A

Project Report

On

"RENEWABLE ENERGY BASED INTERLEAVED BOOST CONVERTER"

Submitted in partial fulfilment of the requirements

of the degree of

Bachelor of Engineering in Electrical Engineering

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I declare that this written submission represents my ideas in my own words and where others ideas or words have been included; I have adequately cited and referenced the original sources. I also declared that I have adhered to all principles of academic honesty and integrity and have not represented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission have not been taken when needed.

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Abstract

Nowadays, there is a demand to increase the power generation capacity because of steadily rising electrical energy consumption. In order to achieve this, renewable energy sources are the best option. Among all the renewable energy sources, solar power generation system tops the list. For increasing the output of these sources we need a suitable boost converter. Interleaved boost converter (IBC) is one of such converter which consists of several identical boost converters connected in parallel and controlled by interleaved method, which has same switching frequency and phase shift. The advantages of using IBC over conventional boost converter are increased efficiency, improved reliability, reduced current peak value and these converter cells have good current sharing characteristics. The proposed method provides the increased output voltage along with efficiency. Here, in this work we have also shown the application of IBC in running BLDC motor. To detect the position of BLDC motor hall sensors are used. The proposed strategies have been verified with the help of MATLAB/SIMULINK along with the hardware implementation.

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List of Abberivation

DC : Direct Current

AC : Alternating Current

PWM : Pulse Width Modulation

IBC : Interleaved Boost Converter

BLDC : Brushless DC Motor

THD : Total Harmonic Distortion

MOSFET : Metal Oxide Semiconductor Field Effect Transistor

Chapter 1

Introduction

1.1 Overview

There is a demand to increase the power generation capacity because of steadily rising electrical energy consumption. In order to achieve this, renewable energy sources are the best option. Interleaved boost converter (IBC) is one of such converter which consists of several identical boost converters connected in parallel and controlled by interleaved method, which has same switching frequency and phase shift. The advantages of using IBC over conventional boost converter are increased efficiency, improved reliability, reduced current peak value and these converter cells have good current sharing characteristics. The proposed method provides the increased output voltage along with efficiency[1].

1.2 Importance

The global electrical energy consumption is steadily rising and consequently there is a demand to increase the power generation capacity without harming the environment.

Renewable energy sources are the best options due to their effective operation and also they do not pollute the environment, the way burning the fossil fuels does. Solar power generation system tops the list of renewable energy sources, as the other sources such as wind, hydro, tidal sources even when taken them together will not meet the demand as the solar energy source does.

But for our application we need more amount of voltage than what we are getting from solar cells, to achieve this, we need to boost up the output voltage. For this purpose we need to use Interleaved method to improve power converter performance in terms of efficiency. The Interleaved consists of several identical boost converters connected in parallel.

As the output current is divided by the number of phases, the current stress on each MOSFET's is reduced. Each MOSFET is switched at the same frequency but at a phase difference of 180 degrees. The desired output voltage for a given input voltage is depends on the duty ratio. For example, if the input voltage is 60V and the desired output voltage is 120V then we have to keep the duty cycle at 0.5. Since, we are using two similar inductors in the circuit this will leads to equal sharing of the input current[1].

Here, in this proposed method two phase IBC is chose in since the ripple content reduces with increase in number of phases. But if the number of phases increased further without much decrease in ripple content, the complexity of circuit increases very much, there by increasing the cost of implementation. Hence, as a trade off between the ripple content and the cost complexity, number of phases are chosen as two[1].

Chapter 2

Literature Review

J.S.Anu Rahavi, T.Kanagapriya,Dr.R.Seyezhai "Design and Analysis of Interleaved Boost Converter for Renewable Energy Source" in Proc, International Conference on computing, Electrical and Electronics Technologies, 2012 in this paper renewable energy is derived from natural resources that are replenished constantly. The commonly used renewable energy systems include photovoltaic cells and fuel cells. A suitable DC-DC converter is proposed for highly efficient renewable energy systems. Interleaved Boost Converter (mC) topology is discussed in this paper for renewable energy applications. The advantages of interleaved boost converter compared to the classical boost converter are low input current ripple, high efficiency, faster transient response, reduced electromagnetic emission and improved reliability. Three cases of interleaved boost converter have been considered and analyzed. Two-phase mc's with (i) the front end inductors magnetically coupled (ii) uncoupled inductors and (iii) inversely coupled inductors performance have been analyzed and compared. The output voltage ripple, input current ripple and inductor current ripple of the three types of converters are compared. The waveforms of input, inductor current ripple and output voltage ripple are obtained using MA TLAB/SlMULINK. The design equations for IBC have been presented. Using the results obtained from simulation the best of the three IBC is inferred

Nasir Coruh,Satilmis Urgun,Tarik Erfidan,Semra Ozturk "A Simple and Efficient implementation of Interleaved Boost Converter" in 6th IEEE Conference on Industrial Electronics and Applications,2011 in this paper DC-DC boost converters are usually required in many applications which has low output voltage, such as renewable energy sources. The interleaved boost converters consists of several identical boost converters connected in parallel and controlled by the interleaved method which has the same switching frequency and phase shift. The advantages of interleaved boost converters include increased efficiency, reduced size and improved reliability. This paper presents, simple design and implementation of a two phase interleaved boost converter.

Chandra sekhar, G.Yognjalu reddy and sanjay Lakshmi Narayan "Design simulation and validation of solar inverter with two phase interleaved boost converter" International conference on power and advanced control engineering 2015in this paper brings out design, simulation and validation of 2-phase interleaved DC-DC boost converter for solar inverter application. Handling high currents in high power applications, at the input side is a crucial aspect of the design of DC-DC boost converter. Aninterleaved DC-DC boost converter assimilate high current through current sharing. The performance of the Solar Inverter with two phase interleaved boost converter is verified and validated through simulation and experimental results

Nagabhushan patil, Pradeepakumara V "Renewable Energy Based Interleaved Boost Converter" International Journal of Innovative Science, Engineering & Technology, Vol. 3 Issue 8, August 2016 in this paper there is a demand to increase the power generation capacity because of steadily rising electrical energy consumption. In order to achieve this, renewable energy sources are the best option. Among all the renewable energy sources, solar power generation system tops the list. For increasing the output of these sources we need a suitable boost converter. Interleaved boost converter (IBC) is one of such converter which consists of several identical boost converters connected in parallel and controlled by interleaved method, which has same switching frequency and phase shift. The advantages of using IBC over conventional boost converter are increased efficiency, improved reliability, reduced current peak value and these converter cells have good current sharing characteristics. The proposed method provides the increased output voltage along with efficiency. Here, in this work we have also shown the application of IBC in running BLDC motor. To detect the position of BLDC motor hall sensors are used. The proposed strategies have been verified with the help of MATLAB/SIMULINK along with the hardware implementation.

Chapter 3

Interleaved Boost Converter

3.1 Conventional Boost Converter

A boost converter (step-up converter) is a DC-to-DC power converter that steps up voltage (while stepping down current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) containing at least two semiconductors (a diode and a transistor) and at least one energy storage element: a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supply-side filter)[2].

3.1.1 Operation of boost converter

The schematic in Figure.3.1 shows traditional boost converter. The circuit is used when a higher output voltage than the input is required. When the MOSFET is ON Vx = Vin and OFF state the inductor current flows through giving Vx = Vo. The discontinuous conduction mode (DCM) is usually exists when the inductor current is huge enough and contains ripple in a converter which works with light load. Since it is usually happens in wind energy conversion system, converters operate with their loads on and off, DCM is the most appropriate method used[2].

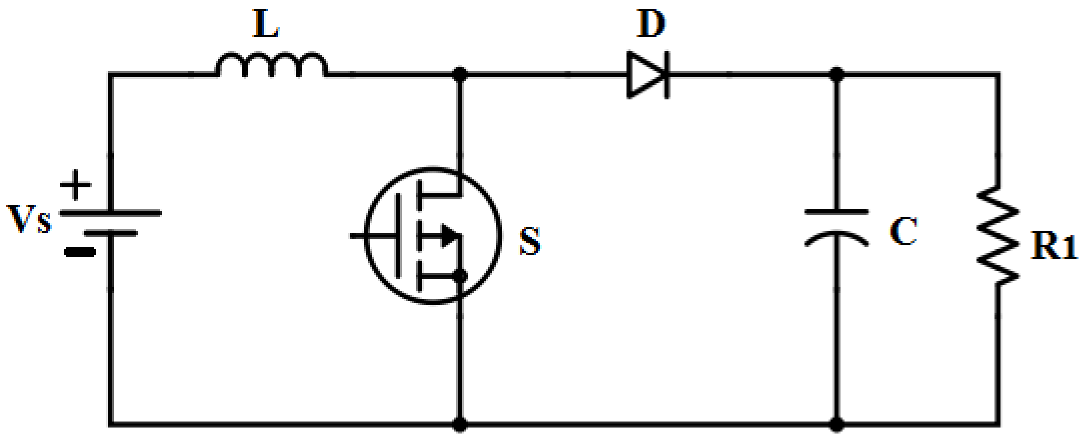


Fig3.1:-The basic schematic of a boost converter[1]

3.2 Interleaved Boost Converter

Interleaved boost converter (IBC) is one of such converter which consists of several identical boost converters connected in parallel and controlled by interleaved method, which has same switching frequency and phase shift. The advantages of using IBC over conventional boost converter are increased efficiency, improved reliability, reduced current peak value and these converter cells have good current sharing characteristics[1].

