A NOVEL METHOD FOR DESIGN AND IMPLEMENTATION OF PWM INVERTER FOR THE CONTROL OF WINDMILL

A PROJECT REPORT

Submitted by

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KUMARAGURU COLLEGE OF TECHNOLOGY

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JULY – 2008

BONAFIDE CERTIFICATE

Certified that this project report entitled **"A NOVEL METHOD FOR DESIGN AND IMPLEMENTATION OF PWM INVERTER FOR THE CONTROL OF WINDMILL"** is the bonafide work of

D. Arun Dominic - Register No. 71206415001

who carried out the project work under my supervision.

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CERTIFICATE

This is to certify that Mr. / ~~Ms~~ D. ARUN DOMINIC *of* Kumaraguru College of Technology, Coimbatore *participated in the National Level Conference on* ***"Emerging Technologies in Electrical & Electronics Systems"*** *organised by the department of Electrical and Electronics Engineering of this Institution on the 8th of March 2008 and presented the paper entitled* A novel method for design and implementation of PWM inverter for control of wind mill

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ABSTRACT

This Project deals with control of Voltage and Frequency output from wind mill. The Output Voltage from wind mill varies with respect to the Wind Velocity .The variable AC voltage obtained from the windmill is converted to rectified DC voltage by the Diode Bridge Rectifier .The variable DC voltage is converted to fixed DC voltage using the Buck-Boost Converter. The fixed DC voltage output from the converter is fed to the single Phase PWM MOSFET based INVERTER Module. The MOSFET's are sequentially triggered to obtain 1-Phase constant AC output voltage of 50 V with constant frequency of 50Hz.The output AC voltage thus obtained is converted to 230 V AC supply by a step up transformer.

Thus in this Project the variable AC output voltage from Wind mill is converted to Single Phase fixed voltage and constant frequency output. The Single Phase output can then be used for the house hold appliances. The entire circuit for a 3 phase Inverter is designed and simulated using **PSIM 7.0.5** Software. The hardware is implemented for a single phase application.

ஆய்வு சுருக்கம்

இந்த ஆய்வானது காற்றாலையில் உற்பத்தி செய்யப்படுகின்ற வெவ்வேறு மாறு மின்னழுத்தத்தை ஒரு சீரான மாறு மின்னழுத்தமாக மாற்ற துணை செய்கின்றது. காற்றாலையில் இருந்து உற்பத்தி செய்யப்பட்ட மாறு மின்னழுத்ததை டயோட் பிரிட்ஜ் ரெக்டிபயரை கொண்டு நேர் மின்னழுத்தமாக மாற்றப்படுகின்றது. இந்த நேர் மின்னழுத்தமானது வேறுபட்ட நேர் மின்னழுத்தமாக இருக்கின்றது. இதை பக்பூஸ்ட் கண்வர்டர் கொண்டு ஒரு நிலையான நேர் மின்னழுத்தமாக மாற்றப்படுகின்றது. இந்த நிலையான நேர் மின்னழுத்தத்தை பி.டபில்யு.எம். மாஸ்பெட் இன்வெர்டர் மூலம் மாறு மின்னழுத்தமாக மாற்றப்படுகின்றது.

இவ்வாறு மாற்றப்பட்ட மாறு மின்னழுத்தத்தை நுகர்வோர் பயன்படுகின்ற விதமான அதை வெவ்வேறு மின்சார உபயோகப்பொருளுடன் இணைக்கப்படுகின்றது. இந்த ஆய்வில் **“ பிசிம் 7.0.5”** என்னும் புதிய மென்பொருளைக் கொணடு சிமூலேசன் செய்யப்பட்டு பின்னர் அதை வன் பொருளாக ஆக்கப்பட்டுள்ளது.

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I express my gratefulness to our principal **Dr. Joseph .V. Thanikal** Ph.D for having offered me a golden opportunity to do this project work in this prestigious institution.

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I would like to express my deep sense of gratitude and profound thanks to my guide **Mr. C.Udhayashankar** M.Tech., Lecturer, Electrical and Electronics Engineering Department, for his valuable guidance, support, constant encouragement and co-operation rendered throughout the project.

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CONTENTS

TITLE **PAGE NO**

CHAPTER I INTRODUCTION

CONTENTS

TITLE **PAGE NO**

CHAPTER II **HARDWARE PART**

CHAPTER III **EMBEDDED PART**

CONTENTS

TITLE **PAGE NO**

CONTENTS

TITLE **PAGE NO**

CHAPTER IV **SIMULATION USING PSIM 7.0.5**

CHAPTER V **CONCLUSION AND FUTURE WORK**

LIST OF FIGURES

LIST OF FIGURES (Contd...)

LIST OF FIGURES (Contd...)

LIST OF FIGURES (Contd...)

LIST OF TABLES

LIST OF SYMBOLS AND ABBREVIATIONS

PWM	Pulse Width Modulation
SPWM	Sinusoidal Pulse Width Modulation
PIC	Peripheral Interface Controller
ICD	In - Circuit Debugger
RISC	Reduced Instruction Set Computer
EEPROM	Electrically Erasable Programmable Read only Memory
SSP	Synchronous Serial Port
USART	Universal Synchronous Asynchronous Receiver Transmitter
PSP	Parallel Slave Port
WDT	Watch Dog Timer
SFR	Special Function Register
Rpm	Rotations per minute
R	Turbine radius
V	Wind velocity
ω	Rotational speed of the wind turbine
λ	Tip Speed Ratio

CHAPTER I

INTRODUCTION

1.1 INTRODUCTION:

Wind Energy is clean and safe form of Energy that does not pollute the Global Environment. It is one of the most utilized sources of energy together with hydro power. Currently, wind power is a fully established branch in the electricity market. In remote locations power electronics circuitry is used for the control of windmill. In this Project the Buck-Boost Converter is cascaded with Single-Phase PWM Inverter and used for the control of the variable voltage and frequency generated from the wind mill. The Controlled output voltage from the windmill is given to the house hold appliances Load as a part of consumer power requirement. It can be also used for the Induction Motor Drives by using IGBT based Inverter Module and stepping up the Voltage with the Single Phase Transformer .One of the control aspects should deal with the over speed situation so that the mechanical and electrical components of the turbine are able to handle such events. Also, as far as the power production is concerned, it is desirable to extract the maximum power from the wind turbine system.

1.2 NEED FOR THE CONTROL OF WIND MILL:

To get desired maximum Power output, certain parameters (Speed, direction of the turbine movement) are needed to be controlled for various operating conditions. The output must be a constant voltage with fixed frequency of 50 Hz, so that the voltage obtained can be connected to the grid for distribution purpose.

1.3 OBJECTIVE:

To convert the variable output voltage and frequency from the wind turbine to a constant sinusoidal output voltage and 50 Hz frequency.

1.4 ORGANISATION OF THE THESIS:

CHAPTER -1:

This chapter contains the information about the objectives and the need for the control of windmill in the project.

CHAPTER-2:

This chapter contains the information about the proposed hardware of the project, the components used and the output obtained from the hardware.

CHAPTER-3:

This chapter contains the information about the microcontroller and the detailed description of the microcontroller used.

CHAPTER-4:

This chapter contains the information about the simulation software also includes the simulation results.

CHAPTER -5:

This chapter contains the conclusion and the future scope of work.

1.5 WINDMILL AN OVERVIEW:

The main components of a wind-mill are:

1) Wind Turbine
2) Transmission System
3) Braking System
4) AC Generator

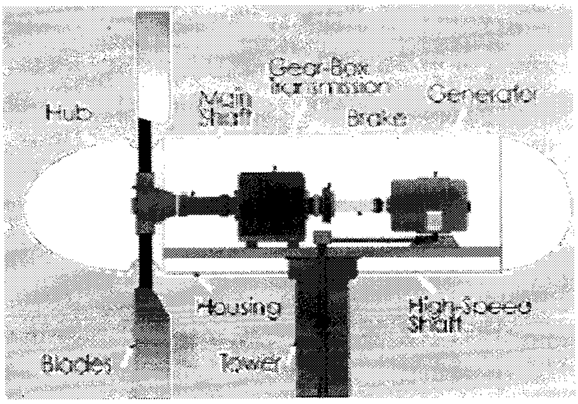


Fig 1.1: Schematic Diagram of the Wind Mill System

1.5.1 Wind Turbine:

The wind turbine, converts the kinetic energy in the wind to rotational motion by the rotor-typically a three-bladed assembly at the front of the wind turbine. The rotor turns the main shaft, which transfers the motion into the nacelle (the large housing at the top of a wind turbine tower).Inside the nacelle, the slowly rotating shaft enters the gearbox that greatly increases the rotational shaft speed. The output (high speed) shaft is connected to the generator that converts the rotational movement into the electric power at medium voltages.

1.5.2 Transmission System:

Hub- The blades on the wind turbine are bolded to the hub. The hub is casted in a special type of strong iron alloy called SG cast iron. The hub is of conical shape.

Main shaft- The main shaft of the wind turbine is usually forged from hardened and tempered steel. Hardening and tempering is result of forgoing the axle after it has been heated until it is white hot at about 1000 deg. Centigrade.

Gearbox- The Gear box is placed between the main shaft and the Generator. Its function is to increase the slow rotational speed of the rotor blades to the generator rotation speed of 1000 or 1500 rpm. The Gear box has a constant tip speed ratio.

1.5.3 Braking System:

The Braking System works in the principle of centrifugal action that controls the rotor speed through governors. The rotor can be stopped under abrupt conditions by mechanical braking systems. In modern windmills electrical braking system is used instead of mechanical braking system because frequent use of mechanical braking system creates heat stress in the Generator.

1.5.4 AC Generator:

The generator converts the mechanical power of the spinning wind turbine into electricity. Inside the generator, coils of wire are rotated in a magnetic field to produce electricity. Induction generators that produce AC Power are generally equipped with features to produce electricity even when the wind speed is fluctuating. In the generator the armature is the coil of wire where the output voltage is generated and the current flows to the load. The portion of generator where the magnetic field is produced is the field .Relative motion between the two is obtained by either spinning the armature within the field or spinning the field with the armature. The power produced by the generator depends on the size and the length of the wires used in the armature, the strength of the magnetic field and the rate of the motion between them.

1.6 OPERATING CHARACTERISTICS OF WIND MILLS:

The wind mills have certain operating characteristics, such as cut-in, rated and cut-out wind speeds.

1.6.1 Cut-in- Speed:

Cut-in speed is the minimum wind speed at which the blades will turn and generate usable power. This wind speed is typically between 10 and 16 kmph.

1.6.2Rated Speed:

The rated speed is the minimum wind speed at which the wind turbine will generate its designated rated power. Rated speed for most machines is in the range of 40 to 55 kmph. At wind speeds between cut-in and rated, the power output from a wind turbine increases as the wind increases.

1.6.3 Cut-out Speed:

At very high wind speeds, typically between 72 and 128 kmph, most wind turbines cease power generation and shut down. The wind speed at which shut down occurs is called the cut-out speed.

1.6.4 Betz Limit:

It is the flow of air over the blades and through the rotor area that makes the wind turbine to function. The theoretical maximum amount of energy in the wind that can be collected by a wind turbine's rotor is approximately 59%. This value is known as the Betz limit.

1.7 WIND POWER CONVERSION:

The function of a wind turbine is to convert the linear motion of the wind energy into rotational energy that can be used to drive a generator. Wind turbines capture the power from the wind by means of aerodynamically designed blades and convert it into rotating mechanical power. The aerodynamic power, P, of a wind turbine is given by:

$$P = 1/2\ \rho\ \Pi\ R^2\ V^3\ C_p$$

Where ρ is the air density, R is the turbine radius, V is the wind speed and Cp is the turbine power coefficient which represents the power conversion efficiency of a wind turbine. Cp is a function of the tip speed ratio (λ) as well as the blade pitch angle (*β*) in a pitch controlled wind turbine. λ is defined as the ratio of the tip speed of the turbine blades to wind speed, and given by:

$$\lambda = \frac{R.\omega}{V}$$

Where ω is the rotational speed of the wind turbine. The Betz limit C_p max, (theoretical) = 16/27=0.529 the maximum theoretically possible rotor power Coefficient.

The Windmill Emulator in this project is shown below:

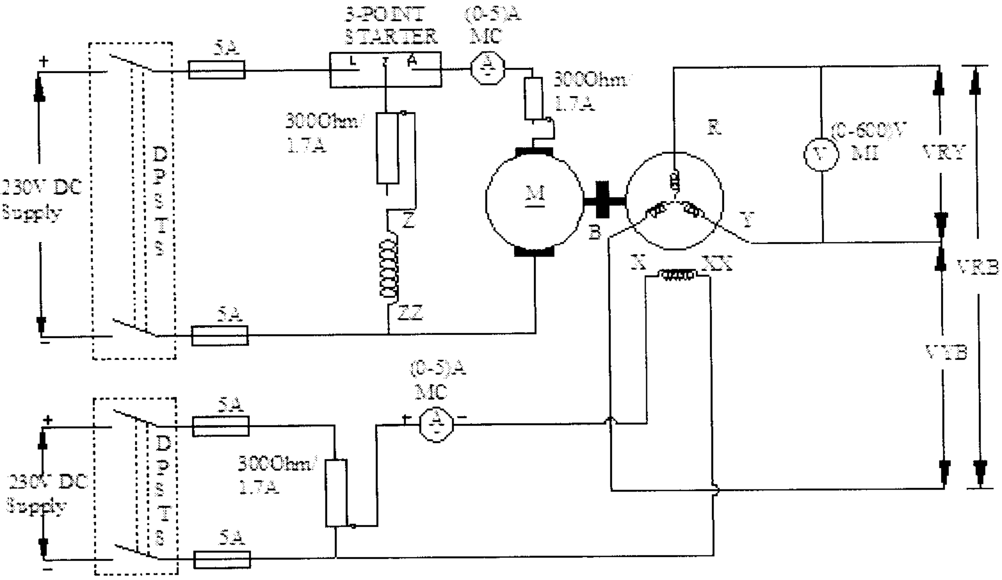


Fig 1.2: Circuit Diagram of the Wind Mill Emulator

Name Plate Details:

Motor	Alternator
Voltage: 230 V	Voltage: 400 V
Current: 1.9 A	Current: 4.3 A
Speed: 1500 rpm	Speed: 1500 rpm
Output Power: 0.7 KW	Output Power: 3 KVA
Excitation: 0.7 A	Excitation: 0.75 A

The Windmill consists of Induction Generator which runs at various speeds proportional to the wind force. A similar model has been developed by coupling a DC motor with a 3-Phase Alternator. The DC motor is made to run at different speeds by using armature speed control .The 3-Phase alternator coupled with DC motor also runs at different speeds. By giving excitation to the field windings the output voltage generated between the lines is measured for various speeds.

The corresponding values of speed and the output voltage obtained from Alternator as an Emulator of the Wind mill is given below:

The field Excitation I_f= 0.08A Vin =230 V DC Supply

S.No	Speed (rpm)	Voltage obtained (volts)
1	1500	60
2	1485	58
3	1429	56
4	1381	54
5	1327	52
6	1274	50
7	1239	48
8	975	46
9	914	44
10	889	42
11	828	40
12	768	38
13	737	36
14	687	34
15	626	32
16	553	30
17	536	26
18	516	24
19	479	22
20	400	20
21	388	18
22	345	16
23	266	14

Table 1 EMF developed for various Speeds

CHAPTER II

HARDWARE PART

2.1 BLOCK DIAGRAM OF THE PROPOSED HARDWARE:

The proposed hardware for the Power Electronics control of windmill mainly consists of:

1) Buck-Boost Converter
2) 1Φ PWM Inverter
3) Loads

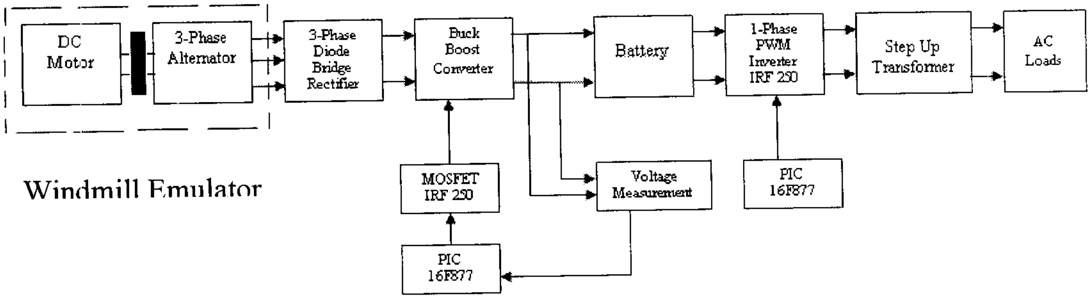


Fig 2.1 Block Diagram of the proposed method

2.2 PRINCIPLE OF OPERATION:

The varying output voltage from the 3-Phase Induction Generator is rectified into DC voltage by a 3-Phase Diode Bridge Rectifier .The rectified variable DC voltage is given as input to the Buck-Boost Converter. The output voltage in the Buck-Boost converter is maintained constant by giving suitable triggering pulse to the power MOSFET present in the converter .This triggering pulse (Turning ON and Turning OFF) is controlled by the microcontroller .The constant DC output voltage from the Buck-Boost Converter is given to the battery. The purpose of the battery is when the demand is very less at high potential of power generation; the power generated can be stored in the battery and can be used for other times. This DC output voltage is inverted into AC by the help of 1-Phase PWM Inverter. The power MOSFET triggering signals are generated by the PWM pulse generated ports of the PIC microcontroller. The AC output voltage thus obtained is stepped up using a step up transformer. As a part of the consumer requirement various light loads are connected.

