrication of the driver card and it's supply is done and accordingly the required results are obtained and with that IGBT module is also fabricated with dead band circuit. Here results of dead band circuit are obtained. And SPWM pulses are obtained through PIC by comparing sinusoidal signals.

5.2 Future Work

a. Closed loop control is implemented through PIC controller.

b. The power topology can be replaced by multilevel converter for better harmonic profile.

c. Control algorithm can be changed.

Referencs

1 "Power Factor Improvement of an AC-DC Converter via Appropriate sPWM Technique" K. Georgakas, A. SafacasUniversity of Patras, Department of Electrical and Computer Engineering, Laboratory of Electromechanical Energy Conversion, 26500 Rion-Patras, Greece..

2 "The Research of Single-phase PWM Rectifier Based on Direct Current Control Technology"Li Taofeng, Ouyang Hui,Kang Yong, XiongJian, Fan Shengfang, Zhang Kai, Zhang PengjuCollege of Electrical and Electronic Engineering, Huazhong University of Science and Technology, China.

3 Effects of Voltage Unbalance and Harmonics on Three-phase SPWM AC-to-DC converters with Instantaneous Power Feedback.

4 "A Three Phase Five Level Cascaded H-Bridge Rectifier with Zero Current Injection Scheme", Jayaram ,Pramod Agarwal and S

5 "Simulation of a complex traction PWM rectifier using simulink and the dynamic node technique",Frank Flinders, WardinaOghanna.

6 "Single Phase Rectifier With High Power Factor In Continuous and Discontinuous Conduction Mode" B.-R. Lin and T.-S.Hwang Power Electronics Research Lab. ,Dept. of Electrical Engineering National Yunlin Institute of Technology Touliu city, Yunlin 640, Taiwan, R. 0. C.

7 "A PWM Inverter Algorithm for Adjustable Speed AC Drives Using a Nonconstant Voltage Source"Raymond s.ramshaw, member, ieee, guoliang xie, associate mem- ber, ieee, barry w. Henderson, member, ieee, and johan h. De groot pages:673-677.

8 "Ned Mohan "power electronics book" chapter-1,10, Muhammad H. Rashid. "Power electronic handbook". PWM generation

9 "Microcontroller Based Sinusoidal PWM Inverter for Photovoltaic Application" S. M. Mohaiminul Islam, Gazi Mohammad Sharif School of Engineering and Com- puter Science, Independent University, Bangladesh.pages:1-4

10 "A Review of Three PWM Techniques" Zhenyu Yu, Arefeen Mohammed and Issa Panahi DSP Automotive/Industrial Control Applications. pages:257-261

11 "Analysis and implementation of a three phase four wire switching mode rectifier based on a switch clamped scheme " B.R.Lin and Y.C.Lee.