3.2.1 Block diagram

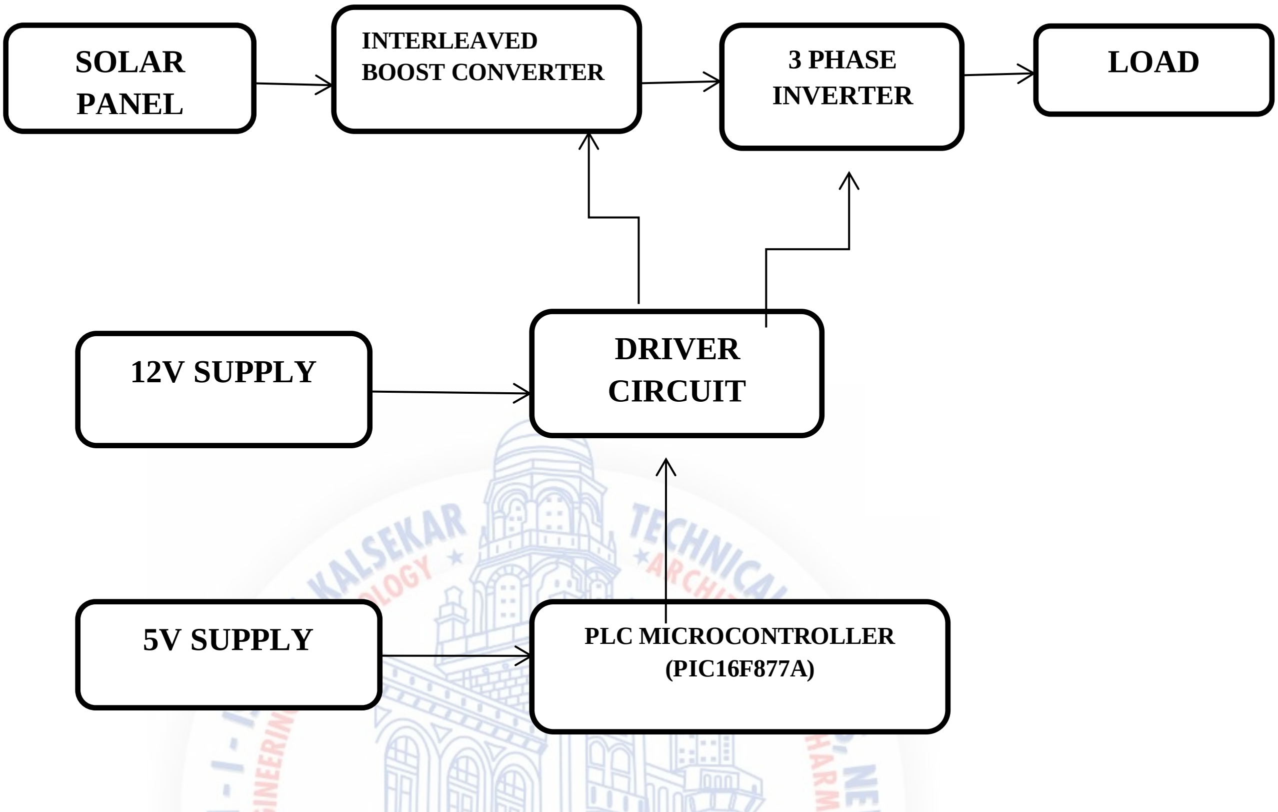


Fig3.2:Block Diagram of proposed system

Due to the nature of solar energy, two components are required to have a functional solar energy generator. These two components are a collector and a storage unit. The collector simply collects the radiation that falls on it and converts a fraction of it to other forms of energy (either electricity and heat or heat alone). The storage unit is required because of the non-constant nature of solar energy; at certain times only a very small amount of radiation will be received. Or else we need to have a backup power supply[1].

The output of the solar panel is given to the interleaved boost converter (IBC), which will boost the output voltage of the solar panel. This IBC consists of two switches and the control circuit of the BLDC motor which is a three phase inverter consists of 6 switches, the driver signals for these switches are taken from a driver circuit, which intern is controlled by the PIC16F877A microcontroller. The control circuit energizes proper winding at proper time, in a pattern which rotates around the stator of the BLDC motor. Feedback from the BLDC motor is achieved by using hall sensor, which is connected to the PIC16F877A microcontroller. Hall sensors will work on the hall-effect principle, that when a current carrying conductor is exposed to the magnetic field, charge carriers experience a force based on the voltage developed across the two sides of the conductor. If the direction of the magnetic field is reversed, the voltage developed will reverse as well. For hall-effect sensors used in BLDC motors, whenever rotor magnetic poles (N or S) pass near the hall sensor, they generate a HIGH or LOW level signal, which can be used to determine the position of the shaft. According to these signals the microcontroller will control the driver circuit, which intern will control the operation of the BLDC motor. The driver circuit here works as an amplifier. The output pulse voltage from PIC16F877A is of only 5V, driver circuit will amplify this voltage pulse to 12V, and then it will send those switching pulses to switches used in the circuit. Here, in my work I am also controlling the speed of the BLDC motor, by controlling the switching frequency of the inverter switches. This will help us to run the motor above or below the rated speed.

3.2.2 Operation of IBC

Since as we are using two phases the converter is driven 180 degrees out of phase, this is because the phase shift is given by 360/n. where n stands for number of phases. Hence its clear that the phase shift is depends the number of phases used. When gate pulse is given to the first for time t1, the current across the inductor rises and energy is stored in the inductor. When the switch s1 in the first phase turned off, the energy stored is transferred to the load through the output diode SD1. The inductor and the capacitor serve as voltage sources to extend the voltage and to reduce the voltage stress on the switch. The increasing current rate across the output diode is controlled by inductances the phases. Now the gate pulse is given to the second phase during the period t1 to t2 when the switch in the first phase is turned OFF. When the switch in the second phase turned ON, the inductor charges for the same time and transfers energy to the load in the similar way as in the first phase. Therefore, two phases feed the load continuously. Thus the proposed converter operates in continuous conduction mode.

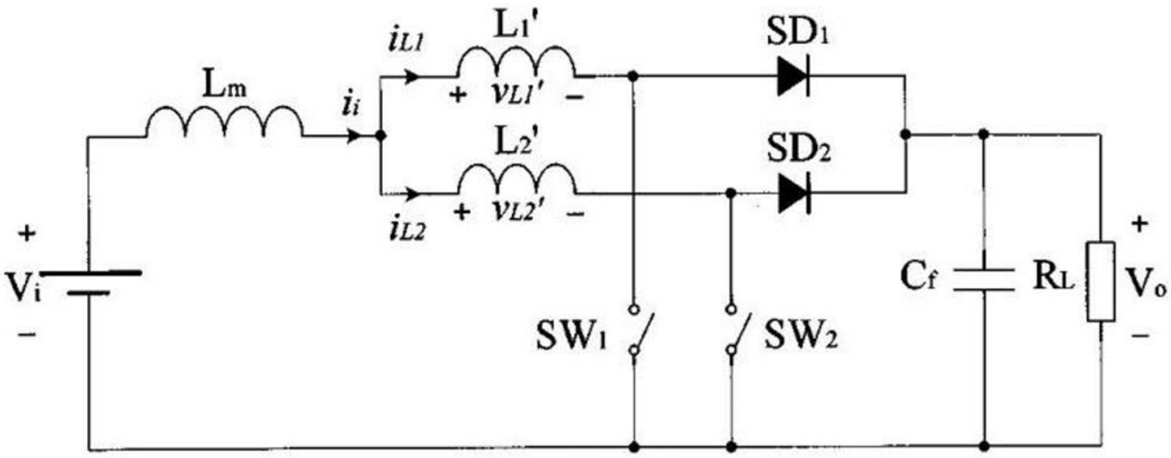
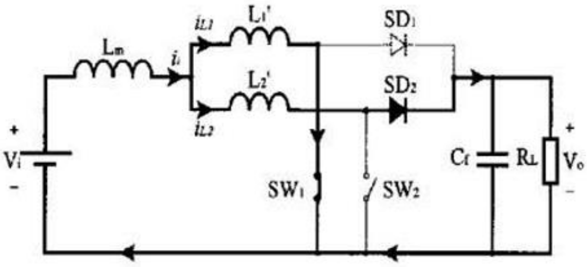
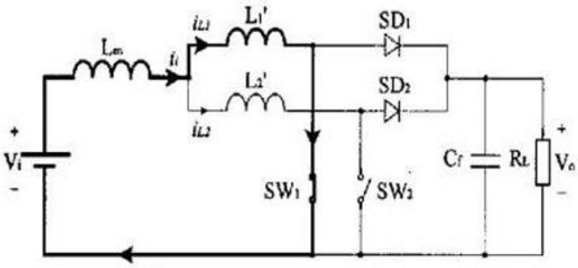


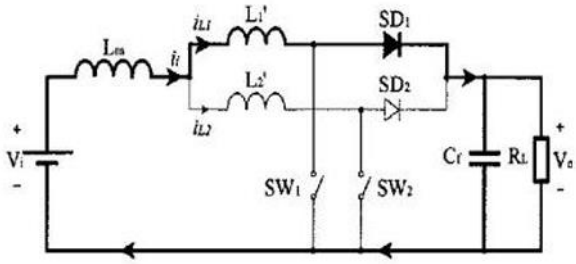
Fig3.3:-Circuit diagram of IBC



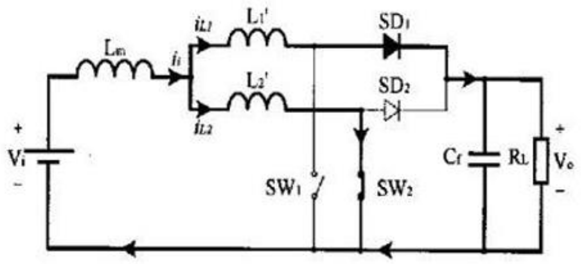
Time t_0–t_1
(a)



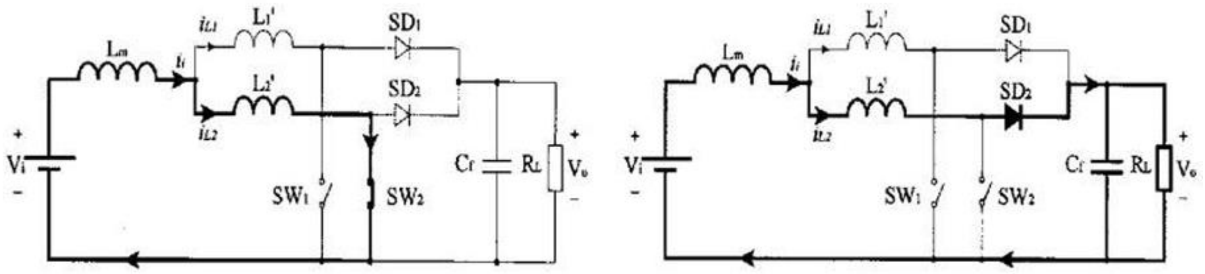
Time t_1–t_2
(b)



Time t_2–t_3
(c)



Time t_3–t_4
(d)



Time t_4–t_5
(e)

Time t_5–t_6
(f)

Fig3.4:-Operation state and current paths of the converter

1) State a [fig(a)] :

At time t_0, SW_1 is closed. The current in the inductor L_1' starts to rise while L_2' continues to discharge. The rate of change of iL_2' is approximately given by

$diL_1/ dt = -V_0/ L_1' + L_2'$

2) State b [fig (b)] :

At time t_1, iL_2 falls to zero, iL_1 continues to rise and the rate of change of iL_1 is given by $diL_1\ dt = Vi\ L_1$ Where $L_1' = L_1 + Lm$

3) State c [fig (c)] :

At time t_2, SW_1 is opened. The energy stored in the inductor L_1 is transferred to the load via the boost rectifier SD_1. The rate of change of iL_1 , is

$diL_1\ d = -(V_0 - Vi)/ L_1$

4) State d [fig (d)] :

The switch SW_2 is closed at time t3. The current in inductor L_2' starts to rise, L_1' continues to discharge. The rate of change of iL_1 is approximately given by

$diL_1 /dt = -V_0 /L_1' + L_2'$

5) State e [fig (e)] :

At time t4, the inductor current iL_2 rises at the rate of

$diL_2/ dt = -V_0/ L_2$

Where $L_2 = L_2' + Lm$

6) State f [fig (f)] :

At time t5, SW_2 is opened. L_2' discharges through the output circuit. The rate of change of iL_2 is

$diL_2/dt = -(V_0 - Vi)/L_2$

3.2.3 Design of IBC

The design process involves the proper selection of inductor, duty cycle, resistance and capacitor values.

1) Duty cycle

$V0/Vin = 1/1-D$

$D = 1 - (Vin/V_0)$

$D = 1 - (60/120)$

$= 0.5$

2) Resistance

$RLoad = V_0/I_0$

$RLoad = 120/12$

$= 10\ \Omega$

3)Capacitor

$C = (D*V0*T)0/(R*\Delta V0)$

Take fs = 1 KHz

$T = 1/fs$

$= 1/1K$

$= 1 * 10^{-3}$ sec

$\Delta V0 \simeq 0.5\%$ = voltage ripple

C = 0.5 ∗120∗1∗ 10−3/ 10∗05

= 120 * 10−3 F

4) Inductor

L = $Vin * D / m * n * f * \Delta I$

m = number of switches per channel n = number of channels ΔI = input current ripple ≃ 0.5 %

L = 60 ∗ 0.5 /1∗2∗100∗0.5

= 30 mH

Both the inductors used here are of similar rating that is both are having 30 mH of inductance. Since, we are using two similar inductors this will help us in sharing the input currents equally. And also, the inductor peak current rating is also reduced, there by reducing the inductor rating and cost of inductor.