2.2.1 3-PHASE DIODE BRIDGE RECTIFIER:

In this Project the diode BY 339 is used for the Rectification. It converts the given Ac supply voltage into rectified DC voltage. It has a Peak Reverse Voltage of 1000V and the average forward current of 1A.It has the following advantages:

- High maximum operating temperature
- Low leakage current
- Excellent stability

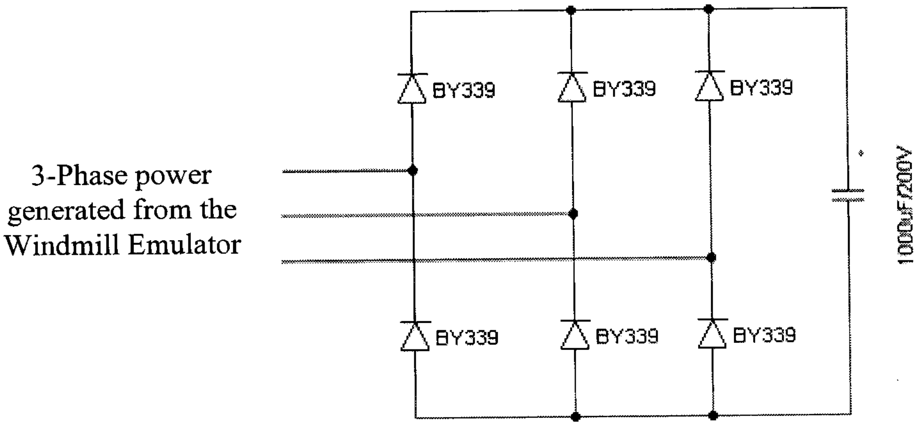


Fig 2.2 3-Phase Diode Bridge Rectifier

2.2.2 BUCK CONVERTER:

The circuit diagram for the Buck converter is given below

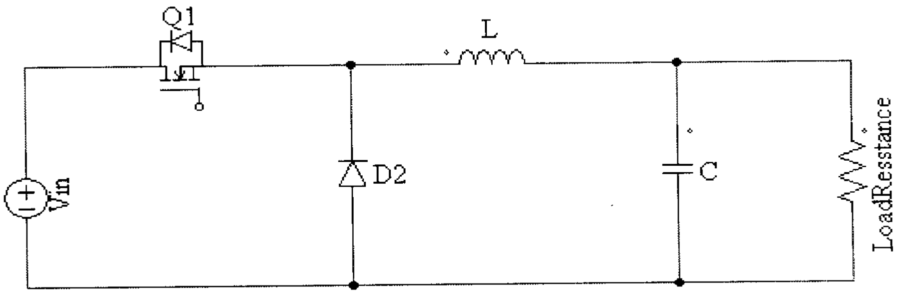
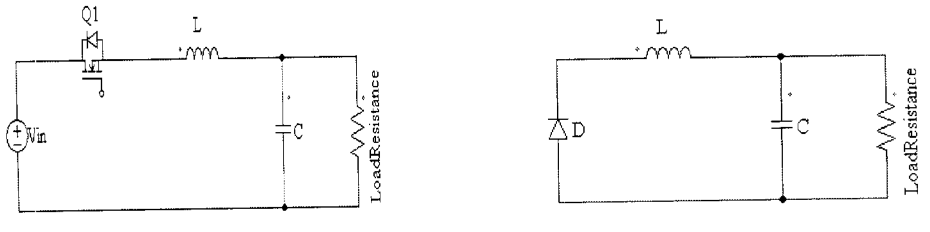


Fig 2.3 Circuit Diagram of Buck Converter

In the Buck converter, the average output voltage is less than the input voltage Vin. The circuit operation has two modes .In mode I the switch Q1 is turned ON and the current flows through the Inductance L, Capacitance C, and the Load Resistance R. In mode II the switch Q1 is turned OFF and the energy stored in the inductor flows through the capacitor and the Diode. The inductor current will flow till the next cycle of operation begins. In this project power MOSFET IRF 250 is used.



Mode I Mode II

Fig 2.4 Equivalent Circuits of Mode I and Mode II operation of Buck Converter

2.2.3 BOOST CONVERTER:

The circuit diagram for the Boost converter is given below:

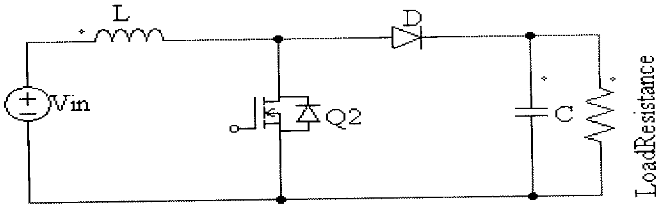
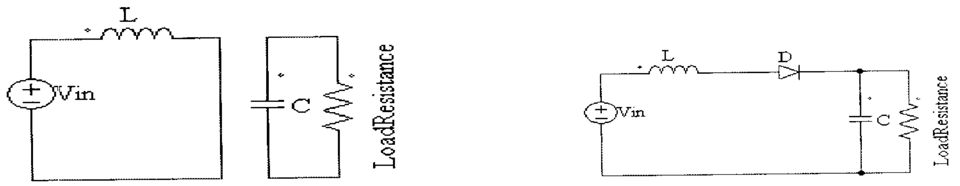


Fig 2.5 Circuit Diagram of Boost Converter

In the Boost converter, the average output voltage is more than the input voltage Vin. The circuit operation has two modes. In mode I the switch Q2 is turned ON and the current flows through the Inductance L, and switch Q2. In mode II the switch Q2 is turned OFF and the current flows through the Inductor Diode capacitor and load. In this project power MOSFET IRF 250 is used.



Mode I

Mode II

Fig 2.6 Equivalent Circuits of Mode I and Mode II operation of Boost Converter

2.2.4 BUCKCONVERTER CASCADED WITH BOOST CONVERTER:

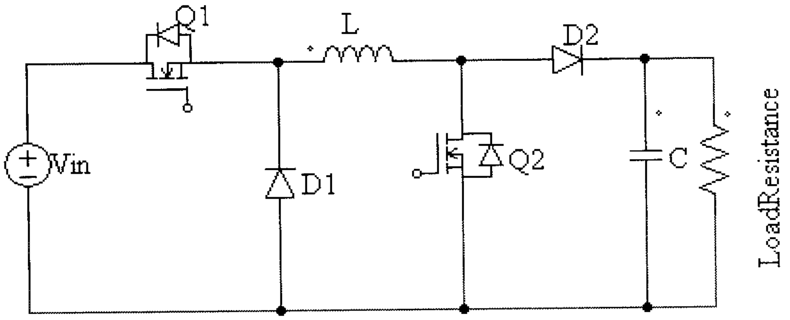


Fig 2.7 Circuit Diagram of Buck converter cascaded with Boost Converter

In this Buck – Boost Converter the output voltage is either less than or greater than the input voltage. The converter will operate in Buck mode by controlling the switch Q1, when Q2 is turned OFF and D2 is conducting. The converter will operate in Boost mode by controlling the switch Q2 when Q1 is ON and D1 is not conducting.

2.2.5 SINGLE PHASE PWM INVERTER:

In this project a fixed DC input voltage from the output of the Buck-Boost Converter is given to the Inverter and a controlled AC voltage is obtained at the output by adjusting the ON and OFF period of the power MOSFET's. The PWM technique has the following advantages:

- The output voltage control in this method can be obtained without any additional components
- The lower order harmonic can be minimized along with the output voltage control.

The pulse width modulation techniques can be classified mainly as:

(a) Single Pulse Width Modulation
(b) Multiple Pulse Width Modulation
(c) Sinusoidal Pulse Width Modulation

2.2.5 (a) SINGLE PULSE WIDTH MODULATION:

The output voltage from the single phase PWM Inverter is shown below .It consists of a pulse of width 2d located symmetrically about Π /2 and the another pulse located symmetrically about 3 Π /2 .The range of pulse width varies from 0 to Π (0<2d< Π) .The output voltage is controlled by the pulse width of 2d.The shape of the output voltage is a quasi-square wave.

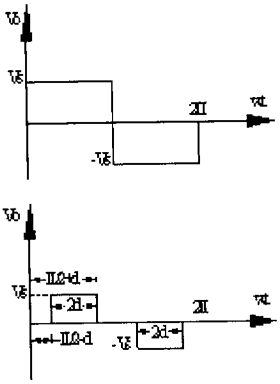


Fig 2.8 Single Phase PWM Output

2.2.5 (b) MULTIPLE PULSE WIDTH MODULATION:

The Multiple Pulse Width Modulation uses two symmetric pulses per half cycle. The symmetrical modulated wave form is shown below:

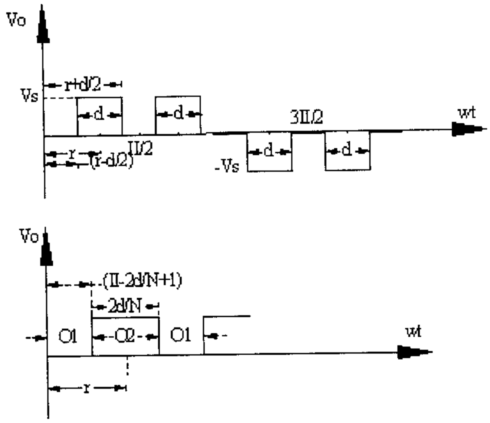


Fig 2.9 Symmetrical modulated wave for Multiple Pulse Width Modulation

This symmetric modulated wave can be generated by comparing an adjustable square voltage wave Vr of frequency ω_c as shown in below:

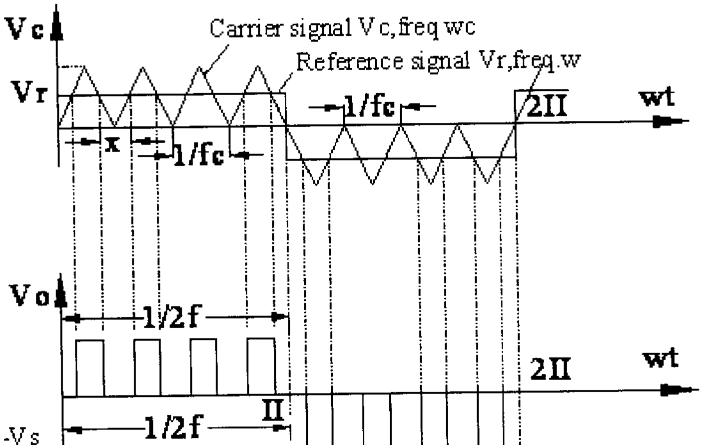


Fig 2.10 Output Voltage waveform with Multiple Pulse Width Modulation

The firing pulse for the power MOSFET is given by the intersection of carrier and reference signal .The firing pulses so generated turn ON the MOSFET so that the output voltage is available during the interval triangular modulating wave exceeds the square modulating wave.

2.2.5 (c) SINUSOIDAL PULSE WIDTH MODULATION:

In this modulation, several pulses per half cycle are used. In Multiple Pulse Width Modulation, the pulse width is equal for all pulses whereas in Sinusoidal PWM the pulse width is a sinusoidal function of the angular position of the pulse given in the cycle.

For releasing sine PWM, a higher frequency triangular wave is compared Vc is compared with the sinusoidal reference wave Vr of desired frequency. The value of Vr/Vc is called Modulation Index and it controls the harmonic content of the output waveform. The intersection of Vc and Vr determines the switching instant and commutation of the modulated pulse. The below diagram shows the Sinusoidal PWM:

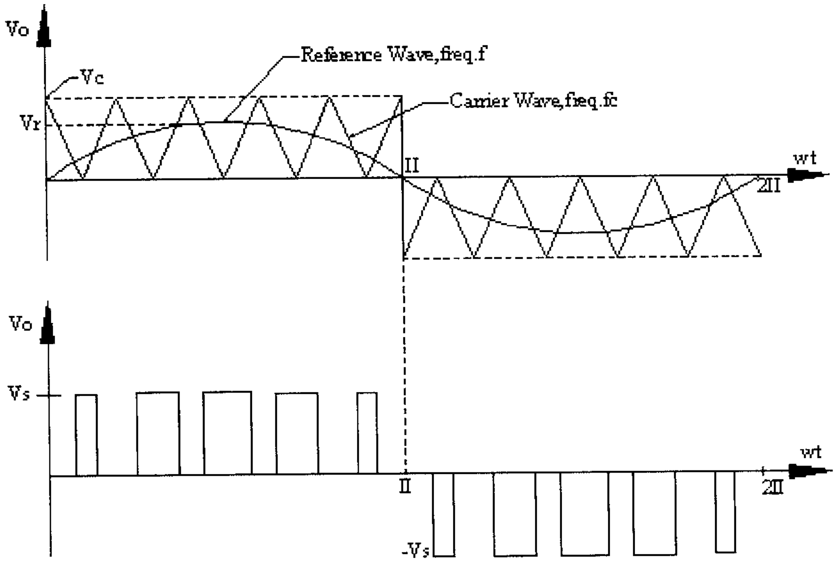


Fig 2.11 Output Voltage waveform with Sinusoidal Pulse Width Modulation

2.3 HARDWARE PHOTOGRAPHS:

The Diode used for the rectification purpose is BY 339 and six numbers are used. The power MOSFET used for Buck, Boost Converter and PWM Inverter is IRF 250 which has voltage rating and current ratings as 200V, 30A respectively.

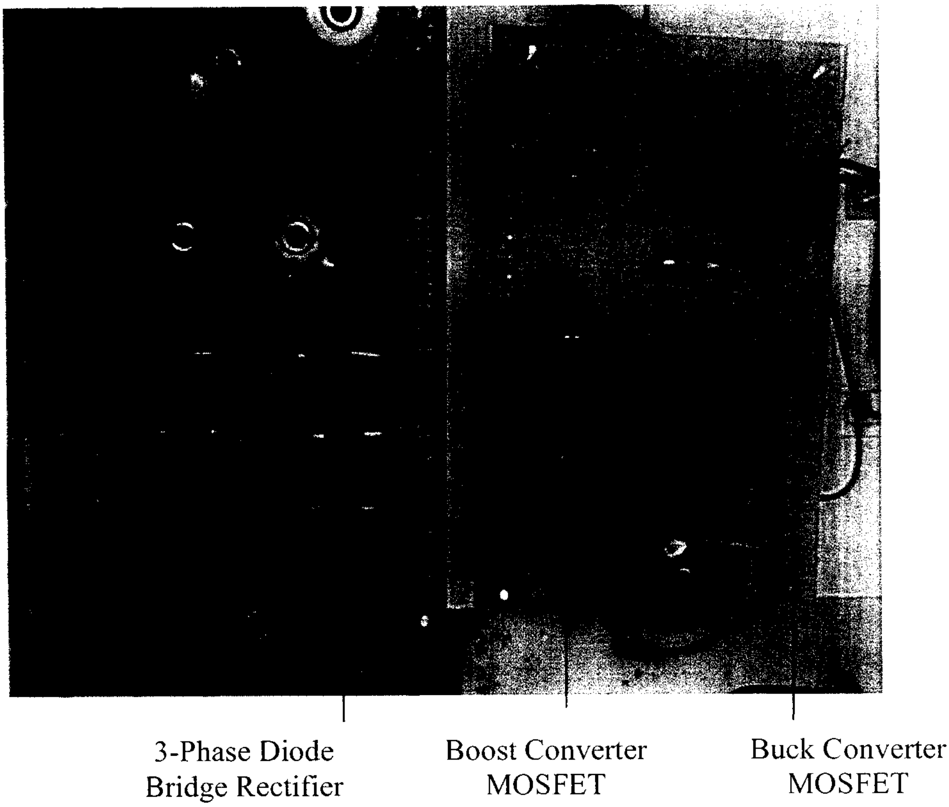


Fig 2.12 3-Phase Diode Bridge Rectifier hardware setup

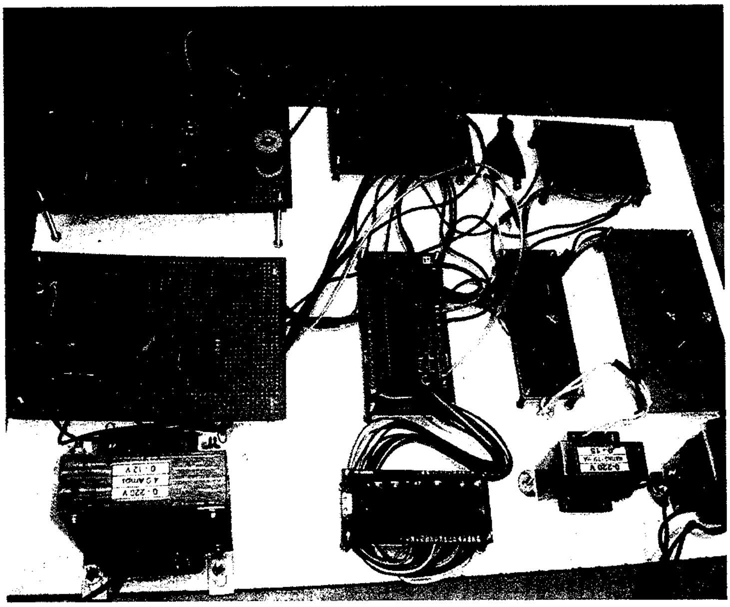


Fig 2.13 PIC Microcontroller Interfaced with Buck Boost Converter hardware setup

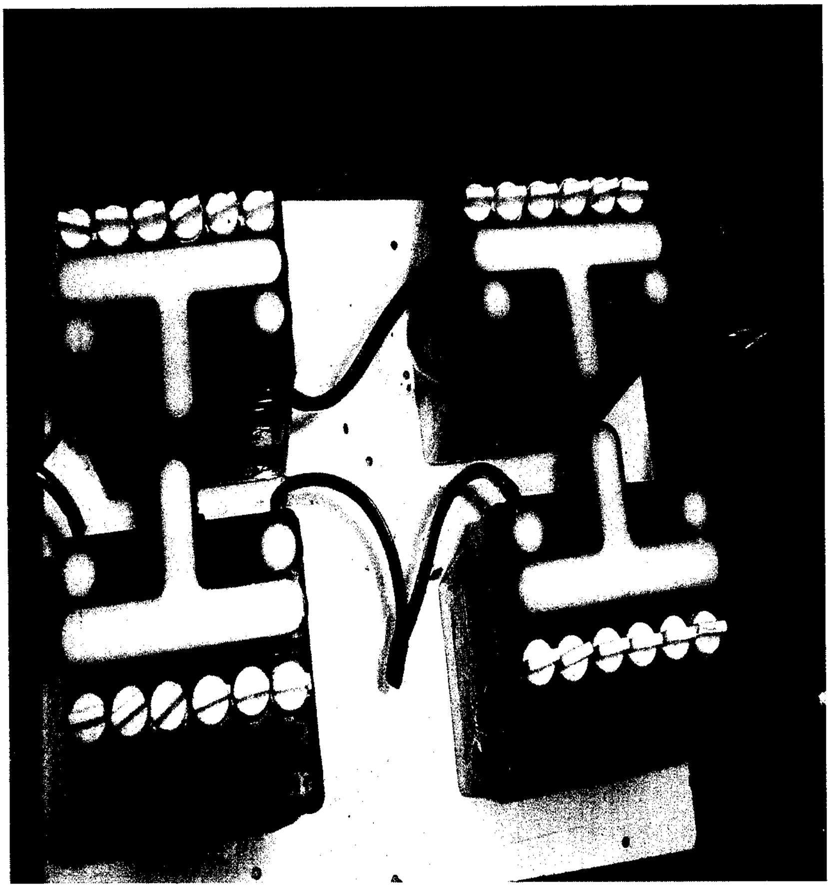


Fig 2.14 Battery for power storage

The Battery used in this project is 12V, 2.5Ah of four in numbers. The output from the battery is a constant DC voltage of 48V .This constant DC voltage is given as input to the single phase PWM Inverter. The output voltage is stepped up to 230V using a step up Transformer.

Fig 2.15Single Phase PWM Inverter hardware setup

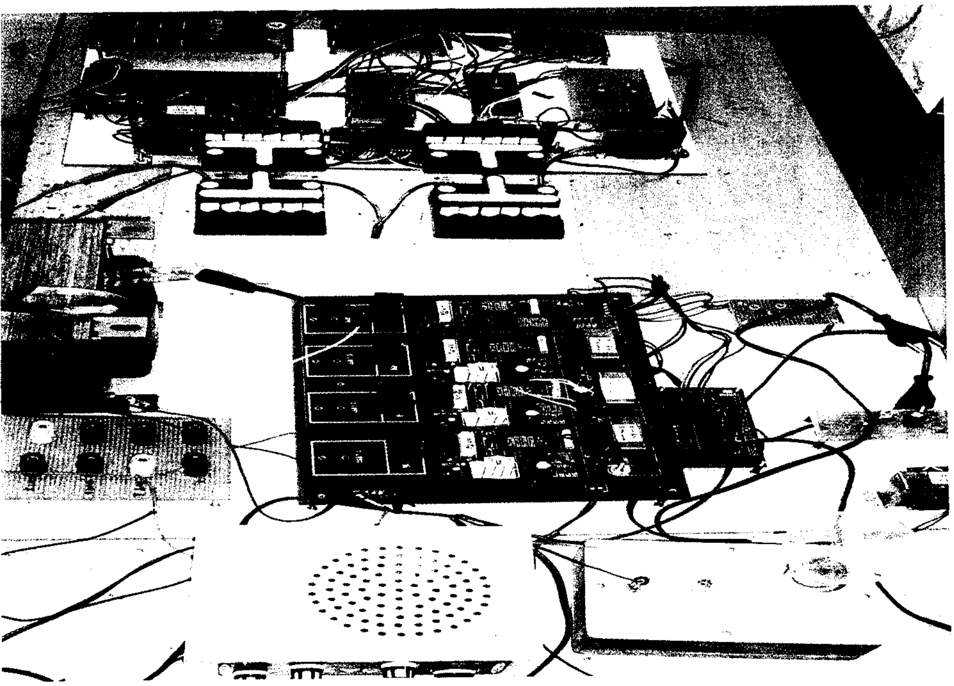


Fig 2.16 Complete circuit hardware setup

2.4 HARDWARE RESULTS:

The hard ware waveform for the Buck-Boost converter is shown below with the output voltage of 48 V (2.4 division and 20volts/division).

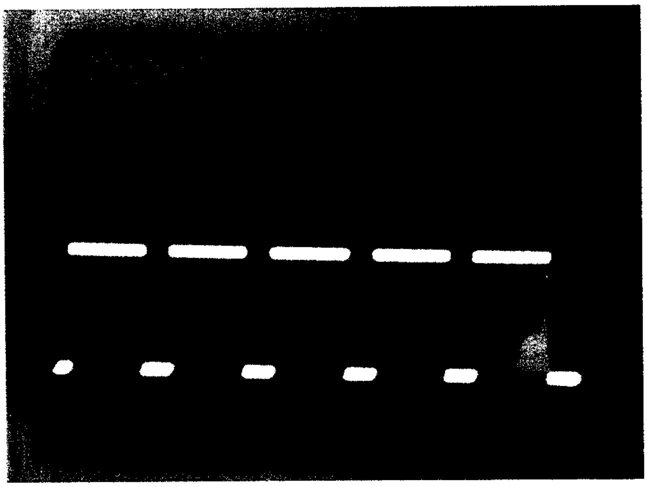


Fig 2.17 CRO output waveform for Buck Boost Converter

The PWM pulse generated from the Microcontroller is generated is given below .The output voltage is 5V (1 divisions and 5V /division)

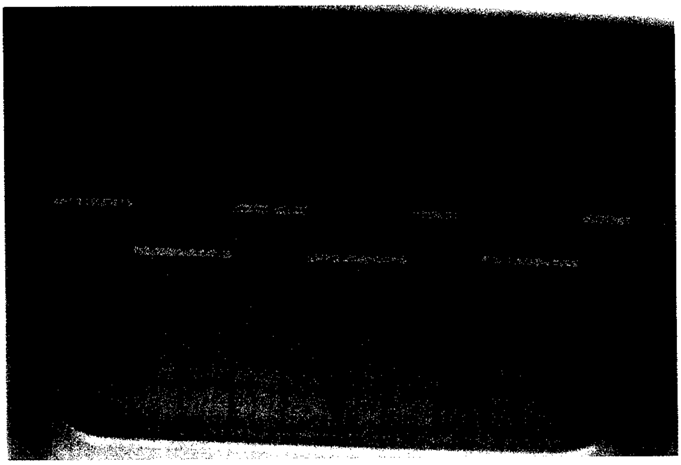


Fig 2.18 CRO output waveform for PWM Pulse

The PWM output is shown below with the output voltage of 48V (2.4 divisions with 20volts/divisions)

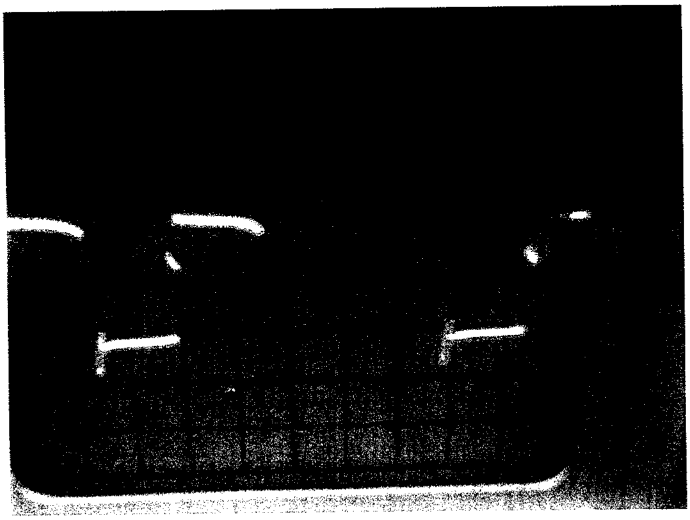


Fig 2.19 CRO output waveform for PWM Inverter

CHAPTER III

EMBEDDED PART

3.1 NEED FOR THE MICROCONTROLLER:

The Turn ON time of the Buck Boost converter and PWM Inverter are controlled using PIC 16F877microcontroller .In this project ,Buck Boost converter uses a separate PIC 16F877 and PWM Inverter uses a separate PIC 16F877.Since the pulse generated from PIC microcontroller cannot drive the MOSFET's of the power circuit ,a driver circuit is needed. Thus the pulses generated from the PIC microcontroller are increased to a higher voltage level using driver circuits.

3.2PIN CONFIGURATION OF PIC16F877:

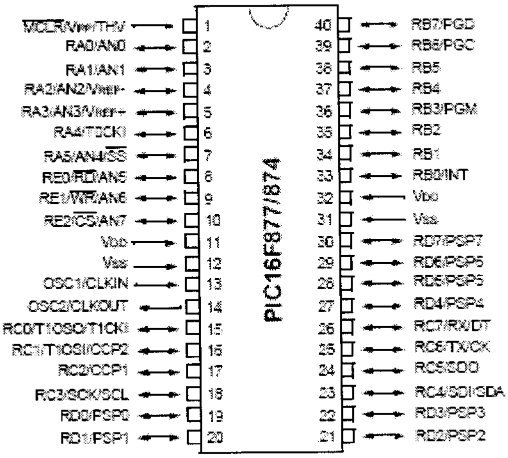


Fig 3.1 Pin Diagram of PIC 16F877

3.3 FEATURES OF THE MICROCONTROLLER PIC16F877:

The microcontroller has the following features:

- High-performance RISC CPU
- All single cycle instructions except for program branches which are two cycle

- It has up to 8K x 14 words of FLASH Program Memory,
- It has up to 368 x 8 bytes of Data Memory (RAM)
- It has up to 256 x 8 bytes of EEPROM data memory
- Direct, indirect and relative addressing modes
- Power-on Reset (POR)
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Power saving SLEEP mode
- Selectable oscillator options
- Low-power, high-speed CMOS FLASH/EEPROM technology
- Single 5V In-Circuit Serial Programming capability
- Wide operating voltage range: 2.0V to 5.5V

3.4PERIPHERAL FEATURES OF THE MICROCONTROLLER PIC16F877:

- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler, can be incremented during sleep via external crystal/clock
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Two Capture, Compare, PWM modules
- Capture is 16-bit, max. resolution is 12.5 ns
- Compare is 16-bit, max. resolution is 200 ns
- PWM max. resolution is 10-bit
- 10-bit multi-channel Analog-to-Digital converter
- Synchronous Serial Port (SSP) with SPI (Master Mode) and I2C (Master/Slave)
- Universal Synchronous Asynchronous Receiver Transmitter (USART/SCI) with 9-bit address detection
- Parallel Slave Port (PSP) 8-bits wide, with external RD, WR and CS controls
- Brown-out detection circuitry for Brown-out Reset (BOR)

3.5 MEMORY ORGANIZATION:

The PIC16F877 has a 13-bit program counter capable of addressing an 8K x 14 program memory space. The PIC16F877 devices have 8K x 14 words of FLASH program memory. Accessing a location above the physically implemented address will cause a wraparound. The reset vector is at 0000h and the interrupt vector is at 0004h.

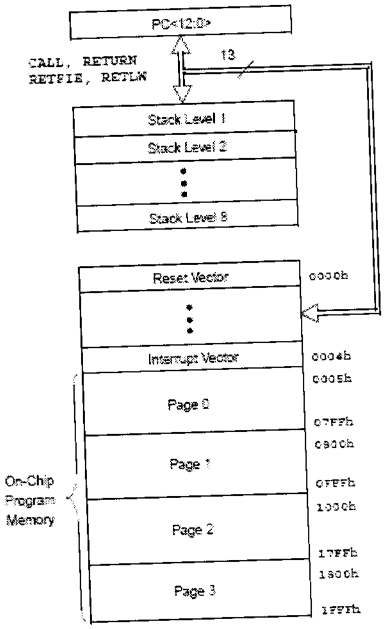


Fig 3.2Memory Organization of PIC 16F877

3.6 FLASH PROGRAM MEMORY:

The Data EEPROM and FLASH Program Memory are readable and writable during normal operation over the entire VDD range. The data memory is not directly mapped in the register file space. Instead it is indirectly addressed through the Special Function Registers (SFR). There are six SFRs used to read and write the program and data EEPROM memory. These registers are:

- EECON1
- EECON2
- EEDATA
- EEDATH
- EEADR

- EEADRH

The PIC 16F877 also has three timers namely:

- Timer 0 Module
- Timer 1 Module
- Timer 2 Module

3.6 (a) TIMER 0 MODE:

Timer mode is selected by clearing bit T0CS (OPTION_REG 5). In timer mode, the Timer0 module will increment every instruction cycle (without prescaler).Counter mode is selected by setting bit T0CS (OPTION_REG 5). In counter mode, Timer0 will increment either on every rising or falling edge of pin RA4/T0CKI. The incrementing edge is determined by the Timer0 Source Edge Select bit T0SE of (OPTION_REG 4). Clearing bit T0SE selects the rising edge. The prescaler is mutually exclusively shared between the Timer0 module and the watchdog timer.

3.6(b) TIMER 1 MODE:

The Timer1 module is a 16-bit timer/counter consisting of two 8-bit registers (TMR1H and TMR1L), which are readable and writable. The TMR1 Register pair (TMR1H:TMR1L) increments from 0000h to FFFFh and rolls over to 0000h.

Timer1 can operate in one of two modes:

- As a timer
- As a counter

The operating mode is determined by the clock select bit, TMR1CS (T1CON 1).

In timer mode, Timer1 increments every instruction cycle. In counter mode, it increments on every rising edge of the external clock input. Timer1 can be enabled/disabled by setting/clearing control bit TMR1ON (T1CON 0).

3.6 (c) TIMER 2 MODE:

Timer 2 is an 8-bit timer with a prescaler and a postscaler. It can be used as the PWM time-base for the PWM mode of the CCP module(s). The TMR2 register is readable and writable, and is cleared on any device reset. The Timer2 module has an 8-bit period register PR2.Timer2 increments from 00h until it matches PR2 and then resets to

00h on the next increment cycle. PR2 is a readable and writable register. The PR2 register is initialized to FFh upon reset.

3.7CAPTURE/COMPARE/PWM MODES:

Each Capture/Compare/PWM (CCP) mode contains a 16-bit register which can operate as a:

- 16-bit Capture register
- 16-bit Compare register
- PWM master/slave Duty Cycle register

Both the CCP1 and CCP2 modules are identical in operation, with the exception being the operation of the special event trigger.

3.7(a) CCP 1 MODE:

Capture/Compare/PWM Register1 (CCPR1) is comprised of two 8-bit registers: CCPR1L (low byte) and CCPR1H (high byte). The CCP1CON register controls the operation of CCP1. The special event trigger is generated by a compare match and will reset Timer1.

3.7(b) CCP 2 MODE:

Capture/Compare/PWM Register 2 (CCPR2) is comprised of two 8-bit registers: CCPR2L (low byte) and CCPR2H (high byte). The CCP2CON register controls the operation of CCP2. The special event trigger is generated by a compare match and will reset Timer 2 and start an A/D conversion.

3.7(c) PWM MODE:

In pulse width modulation mode, the CCPx pin produces up to a 10-bit resolution PWM output. Since the CCP1 pin is multiplexed with the PORT C data latch, the TRISC 2 bit must be cleared to make the CCP1 pin an output. The Block Diagram of the PWM Mode and the PWM output is given below:

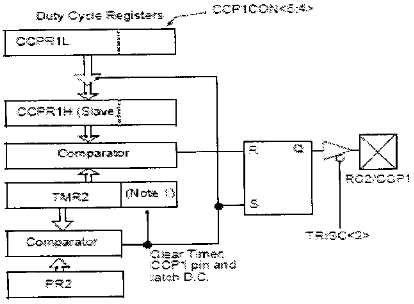


Fig 3.3 Functional Block Diagram of PWM operation

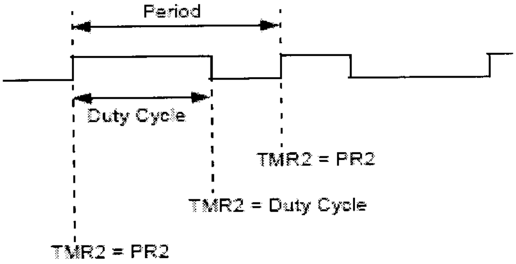


Fig 3.4 PWM output

A PWM output has a time-base (period) and a time that the output has high (duty cycle). The frequency of the PWM is the inverse of the period (1/period).