3.2.4 Advantages of IBC

1) IBC has increased efficiency as compared to that of conventional boost converters.

2) IBC has low input current ripple.

3) It also has fast transient response and improved reliability.

4) Steady-state voltage ripples at the output side of capacitors of IBC are reduced.

5) By using IBC we can efficiently utilize the PV cell output.

6) By using TWO phases IBC we can reduce the cost complexity.

7) This method is Environmental friendly.

Chapter 4

Inverter and Microcontroller

4.1 Introduction

Power inverter is a device that converts electrical power from DC form to AC form using electronic circuits. Its typical application is to convert battery voltage into conventional household AC voltage allowing you to use electronic devices when an AC power is not available [5]. Inverters have become more and more common over the past several years as support for self-sufficient solar power has increased. Because solar power is comes as a DC source, it requires an inverter before it can be used as general power.

4.2 CLASSFICATION OF INVERTERS

(i) Current fed inverter (CFI) – input current remains constant

. (ii) Voltage fed inverter (VFI) - input voltage remains constant

(iii) Variable DC linked inverter – input voltage is controlled.

There are basically three kinds of VFI power inverter out of which, the first set of inverters made, which are now obsolete, produced a Square Wave signal at the output.

i. Square wave inverter.

Square wave inverter produces a square wave by switching the DC source at equal magnitude in opposite direction across a load at set frequencies. They are rarely used because many devices utilize timing circuits that rarely on input power waveform for a clock timer .

ii. Pure sine wave.

Pure sine wave inverter simulates precisely the AC power that is delivered by a wall socket. It introduces the least amount of harmonics into an electrical devices but it's also the most expensive method because of the extra components and design required to produce the output. Its main advantage is that it can power all devices

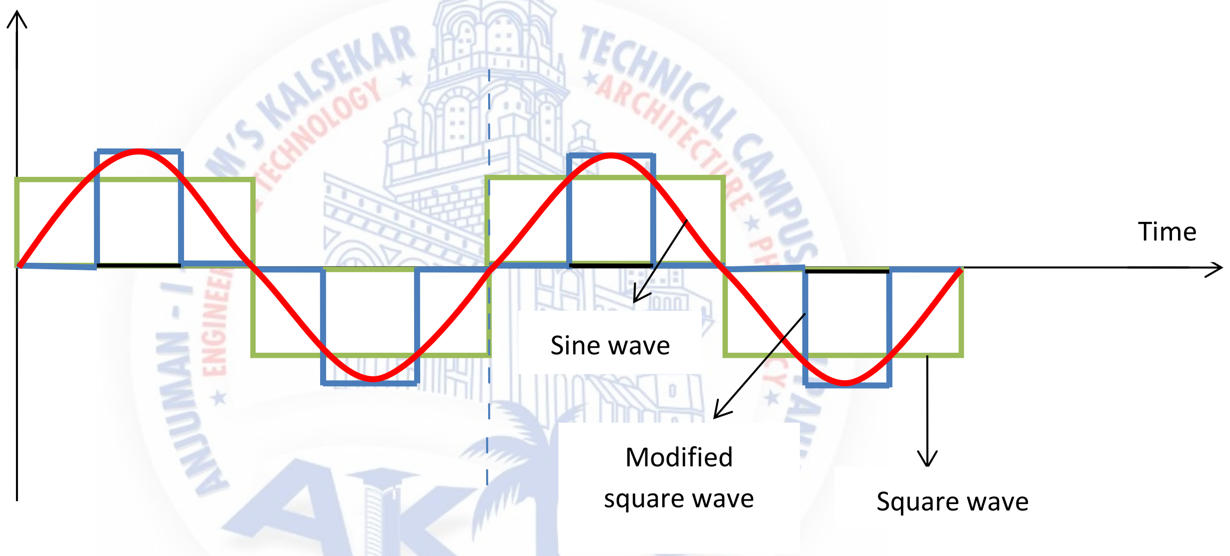


Fig4.1:-types of inverters

iii. Modified sine wave

Modified sine wave inverter emulates a sine wave. It introduces a dead time in a normal square wave output. The wave is produced by switching the DC source between three values at set frequencies thus produces fewer harmonics than square wave. It provides a cheap and easy solution of powering devices that need AC power. Its main drawbacks are that not all device that are not resistant to the distortion of the signal like medical equipment and computers work properly on it. It should be noted that modified-sine wave inverters are not rated for Total Harmonic Distortion (THD). Rating a modified-sine wave inverter for harmonic distortion would be useless, for their intended use is not to reduce the harmonics introduced to devices. Their purpose is to provide affordable and portable AC power. A question of efficiency is brought up in the discussion of harmonics. The pure sine wave inverters are 5% less efficient, but this rating is from the conversion of battery energy to modified sine wave output. This does not take into consideration the effect of harmonics on battery-to-device output efficiency. The high frequency harmonic content in a modified sine wave produces enhanced radio interference, higher heating effect in motors / microwaves and produces overloading due to lowering of the impedance of low frequency filter capacitors / power factor improvement capacitors. A pure-sine-wave inverter may be less efficient in terms of battery energy conversion, but more of the output energy is used by the load.

4.3 PULSE WIDTH MODULATION

Pulse width modulation, or PWM, has become an accepted method for generating unique signals, due to the advancement of microcontrollers and its power efficiency. To create a sinusoidal signal, PWM uses high frequency square waves with varying duty cycles. Duty cycle is the percentage of time the signal is on relative to the period. This means as the duty cycle increases, more power is transmitted. PWM requires rapid on and off signals, which can be achieved using high power MOSFETs. MOSFETs are ideal switches due to the low power loss when the device is activated. It should be noted, however, that when a MOSFET is in transition between on and off, the power loss can be significant. For this reason, the transition times and frequency should be engineered to be as short as possible. This can be achieved by minimizing the amplitude between the on and off stages and lowering the PWM frequency; however as the frequency decreases so does the signal quality. Pulse width modulation inverter can be classified as;

i. Analog bridge PWM inverter

ii. Digital bridge PWM inverter.

i. ANALOG BRIDGE PWM INVERTER

In analog bridge PWM signal is generated by feeding a reference and a carrier signal to a comparator which creates the output signal based on the difference between the two inputs. The reference is a sinusoidal wave at the frequency of the desired output signal. The carrier wave is a triangle or saw tooth wave which operates at frequency significantly greater than the reference wave. When the carrier signal exceeds the reference the output is at high state and when the reference exceeds the carrier the output is at low state.

Advantages:- The level of the inverter output can be adjusted in a continuous range and the through put delay is negligible.

Disadvantages :- Analog components output characteristics change with the temperature and time. Analog component circuitry is complex and bulky and they are nonprogrammable, hence not flexible.

ii. DIGITAL BRIDGE PWM INVERTER

Also known as microcontroller based power inverter.it makes the controller free from disturbance and drift but the performance is not very high due to its speed limitation. However, to reduce through put delay some microcontroller retrieve switching pattern straight from memory so calculation can be minimized, but this technique demands morememory. This drawback can be eliminated by switching patterns executing simple control algorithms. With availability of advanced microcontroller and DSP (digital signal processor) controller that has advanced features like inbuilt PWM generator, event manager, time capture unit, dead time delay generator, watch dog timer along with high clock frequency, the limitation of speed associated with microcontroller can be neglected to some extent.

Advantages :- The inverter is not prone to external disturbance like temperature. It's simple and cost effective technique of implementing single phase AC voltage controller.

Disadvantages:- Even after using simple control algorithms, sometimes through put delay may be substantial.

4.4 Elements of Inverter

4.4.1 Step up DC-DC

The DC output voltage from the battery is in relatively small amplitude compared to standard nominal single phase voltage rating for use with domestic household products or to be transferred at grid. The boosts DC-DC converter circuit will step-up the unregulated DC voltage to 340V DC regulated In this design the DC DC boost will be developed and implemented by another project hence it will not be discussed at depth in this report.

4.4.2 Microcontroller

The main component of this inverter is a microcontroller as it is used to generate control signals. The theory of encoding a sine wave with a PWM signal is relatively simple. A sine wave is needed for the reference that will dictate the output, and a triangle wave of higher frequency is needed to sample the reference and actuate the switches. The process can also be done with a microcontroller and crystal oscillators as shown in fig 3.3. Since the control technique which will be used is a sinusoidal pulse width modulated PIC16F877A was chosen to generate required signal This microcontroller is specially developed for the generation of Sinusoidal PWM (SPWM) and therefor it is programmed to generate two PWM signal and two rectangular pulse signals. Pins RC1, RC2 are output pin for sinusoidal pulse width modulation and RA1, RA2 are output pin for rectangular pulse signals. Also for safety purposes and to indicate when the inverter is ON led has been added and programed at pin RA0 to light green whenever the inverter is functioning.

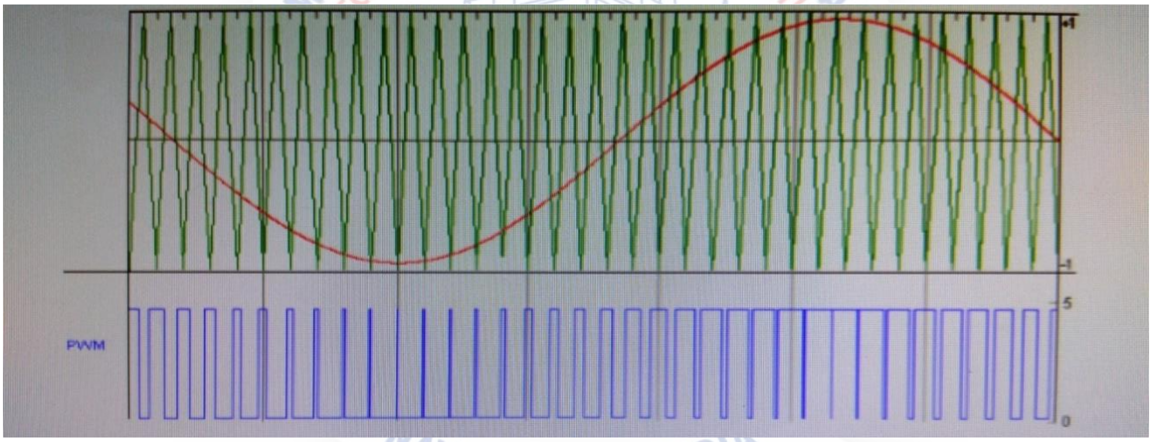


Fig4.2:-PWM generation

4.4.2.1WHY PIC MICROCONTROLLER

4.4.2.1.1 INTERNAL ARCHITECTURE

PIC16F877a has Harvard architecture [4]. Harvard architecture is a newer concept than von Neumann. It rose out of the need to speed up the work of a microcontroller. In Harvard architecture data bus and address bus are separate. Thus a greater flow of data is possible through the central processing unit and of course a greater speed of work. Separating a program from data memory makes it further possible for instructions not to have to be 8-bits instructions which allows for all instructions to be one word instructions. It is also typical for Harvard architecture to have fewer instructions than von-Neumann's, and to have instructions usually executed in one cycle. Microcontrollers with Harvard architecture are also called "RISC microcontrollers". Fig.4.4 presents the internal block of the PIC16F877a.

4.4.2.1.2 INSTRUCTION SET

RISC stands for Reduced Instruction Set Computer. Microcontrollers with von-Neumann's architecture are called 'CISC microcontrollers', which stands for Complex Instruction Set Computer. PIC16F877A is a RISC microcontroller that means it has a reduced set of instructions; more precisely 35 instructions. Advantages of RISC is that the microcontroller is fast, it’s easy to learn programming language needed to program it and the user only sees the final results.

4.4.2.1.3 COST

PIC16F877A is an 8 bit microcontroller classified under medium range microcontrollers which makes it very cost competitive with other similar products in the market and hence its pocket friendly. Due to its low cost the overall cost of the inverter ends up being low and market competitive given that the microcontroller is the most expensive chip in the design.

3.3.2.1.4 AVAILABILITY IN THE MARKET

Since in our country we don’t have a plant to fabricate microchips it is very important to choose a chip which readily available in the local market to avoid incurring extra cost of shipping. PIC16F877A was available in the local stores hence the reason to using it. PIC16F877a perfectly fits many uses, from automotive industries and controlling home appliances to industrial instruments, remote sensors, electrical door locks and safety devices. It is also ideal for smart cards as well as for battery-supplied devices because of its low power consumption .

4.4.2.1.5 GENERATING CONTROL SIGNALS

The microcontroller is tasked with generating four control signals that are used as inputs to the Mosfet driver. They are two 50 Hz square wave and two 2-level pulse width modulated at 180 degrees out of phase. In order for the microcontroller to give this outputs it has to be programmed. The concept used is simpler and easily implement with PIC16f877. A

50Hz sinusoidal with unity magnitude is multiplied with the impulse train of 5000Hz so that one complete cycle of sinusoidal contains 100 impulses as shown in Fig.4.2. 5000Hz PWM can be generated in such a manner that starting position of pulse should be same as that of impulse and duty cycle of the pulse must be equal to the product of unit impulse and value of sine at that instant as shown in Fig. 4.3.

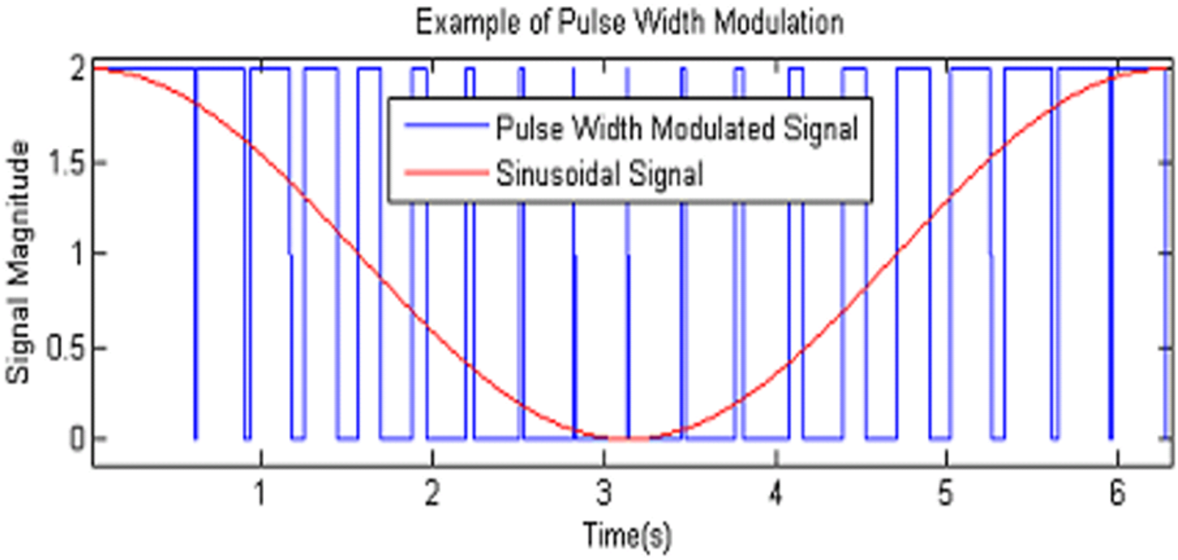


Fig4.3:-Pulse Width Modulation of a Sinusoidal

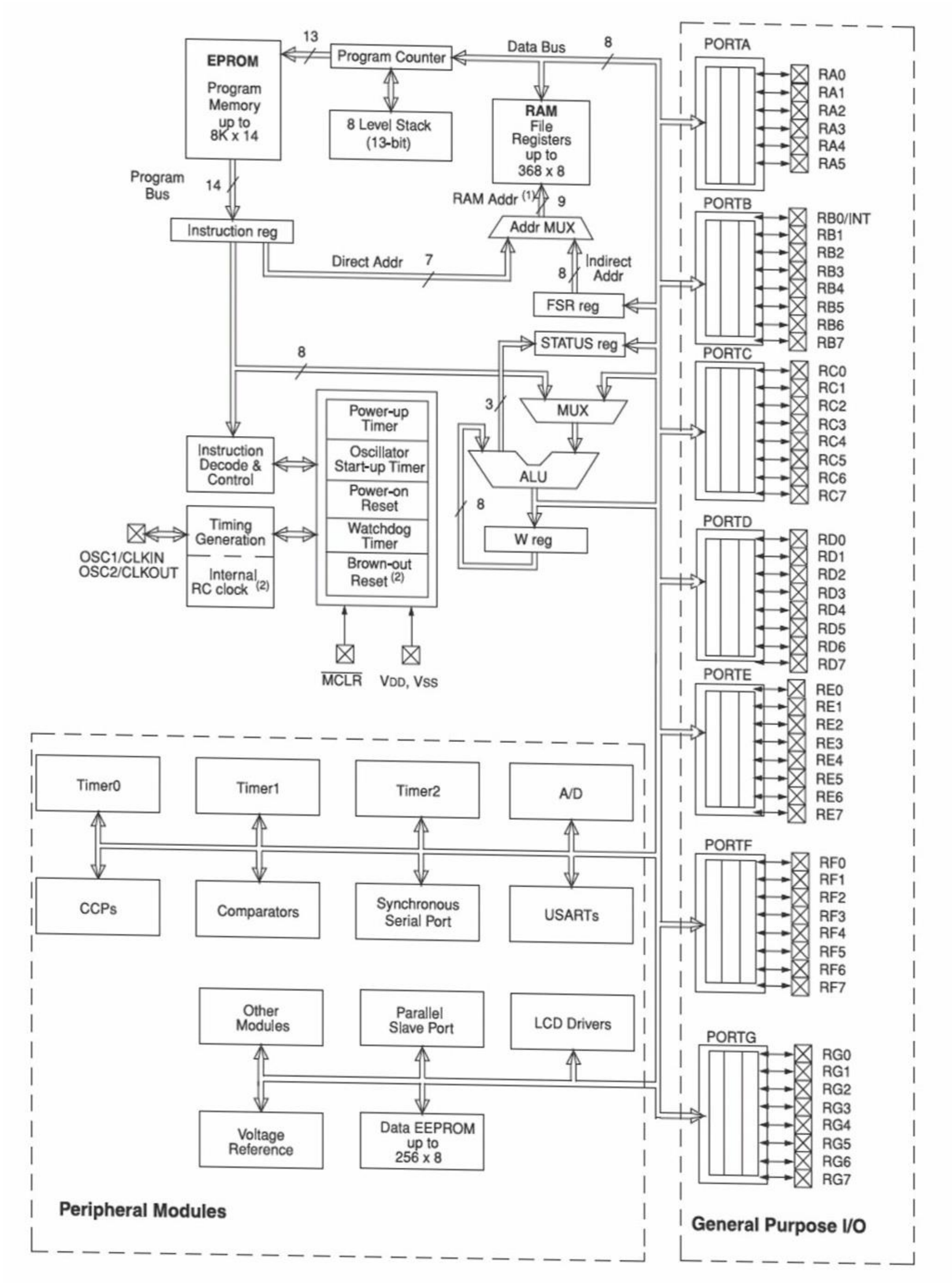
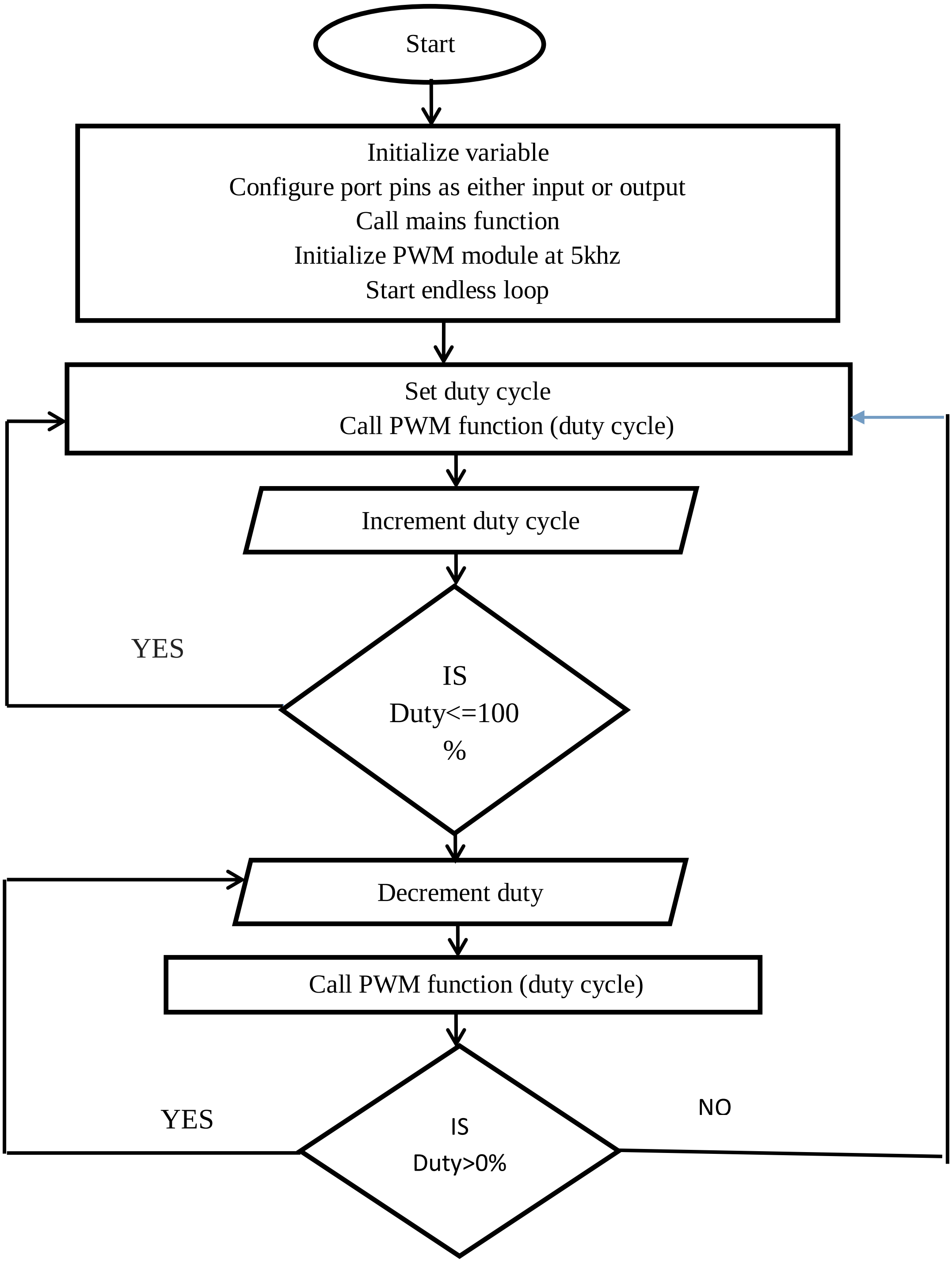


Fig4.4:-internal structure of PIC16F877A microcontroller

Flow chart


Start
Initialize variable
Configure port pins as either input or output
Call mains function
Initialize PWM module at 5khz
Start endless loop
Set duty cycle
Call PWM function (duty cycle)
Increment duty cycle
YES
IS
Duty<=100
%
Decrement duty
Call PWM function (duty cycle)
YES
IS
Duty>0%
NO

4.5 CODING MICROCONTROLLER

Embedded C language was used to write the code needed to program the microcontroller by following flow chart as shown in figure above. The C code is then build using mikroc pro compiler to produce HEX file which is burned to microcontroller or loaded to proteus for simulation. A complete C program is attached in the appendix A.