The PWM period is specified by writing to the PR2 register. The PWM period is calculated using the following formula:

PWM period = [(PR2) + 1] * 4 *TOSC

3.7(d) PWM DUTY CYCLE:

The PWM duty cycle is specified by writing to the CCPR1L register and to the CCP1CON 5, 4 bits. Up to 10-bit resolution is available. The CCPR1L contains the eight MSBs and the CCP1CON5, 4 contains the two LSBs. This 10-bit value is represented by CCPR1L:CCP1CON 5, 4. The following equation is used to calculate the PWM duty cycle in time:

PWM duty cycle = (CCPR1L:CCP1CON 5, 4) * Tosc * (TMR2 prescale value)

CCPR1L and CCP1CON 5,4 can be written to at any time, but the duty cycle value is not latched into CCPR1H until after a match between PR2 and TMR2 occurs (i.e., the period is complete). In PWM mode, CCPR1H is a read-only register.

The following steps should be taken when configuring the CCP module for PWM operation:

1. Set the PWM period by writing to the PR2 register.
2. Set the PWM duty cycle by writing to the CCPR1L register and CCP1CON 5, 4 bits.
3. Make the CCP1 pin an output by clearing the TRISC 2 bit.
4. Set the TMR2 prescale value and enable Timer2 by writing to T2CON.
5. Configure the CCP1 module for PWM operation.

3.8 PIC 16F877 MICROCONTROLLER TO DRIVE BUCK BOOST CONVERTER:

This PIC microcontroller has port A, B, C, D, and E. In this part of the Buck Boost converter port A, B and D is initialized and used .Pins RD 0 to RD 7 is given for the LCD Display. Pins RB6 and RB7 are used to give the triggering pulse to the power MOSFET present in the Buck Boost Converter .The output from the Buck Boost converter is obtained at RA0 . By adjusting the duty ratio (k) of the Buck Boost converter either Buck or Boost operation is performed to maintain the constant output voltage of 50 V. For this adjustment of the duty ratio embedded C codes are written in the microcontroller .This embedded C is compiled in MPLAB IDE is used and the debugger used is In- Circuit Debugger ICD 2. MPLAB IDE is a software program that runs on a PC to develop applications for Microchip microcontrollers. It is called an Integrated Development Environment, or IDE, because it provides a single integrated .environment. to develop code for embedded microcontrollers.

3.8.1 DRIVER CIRCUIT FOR BUCK BOOST CONVERTER:

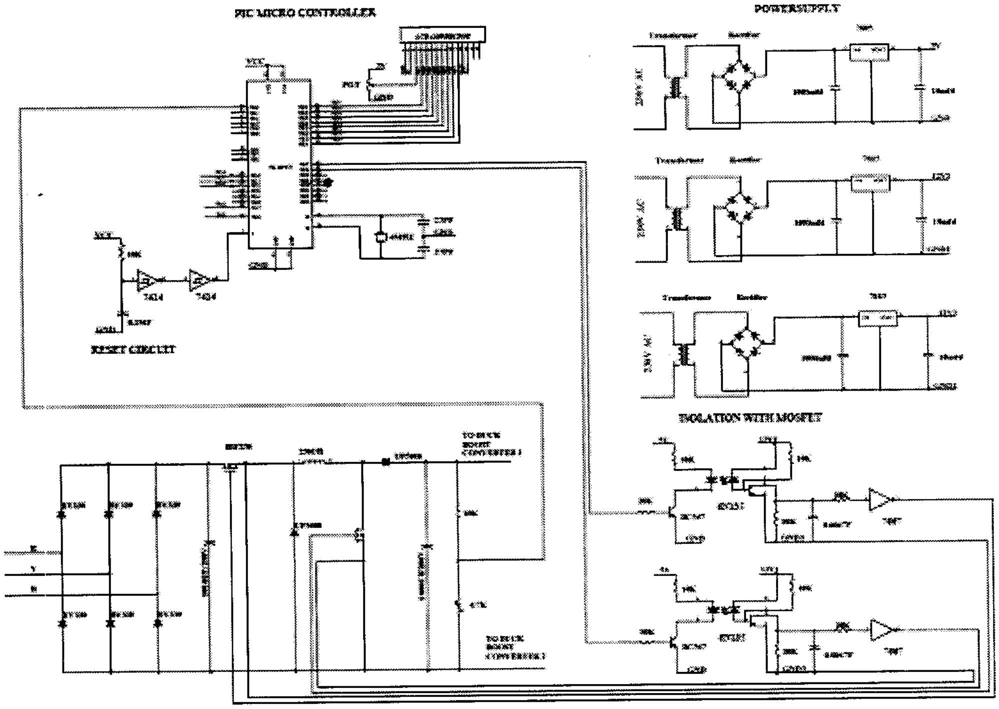


Fig 3.5 Circuit Diagram to drive power MOSFET of Buck-Boost Converter (Also attached in APPENDIX Page No: 61)

3.8.2 DRIVER CIRCUIT OPERATION FOR BUCK BOOST CONVERTER:

In order to give triggering pulse to the power MOSFET IRF 250 for Buck and Boost Converter, the triggering pulse triggering pulse are generated from PB6 and PB7 of port B. These output pins drive the transistor BC 547. Depending on the output voltage (Logic 0 or Logic 1) the transistor gets turn ON and turn OFF. The voltage thus obtained is isolated by using optocoupler IC 6N135.The purpose of the isolation is to give constant output voltage to drive the power MOSFET so that the variation in the input voltage will not affect the output voltage .Thus the isolated output voltage now drives the other transistor BC 547 and gives the triggering pulse to the power MOSFETS.

3.8.3 FLOW CHART OF THE MICROCONTROLLER USED IN BUCK BOOST CONVERTER:

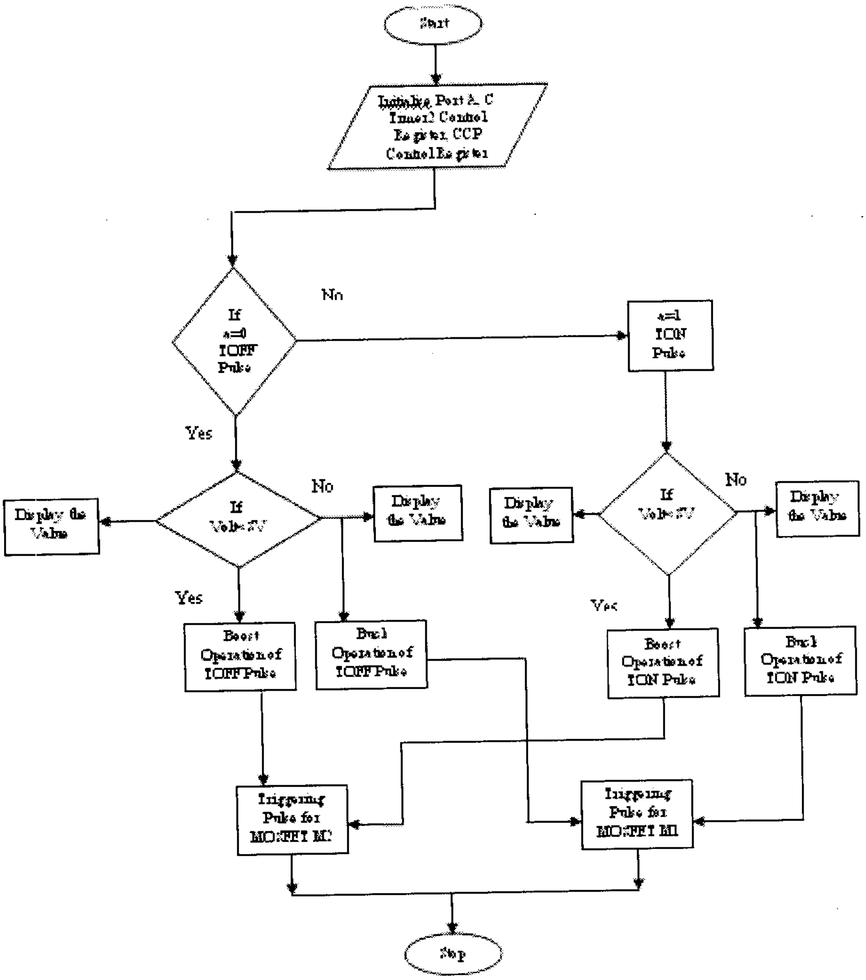


Fig 3.6 Flow chart of Buck Boost operation (Also attached in APPENDIX Page No: 64)

3.8.4 PROGRAM CODING FOR BUCK BOOST OPERATION:

```
#include<pic.h>

#include<lcd.h>

void pwm_dutycycle (void);

void adc_init ();
```

```
void adc0();
void hex_ dec _a (unsigned int);
unsigned int temp0, temp2, temp3, y,msb,lsb,j,difr;
unsigned char sv, volt;
bit a, b;
void interrupt timer2 (void)
{
if (TMR2IF==1)                // Timer2 interrupt flag check
 {
  TMR2ON=0;                   // Timer2 off
  TMR2IF=0;                   // Clear Timer2 flag
  PR2=0xFA;                   // 1 kHz- 4 MHz
 if (!a)
 {
  CCPR2L=msb;
  CCP2CON=lsb;
  CCPR1L=255;
  CCP1CON=0x3c;
 }
 else if (a)
 {
  CCPR2L=0x00;
  CCP2CON=0x0c;
```

```
 CCPR1L=msb;
 CCP1CON=lsb;
}
 T2CON=0x05;                    // Prescale 4
 }
}
void main()
{
TRISC=0x00;                     // Port C as o/p port
lcd_init ();
adc_init ();
command (0x01);command(0x80);
lcd_condis ("Square Wave Ctrl.", 16);
command (0xc0);
lcd_condis ("Vol: 000 SV: 000 ", 16);
sv=48;
command (0xcc);
hex_dec (sv);
  GIE=1;
  PEIE=1;
  TMR2IE=1;
  T2CON=0x05;
  TMR2ON=0;
```

```
 PR2=0xFA;                    // 1 kHz- 4 MHz
a=0;
temp2=50;
while (1)
{
            adc0 ();
            command (0xc4);
            hex_dec (volt);
if (!a)
{
if (volt<(sv-1))
{
difr=volt-sv;
if(difr>20 && temp2<790) temp2+=10;
else if(difr>10 && temp2<795) temp2+=5;
else if(difr>5 && temp2<797) temp2+=3;
else if(temp2<799) temp2++;
}
else if(volt>(sv+1))
{
difr=sv-volt;
if(difr>20 && temp2>10) temp2-=10;
else if(difr>10 && temp2>5) temp2-=5;
```

```
else if(difr>5 && temp2>3) temp2-=3;
else if(temp2>0) temp2--;
}
if(!temp2 && volt>(sv+1)) {a=1; b=0;}
}
else if(a)
{
if(volt>(sv+1))
{
difr=volt-sv;
if(difr>20 && temp2<790) temp2+=10;
else if(difr>10 && temp2<795) temp2+=5;
else if(difr>5 && temp2<797) temp2+=3;
else if(temp2<799) temp2++;
}
else if(volt<(sv-1))
{
difr=sv-volt;
if(difr>20 && temp2>10) temp2-=10;
else if(difr>10 && temp2>5) temp2-=5;
else if(difr>5 && temp2>3) temp2-=3;
else if(temp2>0) temp2--;
}
```

```
if(!temp2 && volt<(sv-1)) a=0;
}
            pwm_dutycycle();
}
}
void pwm_dutycycle()
 {
  temp3=temp2;
  lsb=temp3 & 0x03;
  if(lsb==0x00) lsb=0x0c;
  else if(lsb==0x01) lsb=0x1c;
  else if(lsb==0x02) lsb=0x2c;
  else if(lsb==0x03) lsb=0x3c;
  msb=temp3>>2;
  TMR2ON=1;
 }
 void adc_init()
 {
   ADCON1=0x09;            // 8-channel,ADC control
   TRISA=0xff;             // to select the port A as input port
 }
 void adc0()
 {
```

```
temp0=0;
 for(j=0;j<25;j++)
 {
   ADCON0=0x00;              // Channel select (Cha: 0)
   ADON=1;                    // ADC module ON
   delay(25);
   ADCON0 =0x05;         // selecting a particular channel and making the go/done bit
 high
    while(ADCON0!=0X01);  // Check whether conversion finished or not
             temp0 = temp0 + ADRESH;
  }
 volt=temp0/25;
 }
 void hex_dec_a(unsigned int val)
 {
  th=val/1000;
  thr=val%1000;
  h=thr/100;
  hr=thr%100;
  t=hr/10;
  o=hr%10;
  lcd_disp(h+0x30);
  lcd_disp(t+0x30);
```

```
lcd_disp('.');

lcd_disp(o+0x30);

}
```

3.9 PIC 16F877 MICROCONTROLLER TO DRIVE SINGLE PHASE PWM INVERTER:

In this part of the single phase PWM Inverter port B and port C Timer 0 and TRISB registers are initialized. The PWM pulses are generated from RB4, RB5, RB6, and RB7 of port B. By adjusting the time delay generated from the microcontroller suitable triggering pulses are given to the power MOSFET to get turn ON and turn OFF. For this adjustment of the time delay embedded C codes are written in the microcontroller .This embedded C is compiled in MPLAB IDE. The debugger used is In-Circuit Debugger ICD 2.

3.9.1 DRIVER CIRCUIT FOR SINGLE PHASE PWM INVERTER:

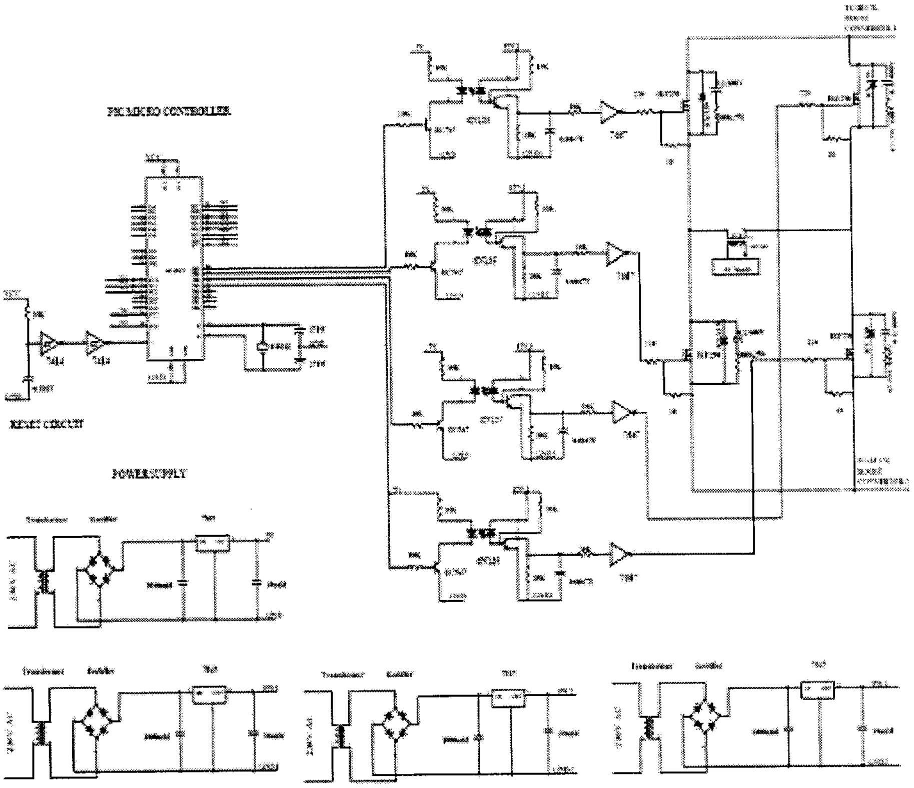


Fig 3.7 Circuit Diagram to drive power MOSFET'S of PWM Inverter (Also attached in APPENDIX Page No: 62)

3.9.2DRIVER CIRCUIT OPERATION FOR SINGLE PHASE PWM INVERTER:

In order to give triggering pulse to the power MOSFET'S for single phase PWM Inverter, the triggering pulse are generated from PB4, PB5, PB6 and PB7 of port B. These output pins drive the transistor BC 547. Depending on the output voltage (Logic 0 or Logic 1) the transistor gets turn ON and turn OFF. The voltage thus obtained is isolated by using optocoupler IC 6N135.The purpose of the isolation is to give constant output voltage to drive the power MOSFET'S so that the variation in the input voltage will not affect the output voltage .Thus the isolated output voltage now drives the other transistor BC 547 and gives the triggering pulse to the power MOSFETS.