4.6 MOSFET DRIVER

As stated in the previous section, it is beneficial to use N-channel MOSFETs as the high side switches as well as the low side switches because they have a lower 'ON' resistance and therefore less power loss. However, to do so, the drain of the high side device is connected to 340V DC power which is to be inverted into the 240V AC power. This is a problem because the 340V is the highest voltage in the system and in order for the switch to be turned on the voltage at the gate terminal must be 10V higher than the drain terminal voltage . Therefore, to drive MOSFETs in the H-Bridge MOSFET driver IC is used with a bootstrap capacitor specifically designed for driving a half-bridge. After considering various IC options, the ideal choice was the IR2110, which is rated at 600V, with a gate driving current of 2A and a gate The MOSFET driver operates from a signal input given from the microcontroller and takes its power from the battery voltage supply that the system uses. The driver is capable of operating both the high side and low side devices, but in order to get the extra 10V for the high side device, an external bootstrap capacitor is charged through a diode from the 18V power supply when the device is off. Because the power for the driver is supplied from the low voltage source, the power consumed to drive the gate is small. When the driver is given the signal to turn on the high side device, the gate of the MOSFET has an extra boost in charge from the bootstrap capacitor, surpassing the needed 10V to activate the device and turning the switch on riving voltage of 10-20V. The turn on and turn off times are 120ns and 94ns respectively

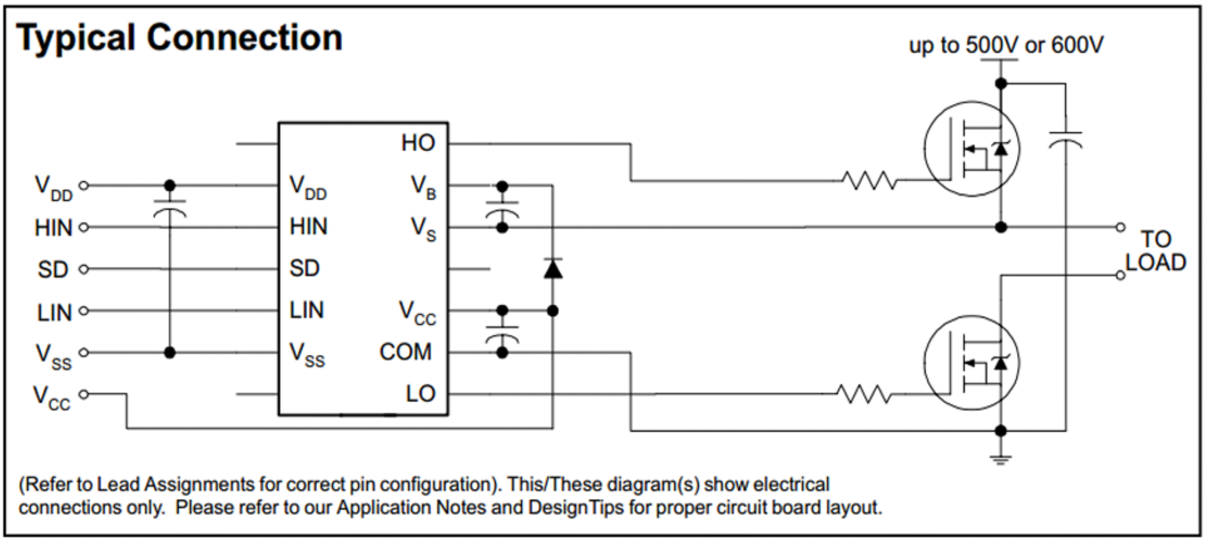


Fig4.5:IR2110 connection

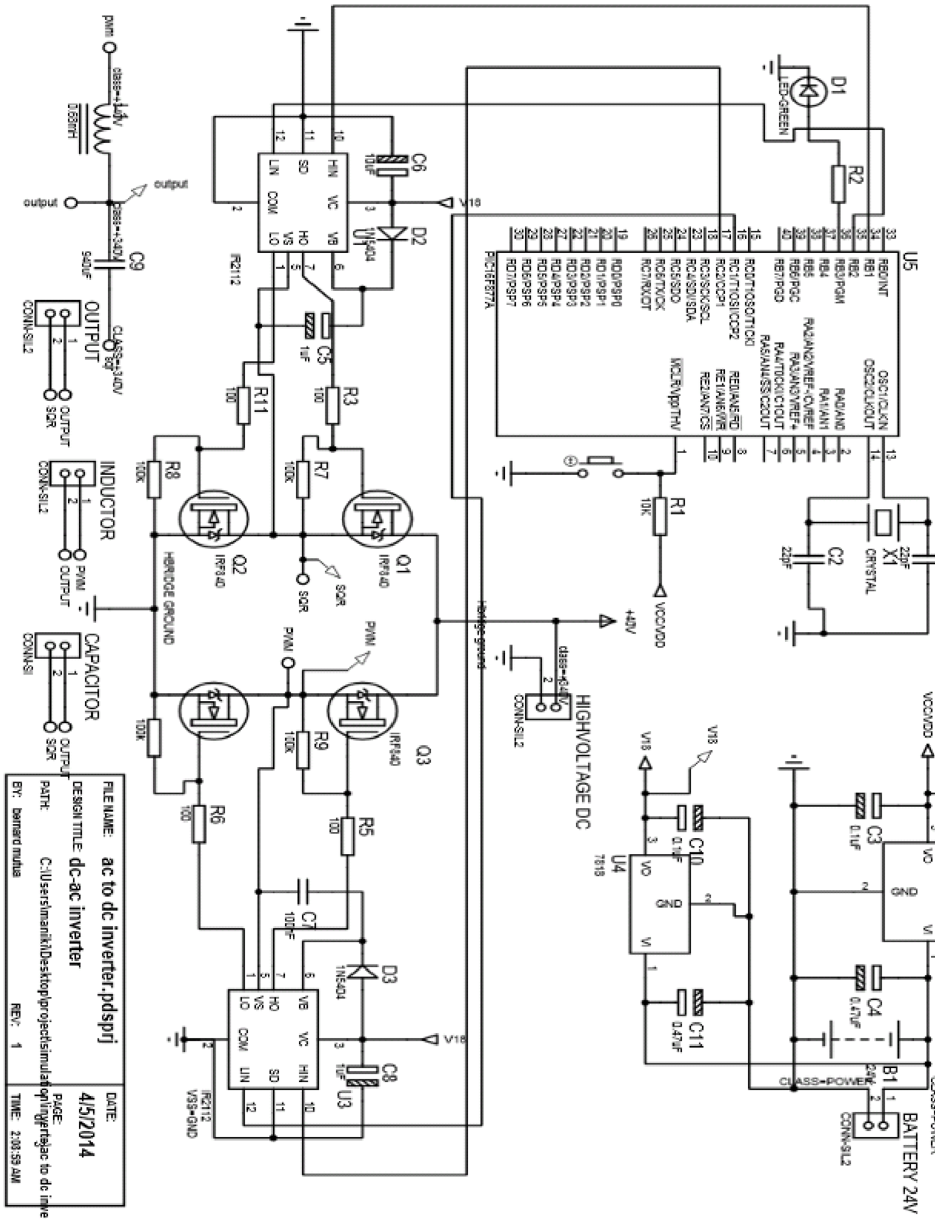


Fig4.6:- Inverter circuit with pic micro-controller

Chapter 5

BLDC Motor

5.1 Construction

BLDC motors have many similarities to AC induction motors and brushed DC motors in terms of construction and working principles respectively. Like all other motors, BLDC motors also have a rotor and a stator.

5.1.1Stator

Similar to an Induction AC motor, the BLDC motor stator is made out of laminated steel stacked up to carry the windings. Windings in a stator can be arranged in two patterns; i.e. a star pattern (Y) or delta pattern (Δ). The major difference between the two patterns is that the Y pattern gives high torque at low RPM and the Δ pattern gives low torque at low RPM. This is because in the Δ configuration, half of the voltage is applied across the winding that is not driven, thus increasing losses and, in turn, efficiency and torque.

Steel laminations in the stator can be slotted or slotless as shown in Figure 2. A slotless core has lower inductance, thus it can run at very high speeds. Because of the absence of teeth in the lamination stack, requirements for the cogging torque also go down, thus making them an ideal fit for low speeds too (when permanent magnets on rotor and tooth on the stator align with each other then, because of the interaction between the two, an undesirable cogging torque develops and causes ripples in speed). The main disadvantage of a slotless core is higher cost because it requires more winding to compensate for the larger air gap.

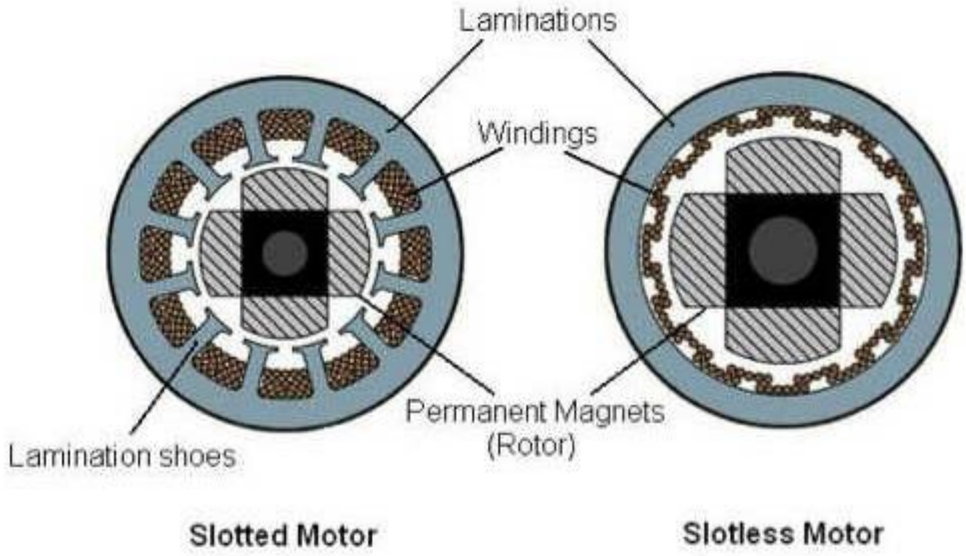


Fig5.1:- Slotted and Slotless motor

5.1.2 Rotor

The rotor of a typical BLDC motor is made out of permanent magnets. Depending upon the application requirements, the number of poles in the rotor may vary. Increasing the number of poles does give better torque but at the cost of reducing the maximum possible speed. Another rotor parameter that impacts the maximum torque is the material used for the construction of permanent magnet; the higher the flux density of the material, the higher the torque.