3.9.3 FLOW CHART OF THE MICROCONTROLLER OPERATION IN PWM INVERTER:

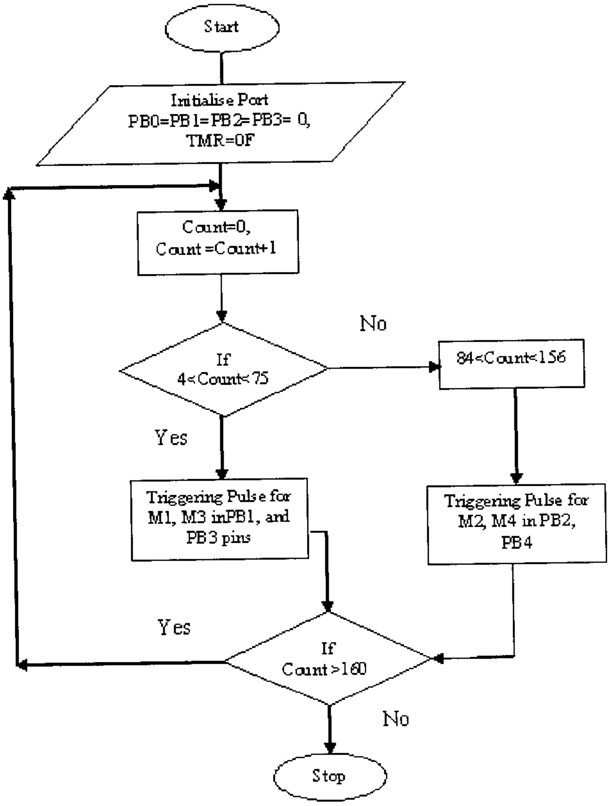


Fig 3.8 Flow Chart for PWM Inverter Operation

3.9.4 PROGRAM CODING FOR PWM INVERTER OPERATION:

```
#include<pic.h>

static bit p1 @ ((unsigned) &PORTB*8+0);

static bit p2 @ ((unsigned) &PORTB*8+1);

static bit p3 @ ((unsigned) &PORTB*8+2);

static bit p4 @ ((unsigned) &PORTB*8+3);

unsigned int count;

void main()

{

TRISC=0x0f;                                   // Port C as o/p port

TRISB=0x00;

p1=p2=p3=p4=0;

count=0;

GIE=1;       // enable global interrupt

PEIE=1;      // enable peripheral interrupt

T0IE=1;      // enable timer0 interrupt

OPTION = 0x01;          // set prescale (00)

TMR0 = 0xfc;            // timer reg set value for ten micro sec F7


while (1)

{

}

}
```

```
void interrupt timer(void)
{
 if(T0IF=1)
 {
  T0IF=0;
  count++;
            if(count>160) count=0;
            if(count>=4&&count<=75) p3=p1=1;
            else p3=p1=0;
            if(count>=84&&count<=156) p4=p2=1;
            else p4=p2=0;
  TMR0 = 0Xfc;
  }
 }
```

CHAPTER IV

SIMULATION USING PSIM 7.0.5

4.1 INTRODUCTION TO PSIM SOFTWARE:

PSIM 7.0.5 is Power Simulation software specifically designed for Power Electronics and Motor Drives. With fast simulation and user friendly interface, PSIM provides a powerful Simulation environment for power electronics, analog and digital control, magnetic, and motor drive system studies. The PSIM has the following Modules:

1) Motor Drive Module
2) Digital Control Module
3) Sim Coupler Module
4) Thermal Module
5) MagCoupler Module
6) MagCoupler-RT Module

The Motor Drive Module has built-in machine models and mechanical load models for motor drive system studies.

The Digital Control Module provides discrete elements such as zero-order hold, z domain transfer function blocks, quantization blocks, digital filters, for digital control system analysis.

The SimCoupler Module provides interface between PSIM and Matlab/Simulink for co-simulation.

The Thermal Module provides the capability to calculate semiconductor devices losses.

The MagCoupler Module provides interface between PSIM and the electromagnetic field analysis software JMAG for co-simulation.

The MagCoupler-RT Module links PSIM with JMAG-RT data files. In addition, PSIM supports links to third-party software through custom DLL blocks.

The overall PSIM environment is shown below.

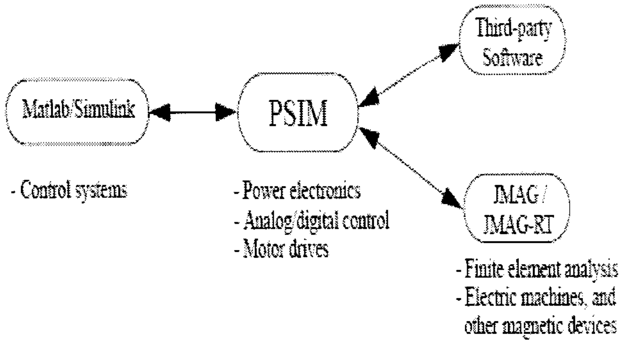


Fig 4.1 Overall PSIM environment

The PSIM simulation environment consists of the circuit schematic program PSIM, the Simulator engine, and the waveform processing program Simview.

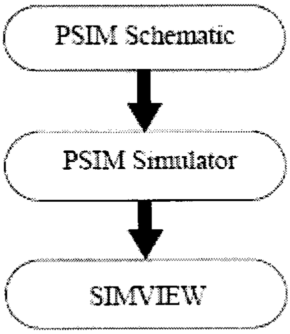


Fig 4.2 Simulation Process of PSIM

The circuit schematic is used to draw the circuits; the simulator engine is used for the simulation of the circuits drawn and the Simview is used to see the simulated outputs.

4.2 SIMULATION OF 3-PHASE DIODE BRIDGE RECTIFIER:

The simulation circuit for the 3-Phase Diode Bridge Rectifier is shown below. The 3-phase input voltage is given with 120 ° phase shift. The output voltage is a rectified DC voltage.

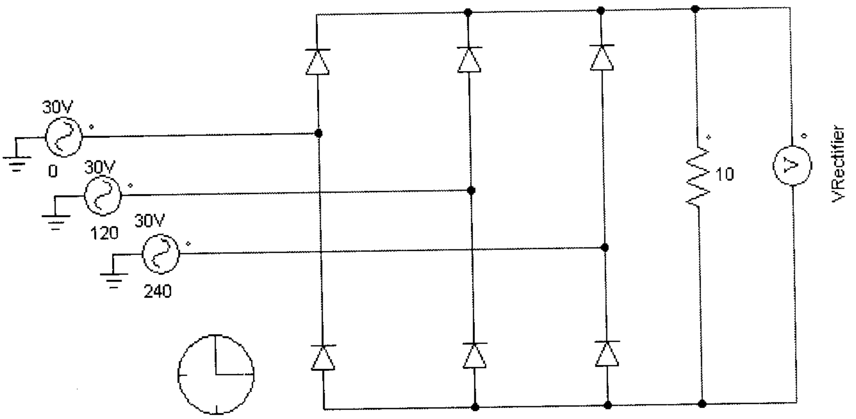
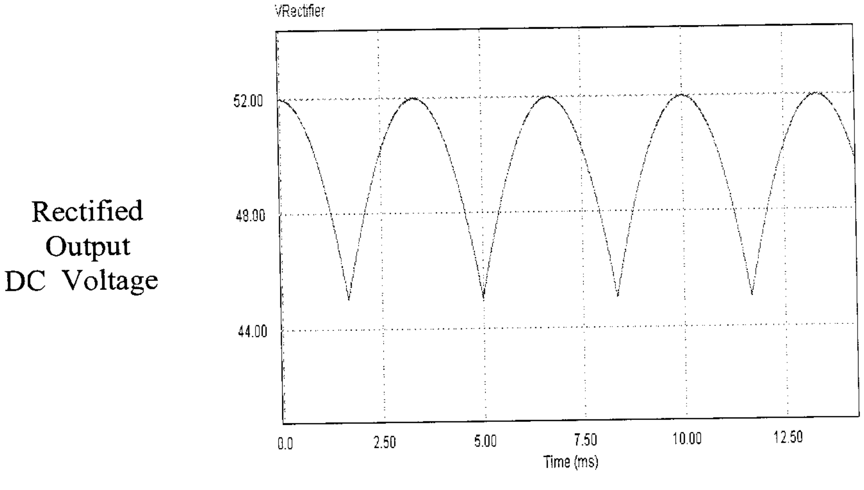


Fig 4.2(a) Simulation Circuit of 3-Phase Diode Bridge Rectifier



Time (msec)

Fig 4.2(b) Simulated output voltage waveform of 3-Phase Diode Bridge Rectifier

4.3 SIMULATION OF BUCK BOOST CONVERTER:

The Buck Boost converter consists of DC input voltage source, controlled switch, inductor L, diode D, filter capacitor C, and load resistance R. With the switch on, the inductor current increases while the diode is maintained off. When the switch is turned off, the diode provides a path for the inductor current.

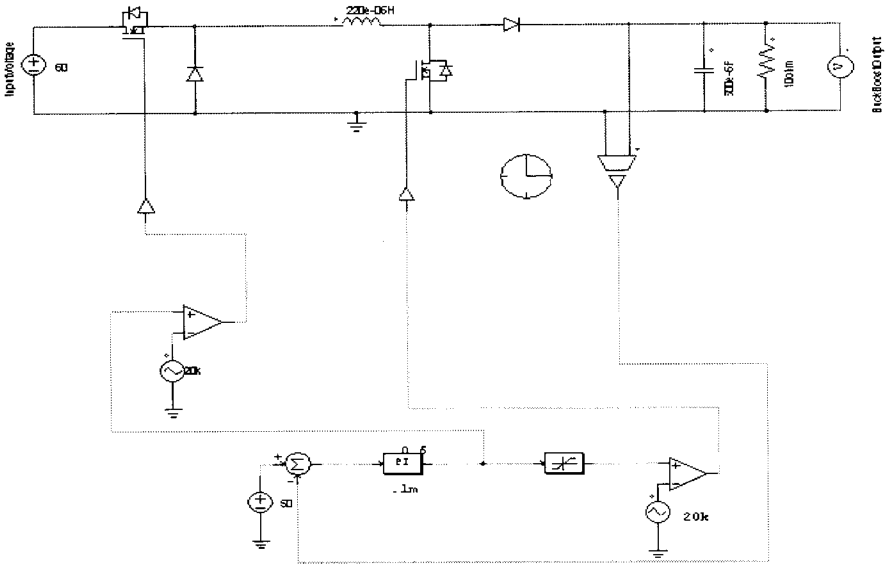


Fig 4.3 (a) Closed Loop Simulation circuit of Buck Boost Converter

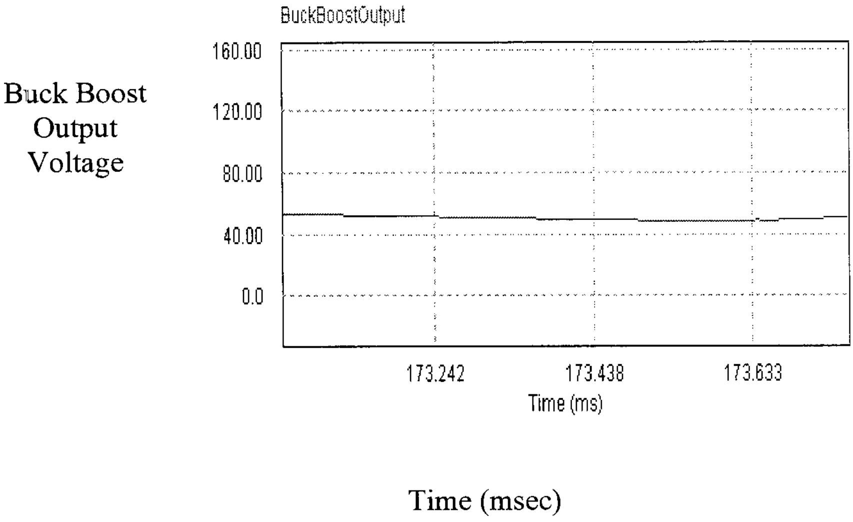


Fig 4.3 (b) Simulated output voltage waveform of Buck Boost Converter

The variable rectified DC output voltage is given as the input the Buck Boost Converter and the output obtained is a constant DC voltage of 50 V. This is done by varying the duty ratio.

4.4 SIMULATION OF 3-PHASE PWM INVERTER:

The function of the Inverter is to convert DC input voltage to a 3-Phase AC output voltage of desired magnitude and frequency. In this Project, 3-Phase Inverter consists of three–legs one for each phase. Each phase has 2 MOSFETS and a total of 6 MOSFETS. This Inverter is also called six-step Inverter. For one cycle of 360° each step (change of firing angle from one MOSFET to another MOSFET) has a 60° interval. The output of each phase is shifted by 120°. The diodes are connected anti parallel to the MOSFET in order to accommodate the phase relationship between current and voltage when we are using inductive Loads. Here 180° Conduction mode is performed since its Utility factor is more when compared to 120° Conduction Mode.

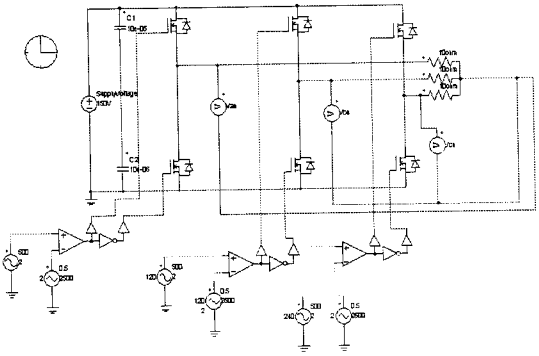
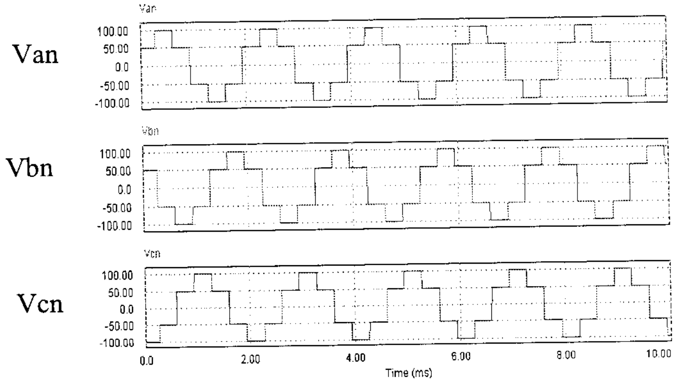


Fig 4.4(a) Simulation circuit of 3-Phase PWM Inverter



Time (msec)

Fig 4.4(b) Simulated output voltage waveforms of 3-Phase PWM Inverter

The Van, Vbn, Vcn are phase voltages of phase a, phase b, phase c with respect neutral.

Along with the simulation of 3-Phase PWM Inverter Sinusoidal PWM Technique is performed. To perform Sinusoidal PWM a triangular reference signal along with a sinusoidal reference signal is used to determine the switching times for the Power MOSFET. These inputs are compared and will control the ON/OFF states of the power MOSFET. The main advantage of this sinusoidal PWM Technique is to have reduced value of Total Harmonic Distortion (THD) and the Lower Order Harmonics (LOH) .The following diagram depicts the two inputs of the comparator.

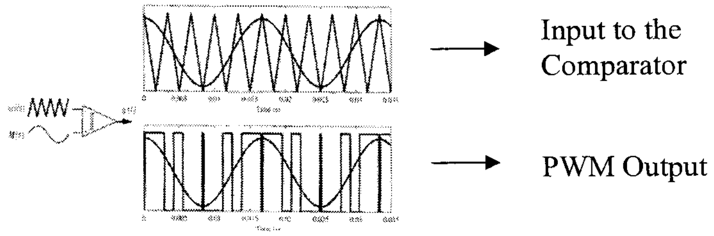


Fig: 4.4(c) Two inputs of the Comparator

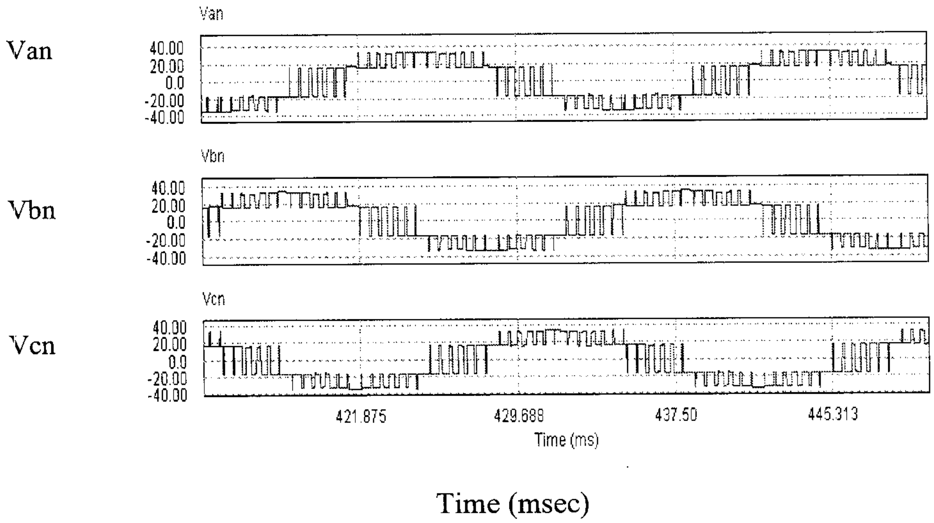


Fig 4.4(d) Simulated output voltage waveforms of 3-Phase Sinusoidal PWM Inverter

The Van, Vbn, Vcn are phase voltages of phase a, phase b, phase c with respect neutral.

4.5 SIMULATION OF BUCK BOOST AND 3-PHASE PWM INVERTER:

The simulation of both the Buck Boost Converter and the 3-Phase Inverter is shown below. Here closed loop operation of Buck Boost Converter is performed. The input voltage is varied from 30V to 60V .The output voltage is maintained constant of 50V.If the value of voltage obtained is less than 50V then Boost Operation takes place and if the output voltage is more than 50V then Buck Operation takes place and maintain the constant output voltage of 50 V.

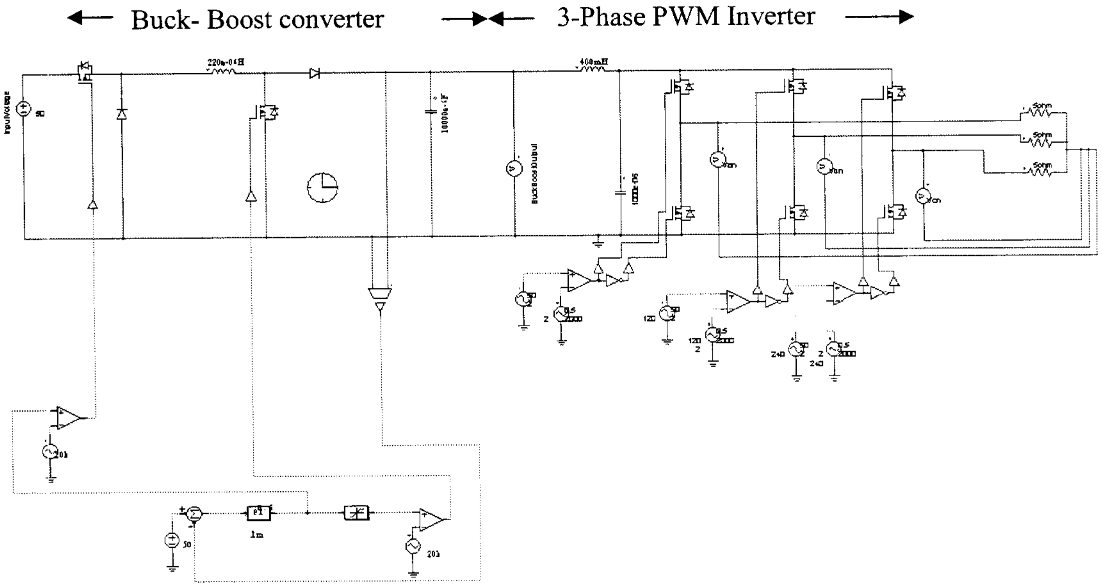


Fig 4.5(a) Simulation Circuit for Buck Boost Converter and 3-Phase PWM Inverter

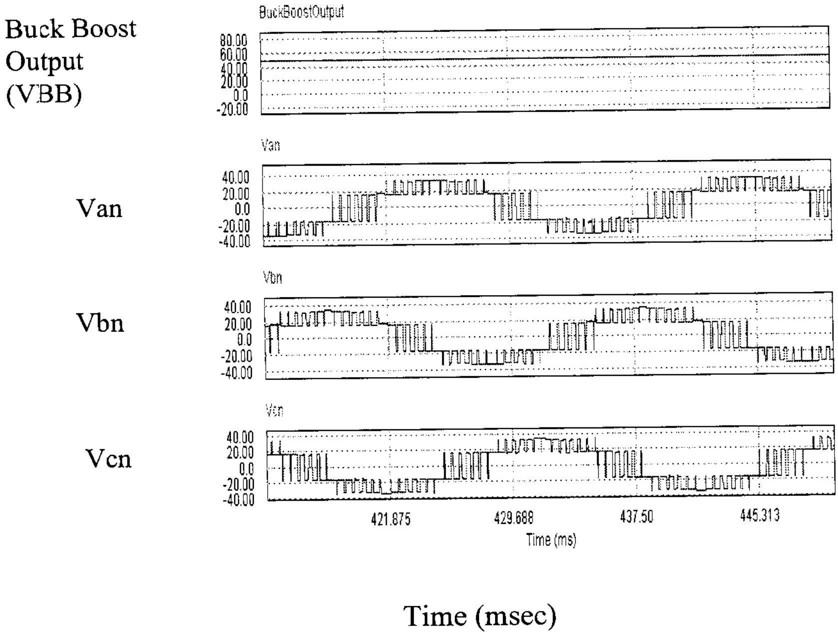


Fig 4.5 (b) Simulated output voltage waveforms of Buck Boost Converter and 3-Phase PWM Inverter

4.6 SIMULATION OF 3-PHASE PWM INVERTER SINE WAVE CONVERSION:

The following diagram shows the sine wave filter analysis to convert the stepped waveform into pure Sinusoidal waveform. In this filter analysis inductance and capacitor combinations are used. The system parameters for this converter are:

DC - link voltage: Vdc = 50 V

Fundamental frequency: f = 50 Hz

PWM (carrier) frequency: fc = 3 kHz

Output filter: Lf = 800 μH and Cf = 400 μF

Load: Lload = 2 mH and Rload = 5 Ω

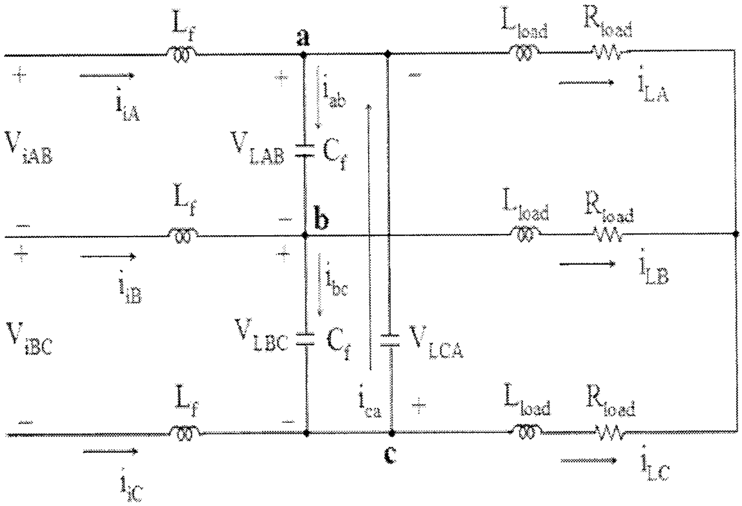


Fig 4.6(a) L-C output filter for current/voltage equations.

By applying Kirchoff's current law to nodes a, b, and c, respectively, the following current equations are derived:

At node a:

$$i_{iA} + i_{ca} = i_{ab} + i_{LA} \;\Rightarrow\; i_{iA} + C_f \frac{dV_{LCA}}{dt} = C_f \frac{dV_{LAB}}{dt} + i_{LA} \text{———} \qquad (4.1)$$

At node b:

$$i_{iB} + i_{ab} = i_{bc} + i_{LB} \;\Rightarrow\; i_{iB} + C_f \frac{dV_{LAB}}{dt} = C_f \frac{dV_{LBC}}{dt} + i_{LB} \text{———} \qquad (4.2)$$

At node c:

$$i_{iC} + i_{bc} = i_{ca} + i_{LC} \;\Rightarrow\; i_{iC} + C_f \frac{dV_{LBC}}{dt} = C_f \frac{dV_{LCA}}{dt} + i_{LC} \text{———} \qquad (4.3)$$

Where

$$i_{ab} = C_f \frac{dV_{LAB}}{dt}, \quad i_{bc} = C_f \frac{dV_{LBC}}{dt}, \quad i_{ca} = C_f \frac{dV_{LCA}}{dt}$$

Subtracting (4.2) from (4.1)

$$i_{iA} - i_{iB} + C_f\left(\frac{dV_{LCA}}{dt} - \frac{dV_{LAB}}{dt}\right) = C_f\left(\frac{dV_{LAB}}{dt} - \frac{dV_{LBC}}{dt}\right) + i_{LA} - i_{LB} \tag{4.4}$$

$$\Rightarrow \quad C_f\left(\frac{dV_{LCA}}{dt} + \frac{dV_{LBC}}{dt} - 2\cdot\frac{dV_{LAB}}{dt}\right) = -i_{iA} + i_{iB} + i_{LA} - i_{LB}$$

Subtracting (4.3) from (4.2)

$$i_{iB} - i_{iC} + C_f\left(\frac{dV_{LAB}}{dt} - \frac{dV_{LBC}}{dt}\right) = C_f\left(\frac{dV_{LBC}}{dt} - \frac{dV_{LCA}}{dt}\right) + i_{LB} - i_{LC} \tag{4.5}$$

$$\Rightarrow \quad C_f\left(\frac{dV_{LAB}}{dt} + \frac{dV_{LCA}}{dt} - 2\cdot\frac{dV_{LBC}}{dt}\right) = -i_{iB} + i_{iC} + i_{LB} - i_{LC}$$

Subtracting (4.1) from (4.3)

$$i_{iC} - i_{iA} + C_f\left(\frac{dV_{LBC}}{dt} - \frac{dV_{LCA}}{dt}\right) = C_f\left(\frac{dV_{LCA}}{dt} - \frac{dV_{LAB}}{dt}\right) + i_{LC} - i_{LA} \tag{4.6}$$

$$\Rightarrow \quad C_f\left(\frac{dV_{LAB}}{dt} + \frac{dV_{LBC}}{dt} - 2\cdot\frac{dV_{LCA}}{dt}\right) = -i_{iC} + i_{iA} + i_{LC} - i_{LA}$$

To simplify (4.4) to (4.6), the following relationship states that an algebraic sum of line to line load voltages is equal to zero and it is applied :

$$\text{VLAB} + \text{VLBC} + \text{VLCA} = 0. \tag{4.7}$$

Based on equations (4.7), (4.4), and (4.6) the equations can be modified to a first-order differential equation, respectively:

$$\left.\begin{aligned}
\frac{dV_{LAB}}{dt} &= \frac{1}{3C_f} i_{iAB} - \frac{1}{3C_f}\left(i_{LAB}\right) \\
\frac{dV_{LBC}}{dt} &= \frac{1}{3C_f} i_{iBC} - \frac{1}{3C_f}\left(i_{LBC}\right) \\
\frac{dV_{LCA}}{dt} &= \frac{1}{3C_f} i_{iCA} - \frac{1}{3C_f}\left(i_{LCA}\right)
\end{aligned}\right\} \tag{4.8}$$

Where $i_{iAB} = i_{iA} - i_{iB}$; $i_{iBC} = i_{iB} - i_{iC}$; $i_{iCA} = i_{iC} - i_{iA}$ and $i_{LAB} = i_{LA} - i_{LB}$, $i_{LBC} = i_{LB} - i_{LC}$, $i_{LCA} = i_{LC} - i_{LA}$

By applying Kirchoff's voltage law on the side of inverter output, the following voltage equations are derived:

$$\left.\begin{aligned} \frac{di_{iAB}}{dt} &= -\frac{1}{L_f}V_{LAB} + \frac{1}{L_f}V_{iAB} \\ \frac{di_{iBC}}{dt} &= -\frac{1}{L_f}V_{LBC} + \frac{1}{L_f}V_{iBC} \\ \frac{di_{iCA}}{dt} &= -\frac{1}{L_f}V_{LCA} + \frac{1}{L_f}V_{iCA} \end{aligned}\right\} \text{———} \quad (4.9)$$

By applying Kirchoff's voltage law on the load side, the following voltage equations are derived:

$$\left.\begin{aligned} V_{LAB} &= L_{load}\frac{di_{LA}}{dt} + R_{load}i_{LA} - L_{load}\frac{di_{LB}}{dt} - R_{load}i_{LB} \\ V_{LBC} &= L_{load}\frac{di_{LB}}{dt} + R_{load}i_{LB} - L_{load}\frac{di_{LC}}{dt} - R_{load}i_{LC} \\ V_{LCA} &= L_{load}\frac{di_{LC}}{dt} + R_{load}i_{LC} - L_{load}\frac{di_{LA}}{dt} - R_{load}i_{LA} \end{aligned}\right\} \text{———} \quad (4.10)$$

Equation (4.10) can be rewritten as:

$$\left.\begin{aligned} \frac{di_{LAB}}{dt} &= -\frac{R_{load}}{L_{load}}i_{LAB} + \frac{1}{L_{load}}V_{LAB} \\ \frac{di_{LBC}}{dt} &= -\frac{R_{load}}{L_{load}}i_{LBC} + \frac{1}{L_{load}}V_{LBC} \\ \frac{di_{LCA}}{dt} &= -\frac{R_{load}}{L_{load}}i_{LCA} + \frac{1}{L_{load}}V_{LCA} \end{aligned}\right\} \text{———} \quad (4.11)$$

Therefore, we can rewrite (4.8), (4.9) and (11) into a matrix form, respectively:

$$\left.\begin{aligned} \frac{d\mathbf{V}_L}{dt} &= \frac{1}{3C_f}\mathbf{I}_i - \frac{1}{3C_f}\mathbf{I}_L \\ \frac{d\mathbf{I}_i}{dt} &= -\frac{1}{L_f}\mathbf{V}_L + \frac{1}{L_f}\mathbf{V}_i \\ \frac{d\mathbf{I}_L}{dt} &= \frac{1}{L_{load}}\mathbf{V}_L - \frac{R_{load}}{L_{load}}\mathbf{I}_L \end{aligned}\right\} \text{———} \quad (4.12)$$

Where,

$$\mathbf{V}_L = [V_{LAB}\ \ V_{LBC}\ \ V_{LCA}]^T\ ,\ \mathbf{I}_i = [i_{iAB}\ \ i_{iBC}\ \ i_{iCA}]^T = [i_{iA}\text{-}i_{iB}\ \ i_{iB}\text{-}i_{iC}\ \ i_{iC}\text{-}i_{iA}]^T,$$

$$\mathbf{V}_i = [V_{iAB}\ \ V_{iBC}\ \ V_{iCA}]^T\ ,\ \mathbf{I}_L = [i_{LAB}\ \ i_{LBC}\ \ i_{LCA}]^T = [i_{LA}\text{-}i_{LB}\ \ i_{LB}\text{-}i_{LC}\ \ i_{LC}\text{-}i_{LA}]^T$$

The Simulation Circuit is given with the designed value of inductance and capacitance.

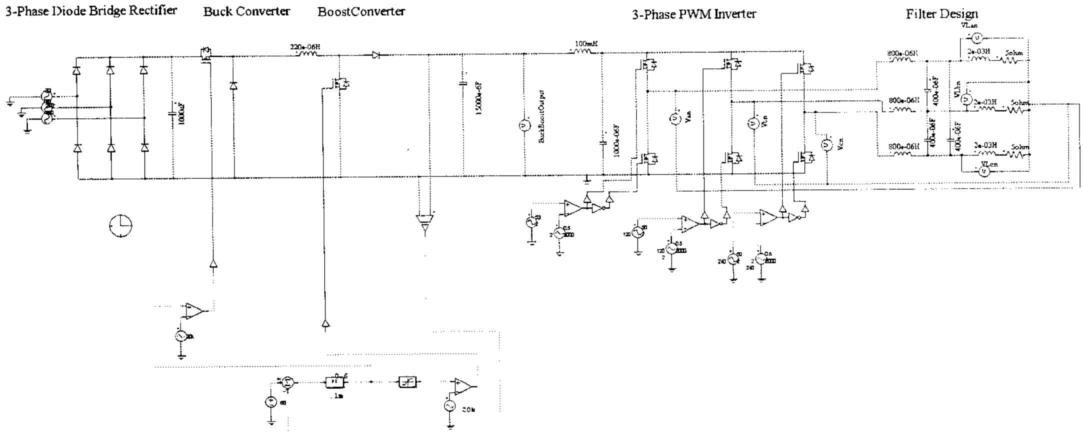


Fig 4.6 (b) Simulation Circuit with output LC filter design

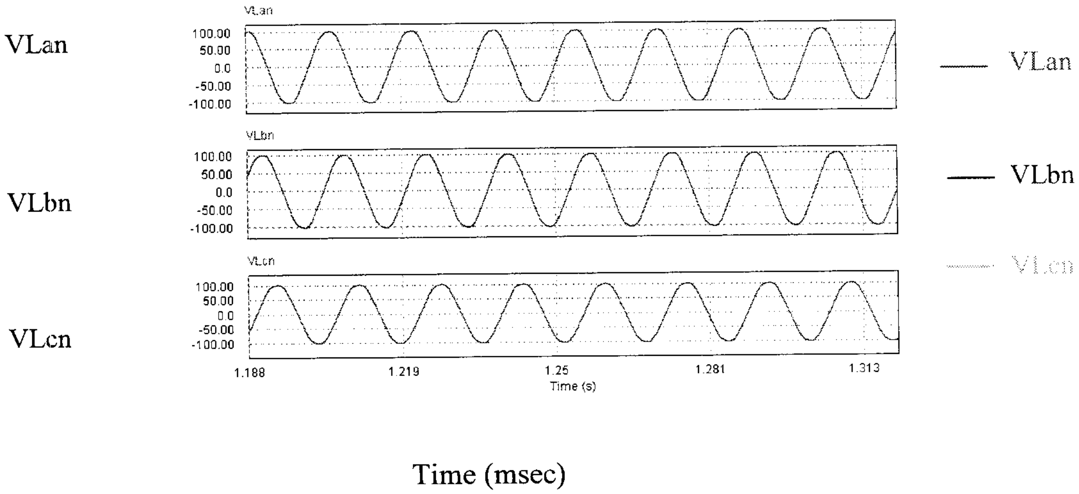


Fig 4.6 (c) Simulated output voltage waveforms with LC filter

The VLan, VLbn, VLcn are phase voltage of phase a, phase b, phase c with respect neutral at the output of the Load.