Fig5.2:- 4 pole and 8 pole –Permanent magnet rotor

5.2 Working

Before explaining working of brushless DC motor, it is better to understand function of brushed motor. In brushes motors, there are permanent magnets on the outside and a spinning armature which contains electromagnet is inside.

These electromagnets create a magnetic field in the armature when power is switched on and help to rotates armature. The brushes change the polarity of the pole to keep the rotation on of the armature. The basic principles for the brushed DC motor and for brushless DC motor are same i.e., internal shaft position feedback. Brushless DC motor has only two basic parts: rotor and the stator. The rotor is the rotating part and has rotor magnets whereas stator is the stationary part and contains stator windings. In BLDC permanent magnets are attached in the rotor and move the electromagnets to the stator. The high power transistors are used to activate electromagnets for the shaft turns. The controller performs power distribution by using a solid-state circuit.

5.3 Types of Brushless Dc motor

Basically, BLDC are of two types, one is outer rotor motor and other is inner rotor motor. The basic difference between the two are only in designing, their working principles are same.

5.3.1 Inner Rotor Design

In an inner rotor design, the rotor is located in the center of the motor and the stator winding surround the rotor. As rotor is located in the core, rotor magnets does not insulate heat inside and heat get dissipated easily. Due to this reason, inner rotor designed motor produces a large amount of torque and validly used.

5.3.2Outer Rotor Design

In outer rotor design, the rotor surrounds the winding which is located in the core of the motor. The magnets in the rotor traps the heat of the motor inside and does not allow to dissipate from the motor. Such type of designed motor operates at lower rated current and has low clogging torque.

5.4 Advantages of Brushless DC Motor

1) Brushless motors are more efficient as its velocity is determined by the frequency at which current is supplied, not the voltage.
2) As brushes are absent, the mechanical energy loss due to friction is less which enhanced efficiency.
3) BLDC motor can operate at high-speed under any condition.
4) There is no sparking and much less noise during operation.
5) More electromagnets could be used on the stator for more precise control.
6) BLDC motors accelerate and decelerate easily as they are having low rotor inertia.
7) It is high performance motor that provides large torque per cubic inch over a vast sped rang.
8) BLDC motors do not have brushes which make it more reliable, high life expectancies, and maintenance free operation.
9) There is no ionizing sparks from the commutator, and electromagnetic interference is also get reduced.

Chapter 6

Simulation and Results

6.1 Simulink Model for IBC

Fig 6.1 shows the MATLAB simulation model for interleaved boost converter. It includes inductor of 2 mH having initial current 3A., Capacitor of 3500microF and MOSFET as a switch. The IBC is fed with 24V and output is around 250V which is displayed and observe in scope. The output of IBC is fed to 3 phase inverter which is sown in fig6.3. BLDC motor is use as a load and its characteristic are analysis in fig6.5. The PWM pulse are use to switching the mosfet which is shown in fig 6.2.

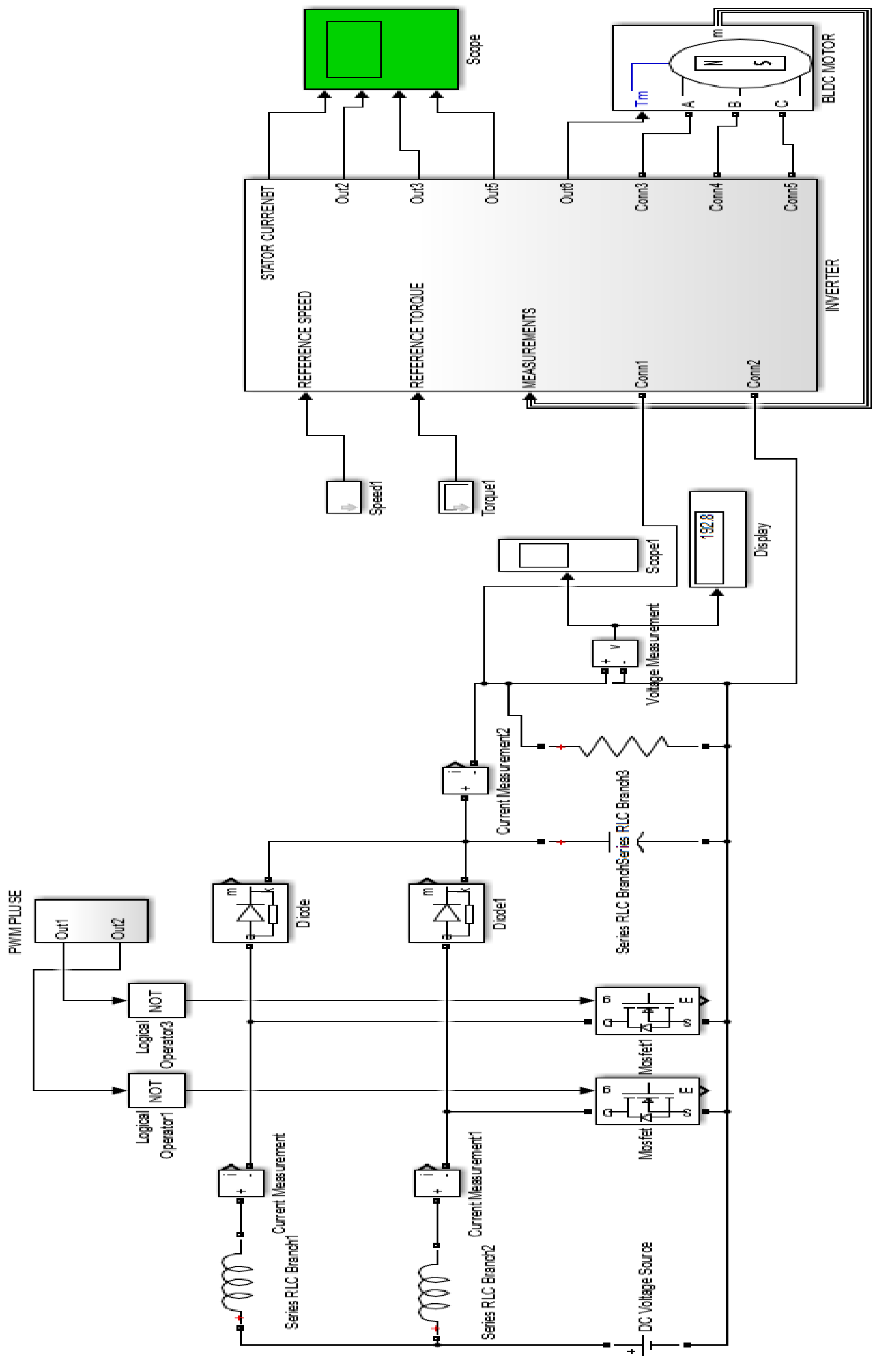


Fig6.1:-MATLAB Simulink Interleaved Boost Converter

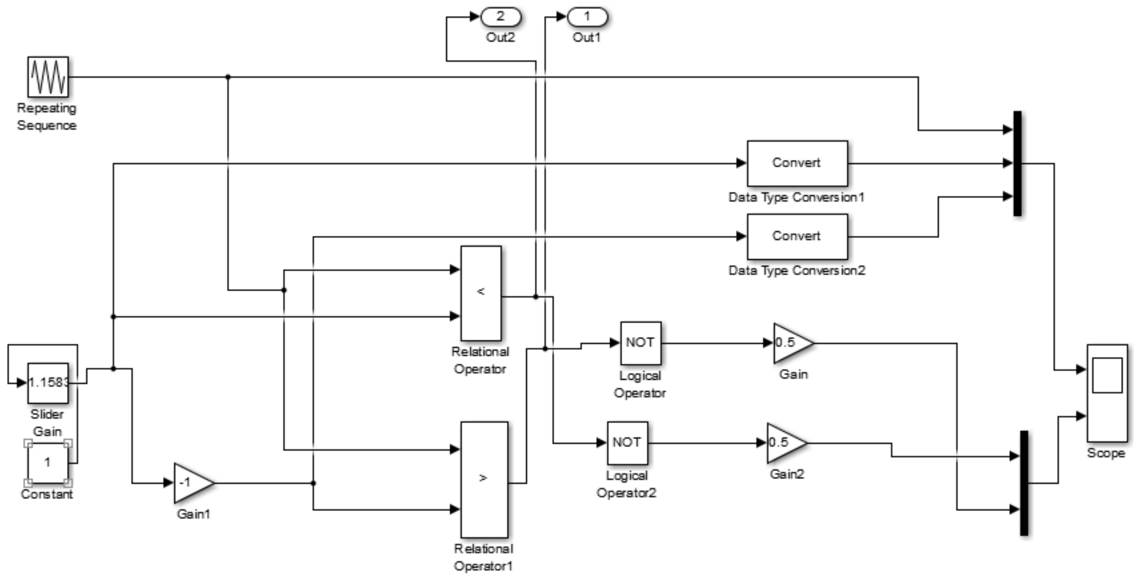


Fig6.2:- Pulse Width Modulator

To analysis the speed and torque characteristic of BLDC motor, reference speed 300 rpm is compare with actual speed of the motor. The control signal is provided by speed controller to generate PWM pluses. Hysteresis-band PWM is basically an instantaneous feedback current control method of PWM where the actual current continually tracks the command current within a hysteresis band. Hysteresis control schemes are based on a nonlinear feedback loop with two level hysteresis comparators. The switching signals are produced directly when the error exceeds an assigned tolerance band. Hysteresis control schemes are based on a nonlinear feedback loop with two level hysteresis comparators. The switching signals are produced directly when the error exceeds an assigned tolerance band .Current error movement if restricted within a specified boundary will help in compensating for harmonics. Researchers have worked upon application of space vector modulation based hysteresis current controllers.