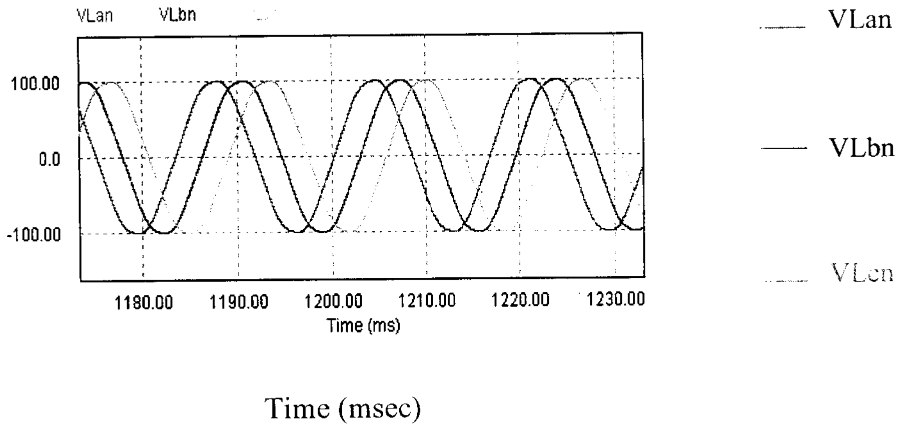


Fig 4.6 (d) Simulated 3-Phase output Voltage waveforms using LC filter

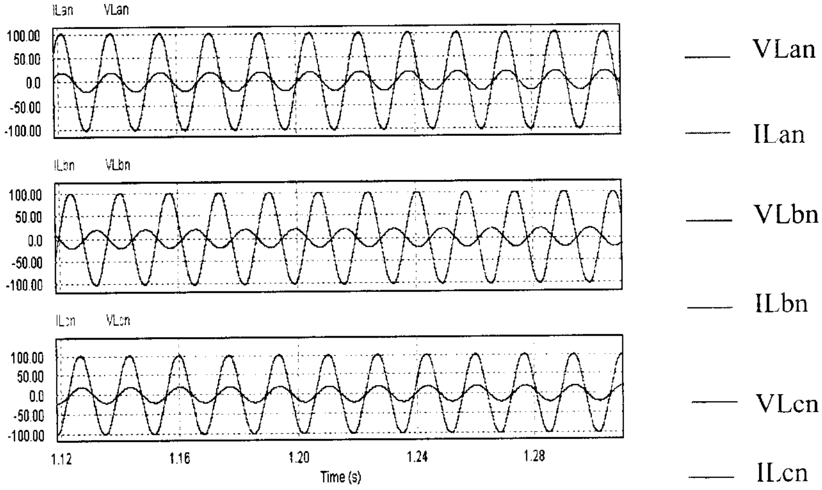


Fig 4.6 (e) Simulated output voltage and current waveforms using LC filter

It is known from the graph the output voltage is a pure sine wave with peak to peak value of voltage of 230 V.

4.7 CALCULATION OF TOTAL HARMONIC DISTORTION (THD):

The Calculation of Total Harmonic Distortion (THD) is done by performing Fast Fourier Transform (FFT) analysis for the output waveforms.

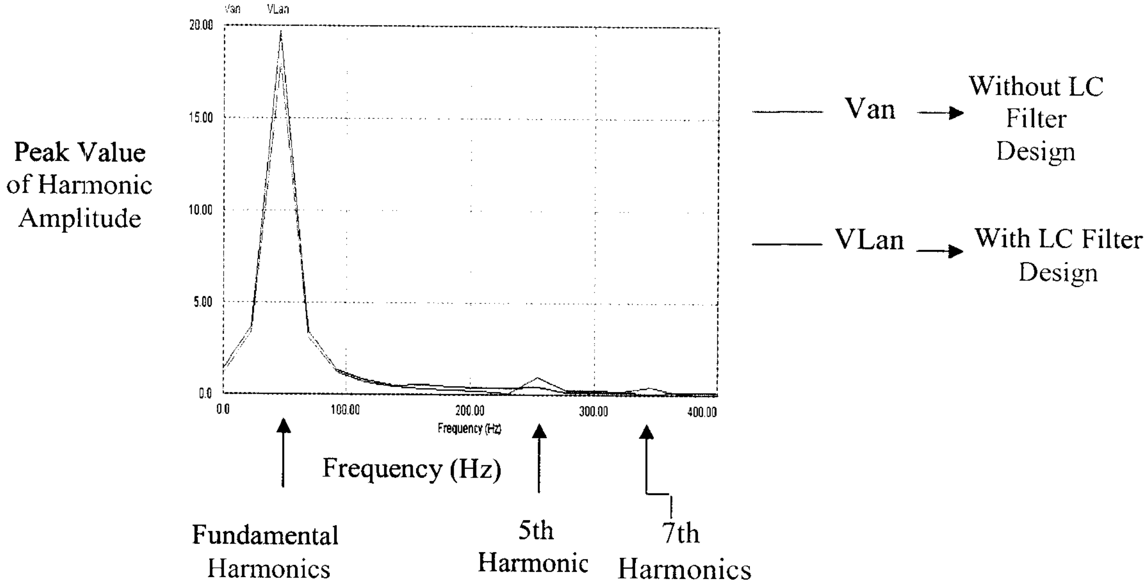


Fig 4.7 Harmonic Spectrum waveform

It is observed from the THD Analysis that the 5th and 7th order harmonics are present before using filter design.

It is also observed that LC filter design at the output, the fundamental is more predominant whereas the 5th and the 7th order harmonics are absent.

CHAPTER V

CONCLUSION AND FUTURE WORK

5.1 CONCLUSION:

In this project the power electronics control mechanism for the control of windmill is carried out. Here the concept of Buck-Boost Converter and PWM Inverter is implemented both in hardware and software. Both the hardware and software results are found to be satisfactory. The output is connected to various loads as a part of consumer requirement. The simulations are carried out using the simulation software **PSIM 7.0.5.**

5.2 FUTURE WORK:

In the future scope of the work the concept of Pitch Angle Control of the windmill can be implemented .Also the power electronics switches can be modified by using IGBT to drive Induction motor loads.

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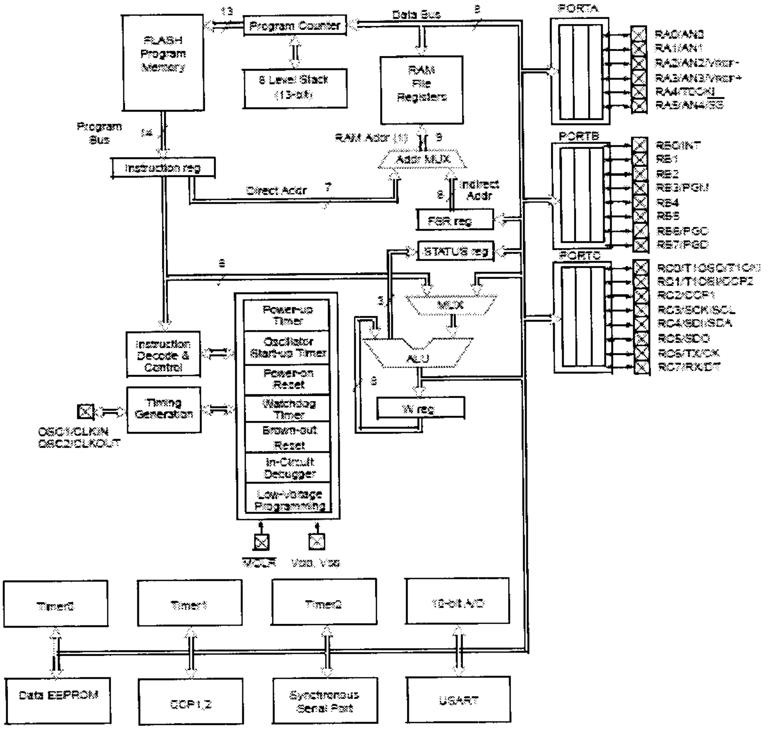
APPENDIX:

ARCHITECTURE OF PIC 16F877:

Device	Program FLASH	Data Memory	Data EEPROM
PIC16F873	4K	192 Bytes	128 Bytes
PIC16F876	8K	368 Bytes	256 Bytes



TIMER 0 CONTROL REGISTER:

R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1
$\overline{\text{RBPU}}$	INTEDG	T0CS	T0SE	PSA	PS2	PS1	PS0
bit 7							bit 0

bit 7: **RBPU**

bit 6: **INTEDG**

bit 5: **T0CS**: TMR0 Clock Source Select bit

1 = Transition on T0CKI pin

0 = Internal instruction cycle clock (CLKOUT)

bit 4: **T0SE**: TMR0 Source Edge Select bit

1 = Increment on high-to-low transition on T0CKI pin

0 = Increment on low-to-high transition on T0CKI pin

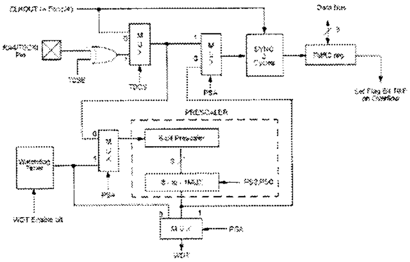
bit 3: **PSA**: Prescaler Assignment bit

1 = Prescaler is assigned to the WDT

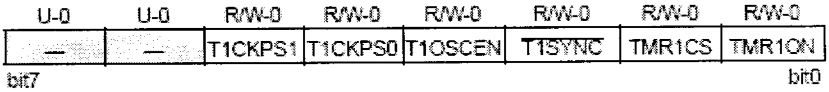
0 = Prescaler is assigned to the Timer0 module

bit 2-0: **PS2 PS1 PS0**: Prescaler Rate Select bits

TIMER 0 BLOCK DIAGRAM:



TIMER 1 CONTROL REGISTER:



U-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
—	—	T1CKPS1	T1CKPS0	T1OSCEN	~~T1SYNC~~	TMR1CS	TMR1ON
bit7							bit0

bit 7-6: **Unimplemented:** Read as ’0’

bit 5-4: **T1CKPS1:T1CKPS0**: Timer1 Input Clock Prescale Select bits

11 = 1:8 Prescale value

10 = 1:4 Prescale value

01 = 1:2 Prescale value

00 = 1:1 Prescale value

bit 3: **T1OSCEN**: Timer1 Oscillator Enable Control bit

1 = Oscillator is enabled

0 = Oscillator is shut off (The oscillator inverter is turned off to eliminate power drain)

bit 2: **T1SYNC**: Timer1 External Clock Input Synchronization Control bit

TMR1CS = 1

1 = Do not synchronize external clock input

0 = Synchronize external clock input

TMR1CS = 0

This bit is ignored. Timer1 uses the internal clock when TMR1CS = 0.

bit 1: **TMR1CS**: Timer1 Clock Source Select bit

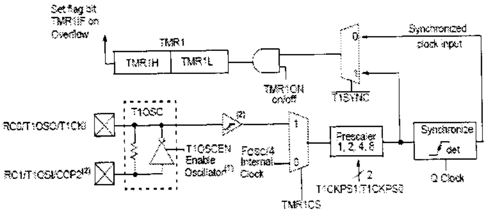
1 = External clock from pin RC0/T1OSO/T1CKI (on the rising edge)

0 = Internal clock (FOSC/4)

bit 0: **TMR1ON**: Timer1 On bit

1 = Enables Timer1
0 = Stops Timer1

TIMER 1 BLOCK DIAGRAM:



TIMER 2 CONTROL REGISTER:

U-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
—	TOUTPS3	TOUTPS2	TOUTPS1	TOUTPS0	TMR2ON	T2CKPS1	T2CKPS0
bit7							bit0

bit 7: **Unimplemented:** Read as '0'
bit 6-3: **TOUTPS3:TOUTPS0**: Timer2 Output Postscale Select bits

0000 = 1:1 Postscale
0001 = 1:2 Postscale
0010 = 1:3 Postscale
1111 = 1:16 Postscale

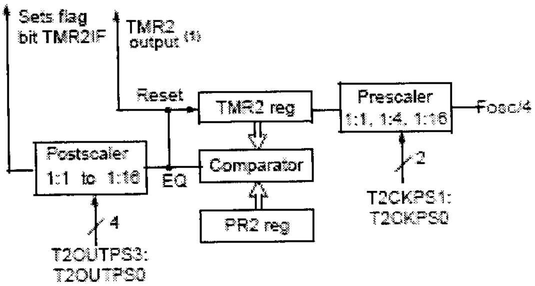
bit 2: **TMR2ON**: Timer2 On bit

1 = Timer2 is on
0 = Timer2 is off

bit 1-0: **T2CKPS1:T2CKPS0**: Timer2 Clock Prescale Select bits

00 = Prescaler is 1
01 = Prescaler is 4
1x = Prescaler is 16

TIMER2 BLOCK DIAGRAM:



CCP1CON REGISTER/CCP2CON REGISTER:

U-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
—	—	CCPxX	CCPxY	CCPxM3	CCPxM2	CCPxM1	CCPxM0
bit7							bit0

bit 7-6: **Unimplemented:** Read as '0'

bit 5-4: **CCPxX :CCPxY**: PWM Least Significant bits

Capture Mode: Unused

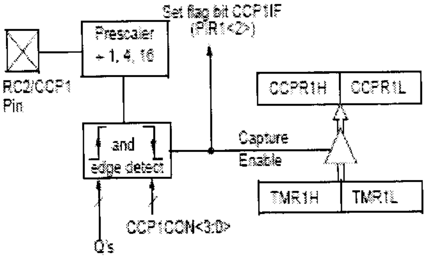
Compare Mode: Unused

PWM Mode: These bits are the two LSB s of the PWM duty cycle. The eight MSB s are found in CCPRxL.

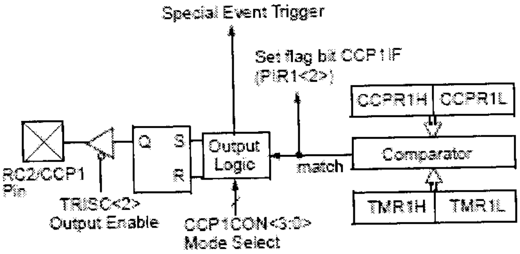
bit 3-0: **CCPxM3:CCPxM0**: CCPx Mode Select bits

0000 = Capture/Compare/PWM off (resets CCPx module)
0100 = Capture mode, every falling edge
0101 = Capture mode, every rising edge
0110 = Capture mode, every 4th rising edge
0111 = Capture mode, every 16th rising edge
1000 = Compare mode, set output on match (CCPxIF bit is set)
1001 = Compare mode, clear output on match (CCPxIF bit is set)
1010 = Compare mode, generate software interrupt on match (CCPxIF bit is set, CCPx pin is unaffected)
1011 = Compare mode, trigger special event (CCPxIF bit is set, CCPx pin is unaffected); CCP1 resets TMR1; CCP2 resets TMR1 and starts an A/D conversion (if A/D module is enabled)
11xx = PWM mode

CAPTURE MODE OPERATION BLOCK DIAGRAM:

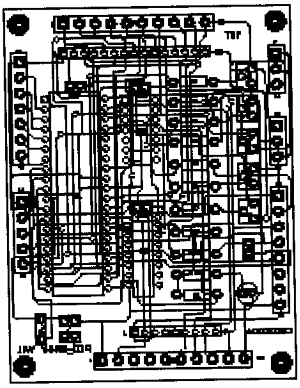


COMPARE MODE OPERATION BLOCK DIAGRAM:

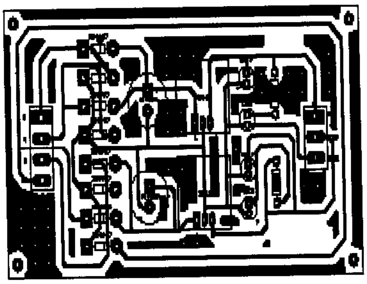


PCB DESIGNS:

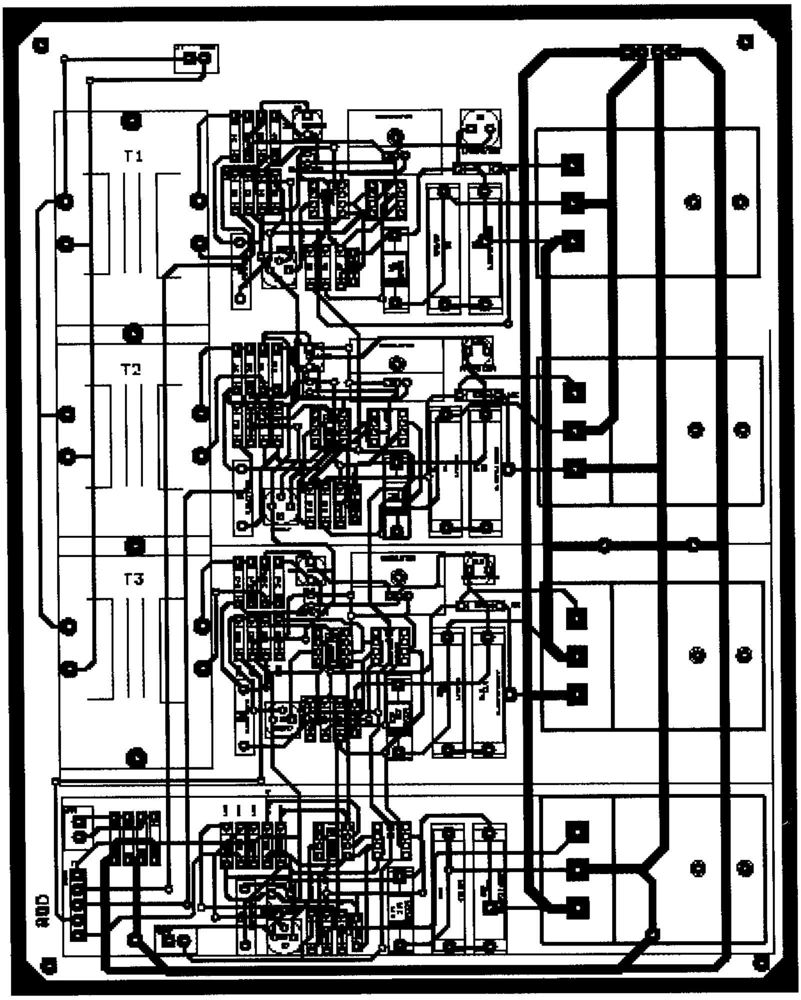
Microcontroller Designs:

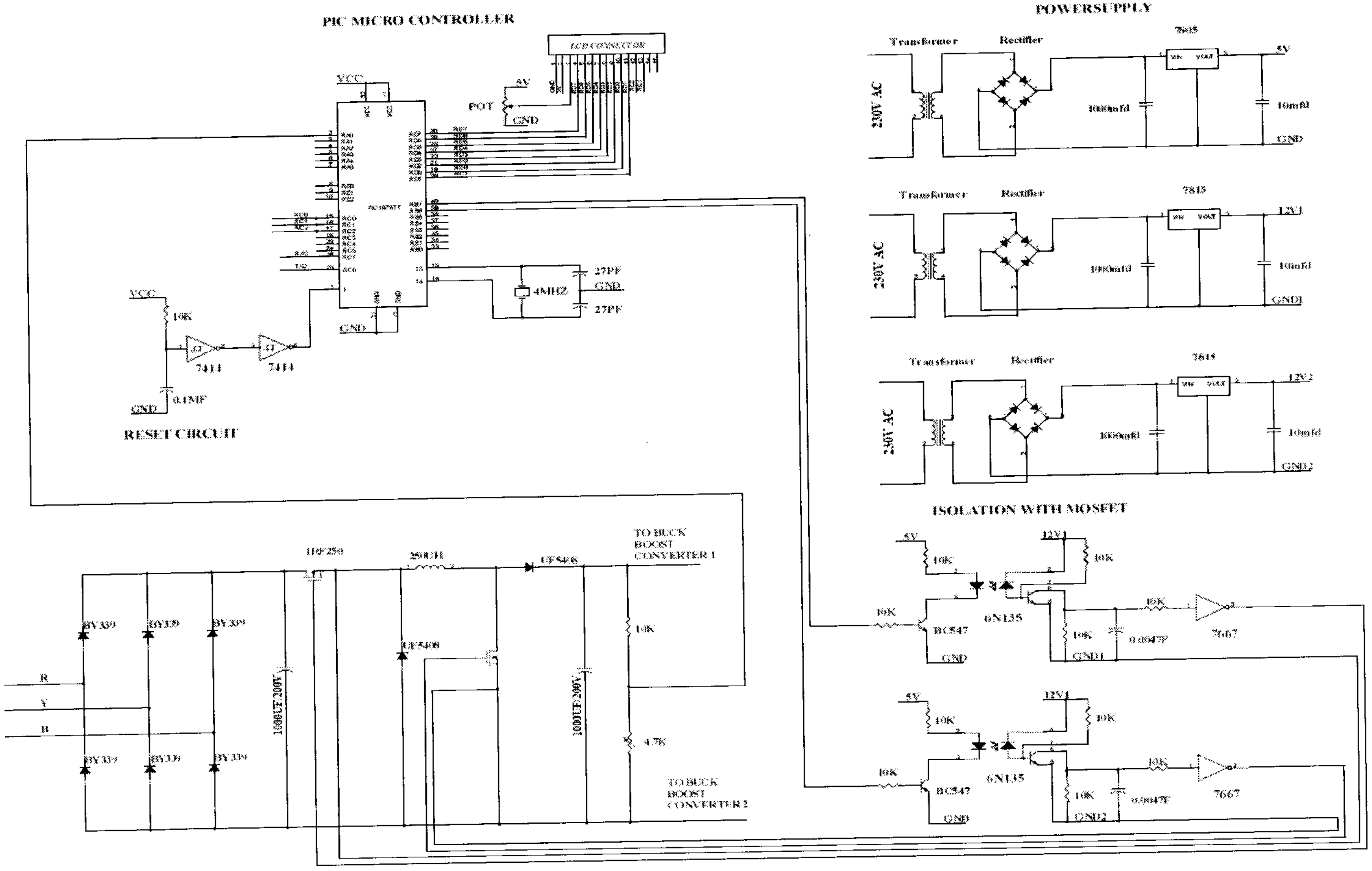


12 V Power Supply:

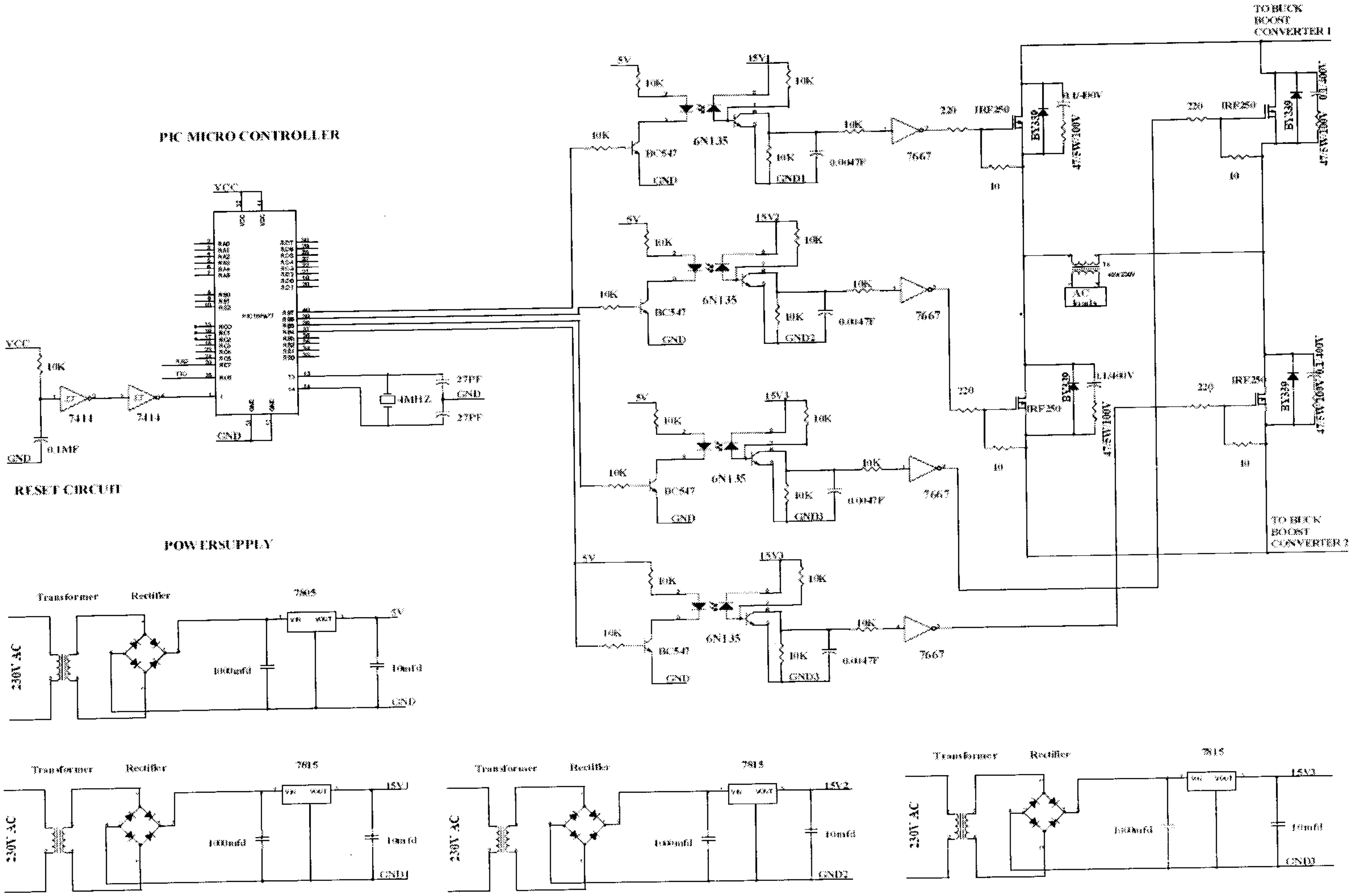


Single Phase PWM Inverter :

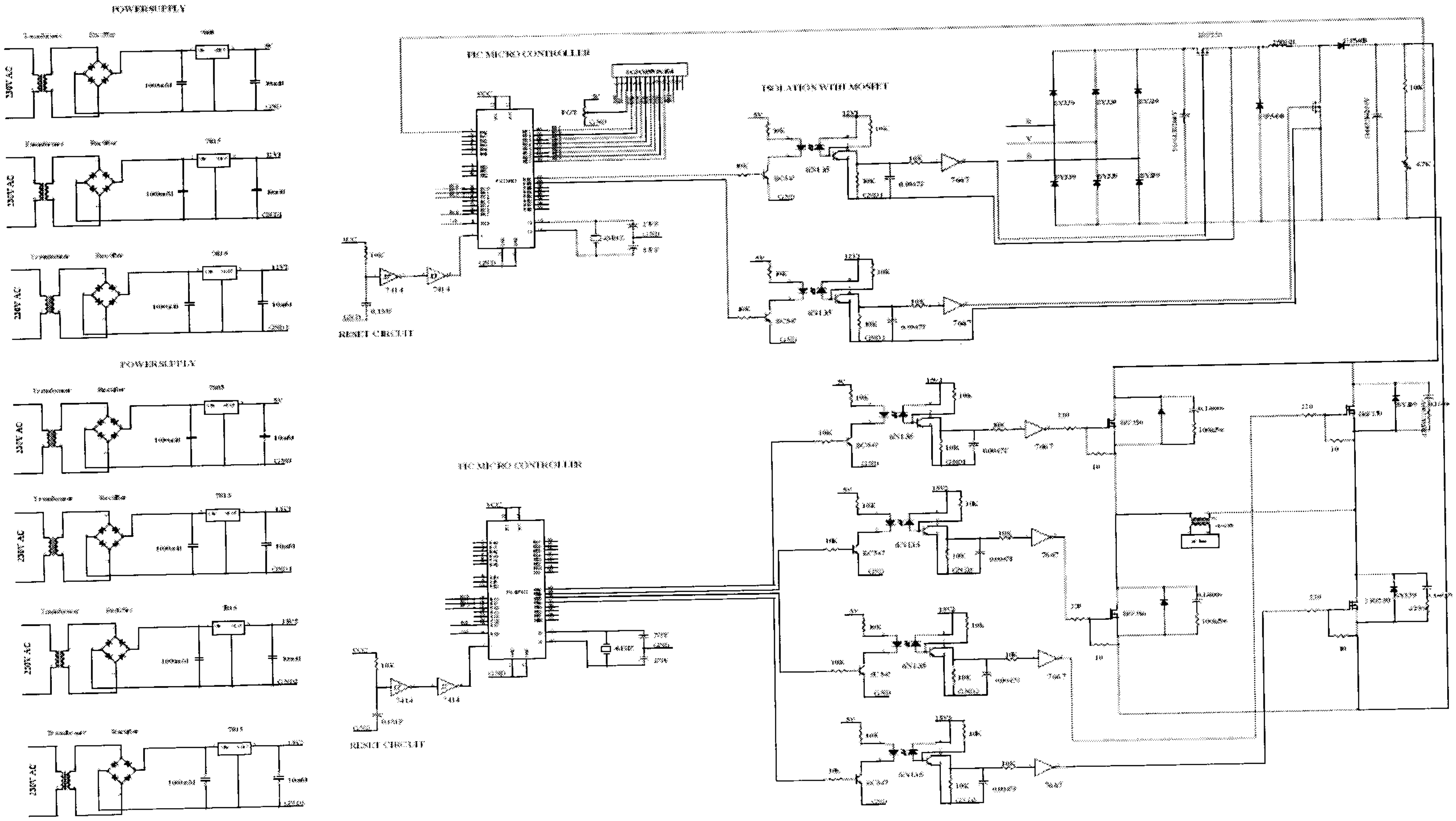




Circuit Diagram to drive power MOSFET'S of Buck Boost Converter

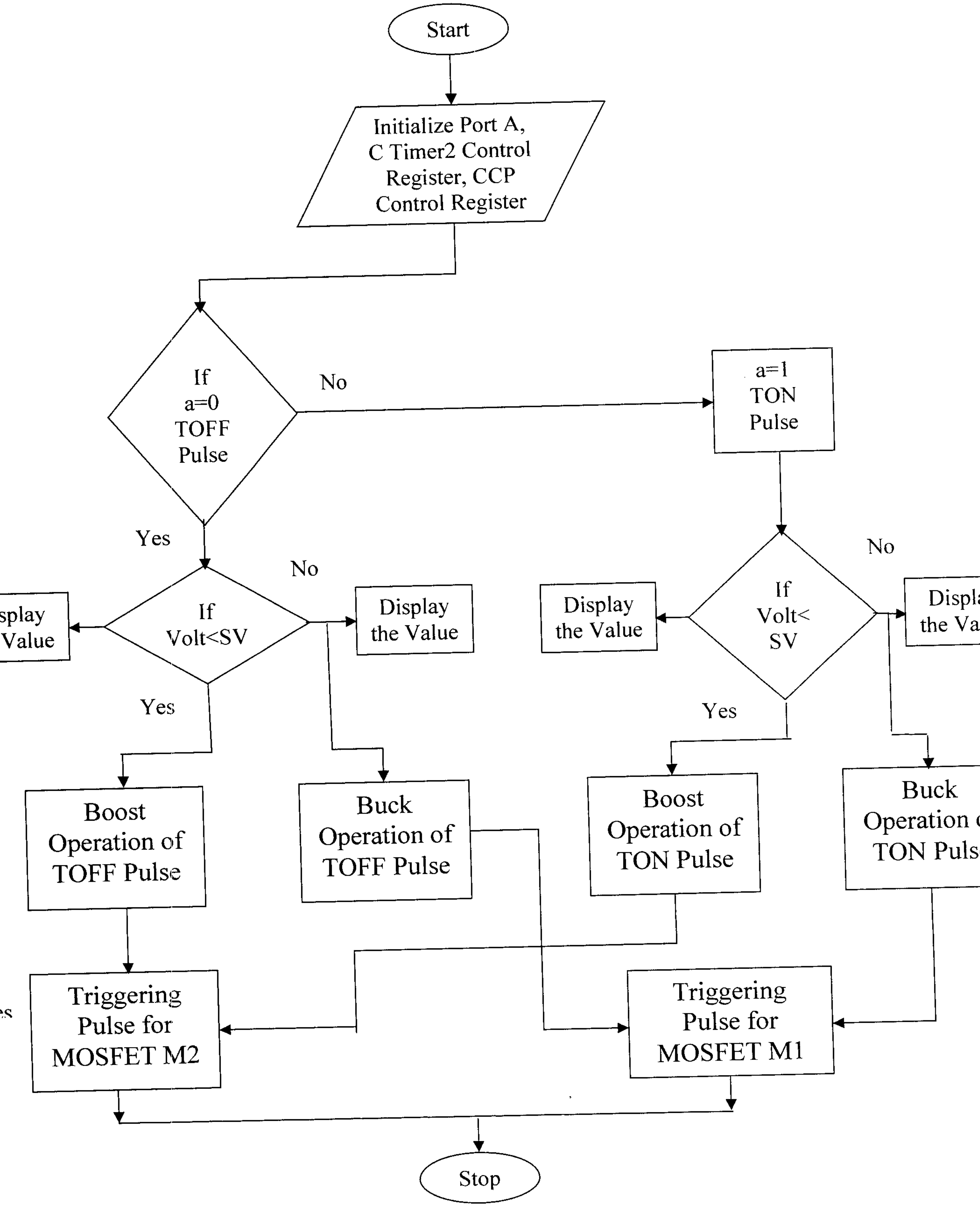


Circuit Diagram to drive power MOSFET'S of PWM Inverter:



Circuit Diagram of the Complete hardware setup

Flow chart of Buck Boost operation



COST DETAILS OF THE COMPONENTS:

S.No:	Name of the Components	Type and Ratings	Quantity	Cost (Rs)
1	MOSFET	IRF 250	6	1000
2	Microcontroller	PIC 16F877	2	250
3	LCD Display		1	300
4	Quartz Crystal	4MHz	1	100
5	AC Capacitor	1000µF/200V	2	100
6	Battery	12V,2.5Ah	4	2400
7	Step - up- Transformer	48/230V	1	2500
8	Inductance	250µH	1	100
9	Capacitor	1000µF	5	50
10	PCB Fabrication			2000
11	Regulator IC-7815	15V	3	50
12	Transformer	230/9 V and 230/15 V	1	200
13	Transformer	230/12V	1	75
14	Transformer	230/9 V	1	50
15	Transformer	230/18 V	1	70
16	Resistor	10k Ω,1M Ω,etc	60	30
17	10k Array	10k	1	20
18	Snubber Circuit Resistance	5Ω,2W	4	20
19	Resistance	100 Ω, 2W	2	10
20	Diode	1N4007	26	30
21	Diode	BY 339	6	50
22	NOT Gate IC	7667	4	50
23	Optocoupler IC	6N135	4	100
24	Transistor	BC 547	6	20
			TOTAL =Rs 9,575	