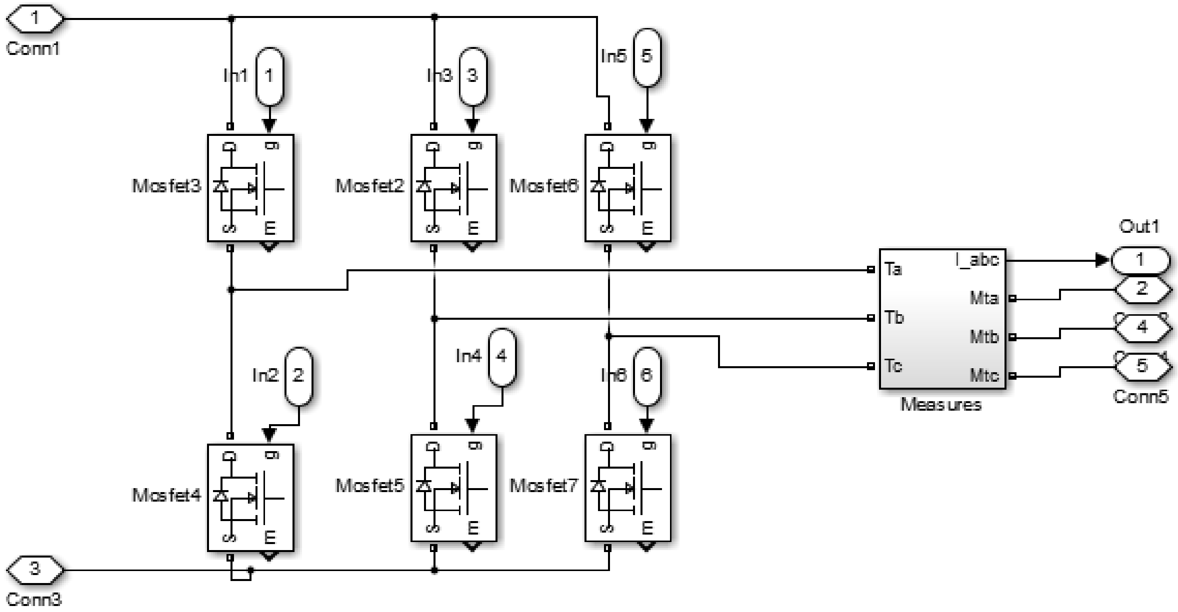


Fig6.3:-3 Phase Inverter

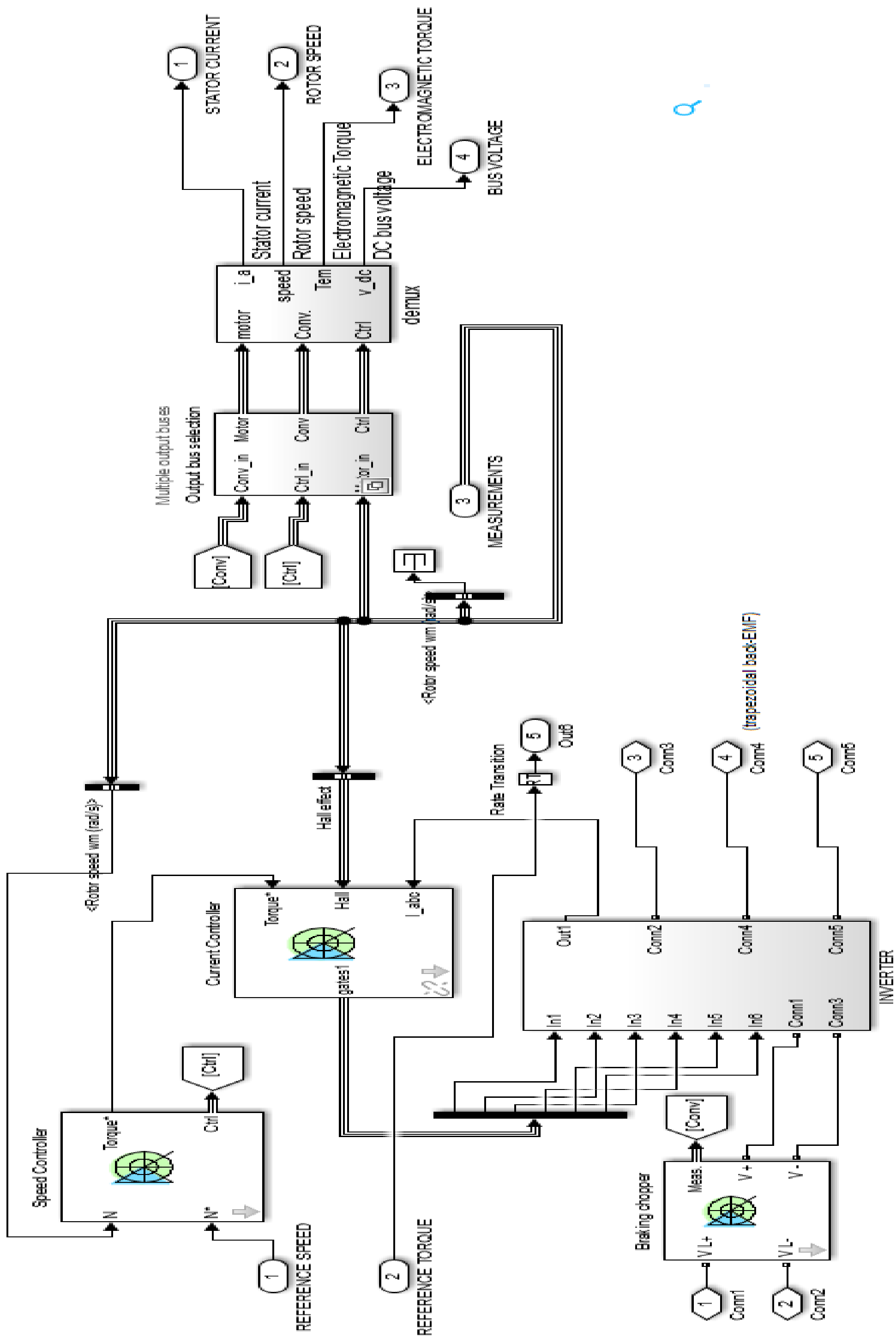


Fig6.4:-Hierarchy control current

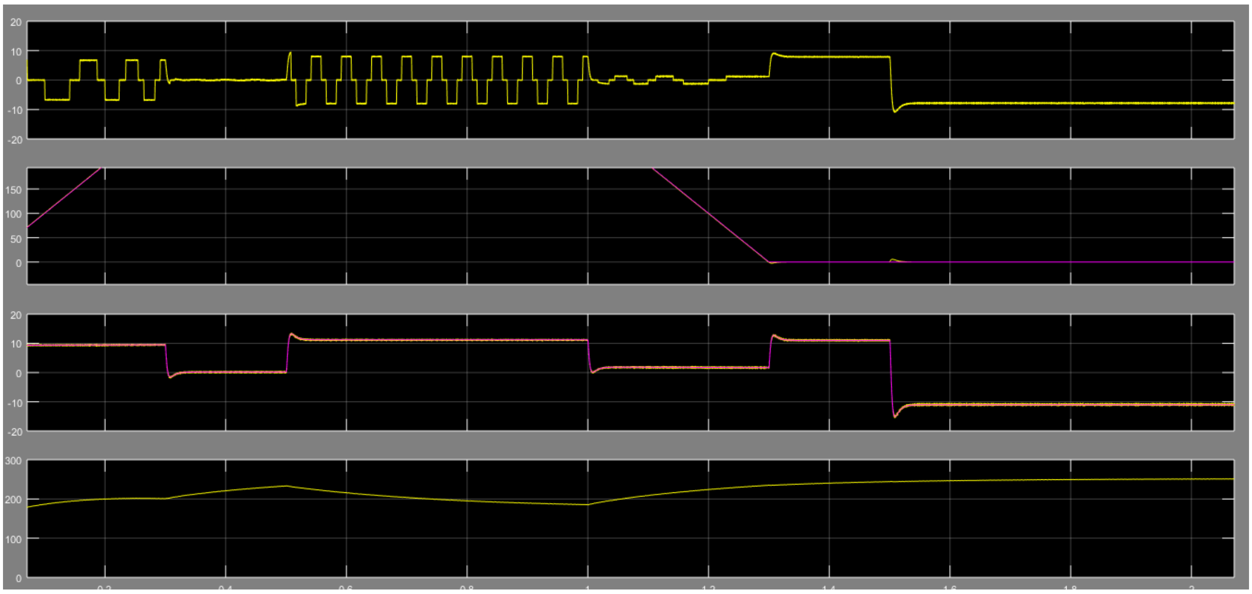


Fig6.5:- Output waveform of BLDC motor

The dc output voltage of IBC is shown in fig6.6 around 250 volts the PWM pulses given to switches are shown in fig6.7

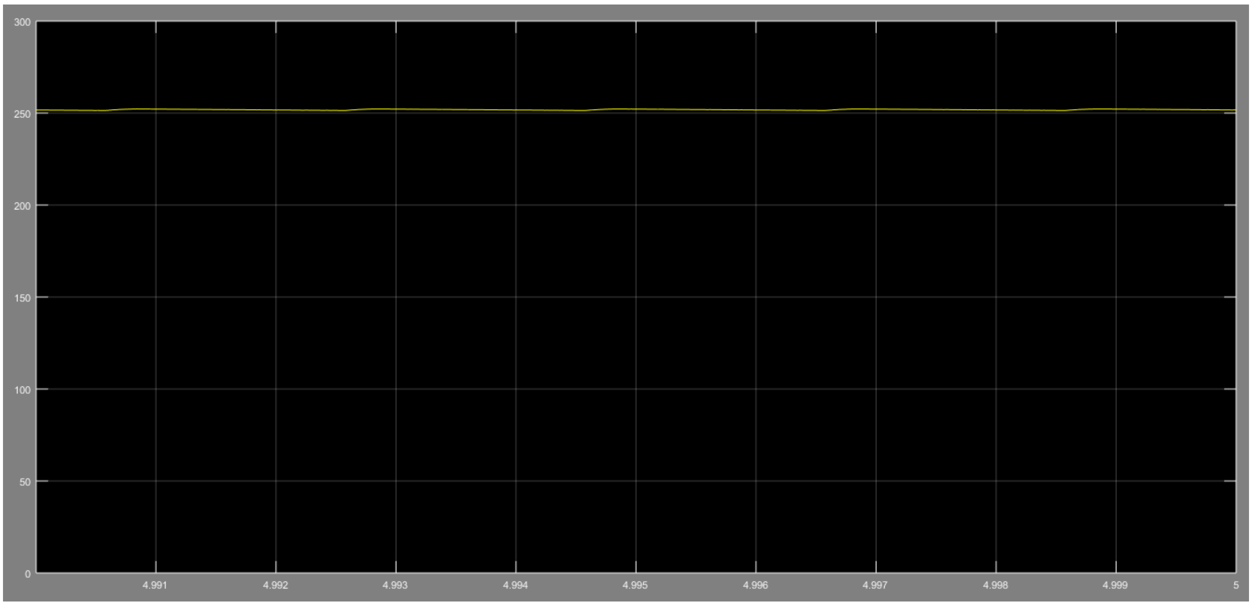


Fig6.6:- Output voltage waveform of IBC

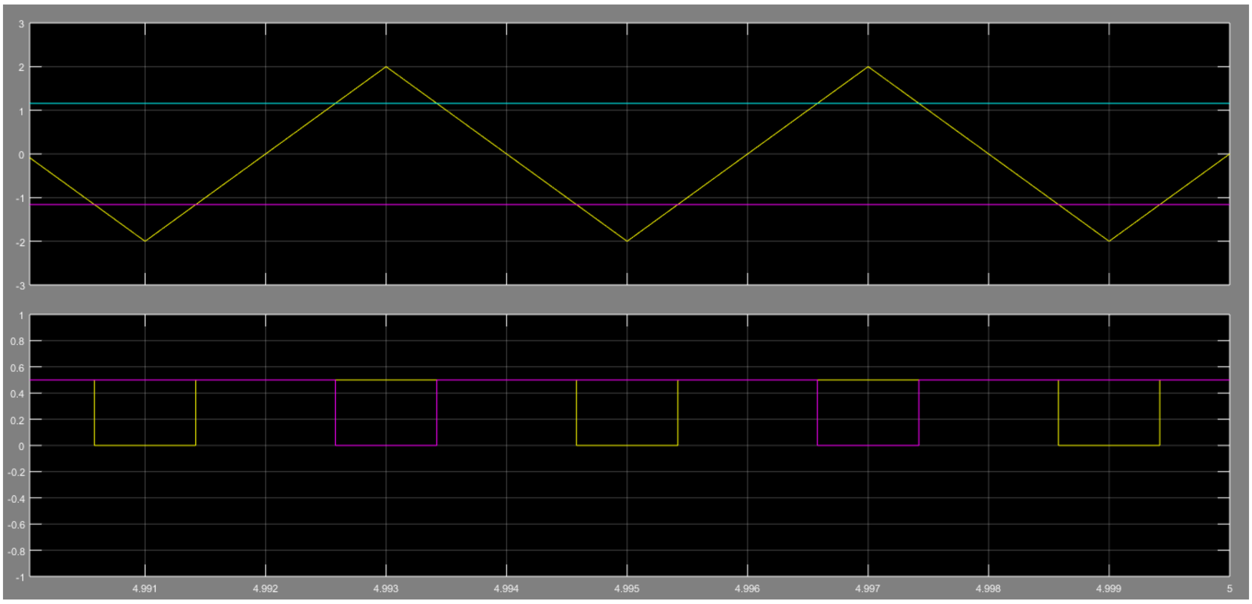


Fig6.7:- Output waveform of PWM

CHAPTER 7

Hardware implementation

7.1 Power Supply

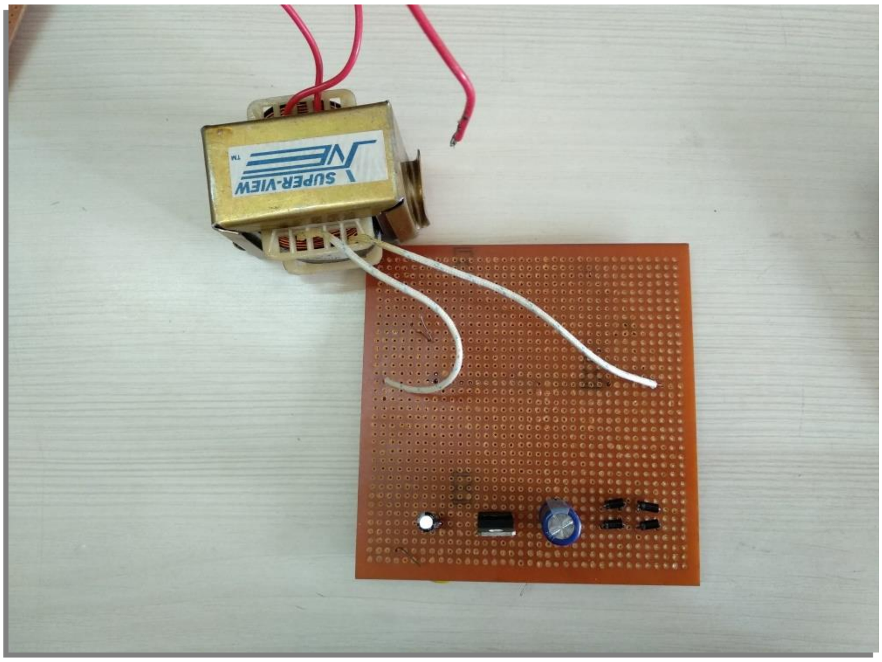


Fig7.1:-Power supply circuit

A power supply circuit consist of step down transformer – 230V to 12V

Capacitor of3500e-6 and they are rectify using bridge rectifier.

The ouput of the circuit given to output driver.

6.2 Interleaved Boost Converter

For IBC we used Mosfet of IRFZ44N ,

Inductor of 2e-3

Capacitor of3500e-6

Resistor of 100 ohm.

.

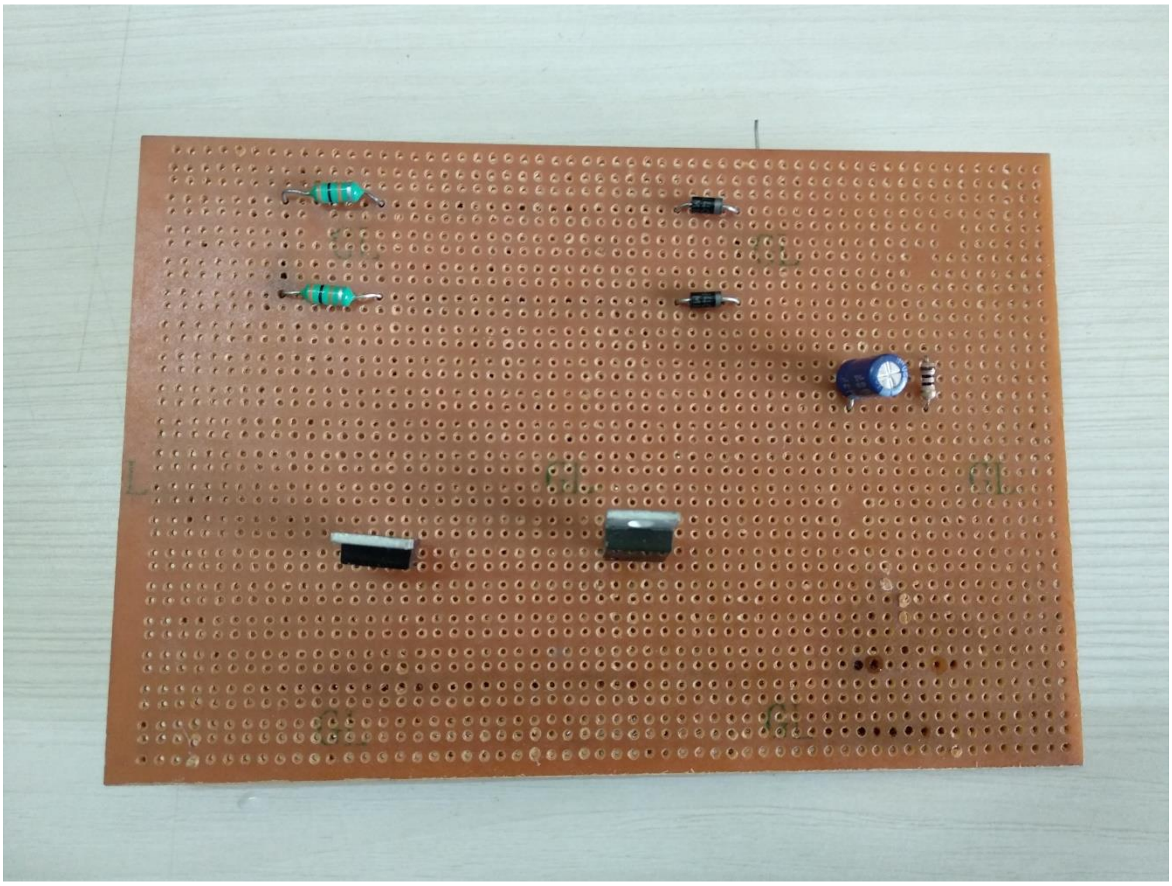


Fig7.2:- Interleaved Boost Converter circuit

6.3 Inverter

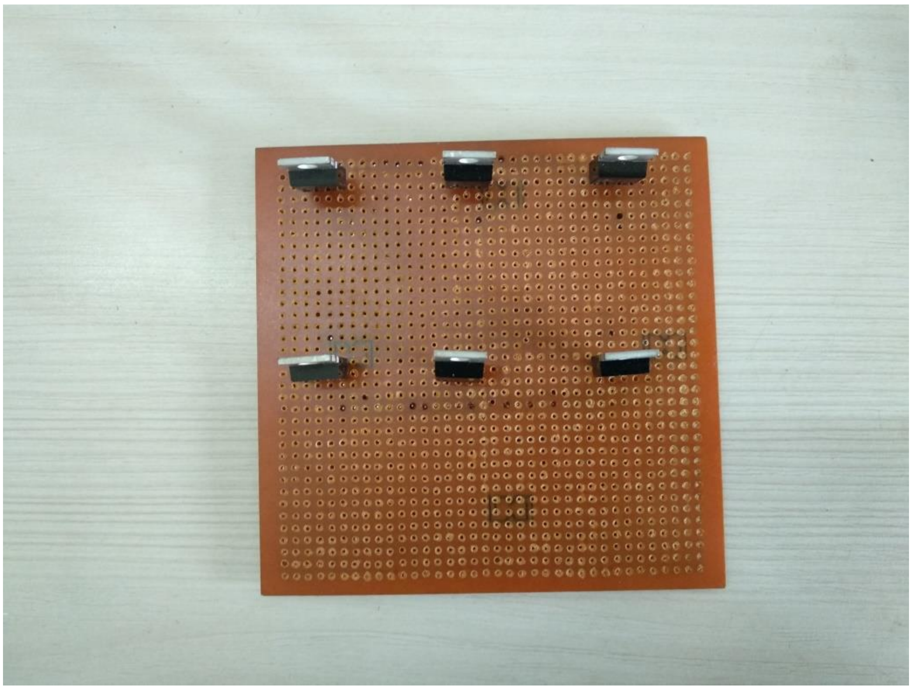


Fig7.3:- Inverter circuit

There are 6 mosfet IRFZ44n are use for inverter

Inverter, is an electronic device or circuitry that changes direct current (DC) to alternating current (AC).

The input voltage, output voltage and frequency, and overall power handling depend on the design of the specific device or circuitry. The inverter does not produce any power; the power is provided by the DC source.

Chapter 7

Reference

1) IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 3 Issue 8, August 2016 ISSN
2) https://en.wikipedia.org/wiki/Boost_converter
3) F17/28234/2009. I. UNIVERSITY OF NAIROBI. FACULTY OF ENGINEERING. DEPARTMENT OF ELECTRICAL AND INFORMATION ENGINEERING. MICROCONTROLLER BASED POWER INVERTER. PROJECT INDEX: PRJ 015. BY. MUTUA JOSHUA BERNARD. F17/28234/2009. SUPERVISOR: DR. G. KAMUCHA.
4) Brushless DC Motors – Part I: Construction and Operating Principles
Pushek Madaan, Cypress Semiconductor -February 11, 2013
5) Comparison of Boost and Interleaved Boost Converters for Wind Energy System G. P. Ramesh1, A. Jaffar Sadiq Ali2

Chapter 8

Conclusion

This dissertation work shows the design and implementation of interleaved boost converter. Comparison between conventional boost converters with the proposed IBC along with their application in running a BLDC motor with the motor speed variation is shown by using MATLAB/SIMULINK. From the obtained results we can conclude that, the IBC has higher boosting capacity, reduced inductor peak current and increased efficiency compared to that of conventional boost converters. The graph of efficiency versus output power is plotted and this graph clearly shows that, the efficiency of the proposed converter increases with increase in output power. And also it is clear that the selection of converter also plays an important role in efficient utilization of the renewable source output. The results also shows us that, the output of IBC is higher with less ripple content than that of conventional boost converter which helps in increasing the speed and efficiency of BLDC motor.

APPENDIX

Appendix A

Microcontroller C code using Micro C pro compiler.

```
int duty=50;                    //initialize variable

void main() {

TRISB=0x00;                     //set port B as output
 TRISC=0x00;                    //set port B as output
 PORTB=0;                       //initalize port B

 PWM1_start();                  //initalize PWM1

 PWM2_start();                  //initalize PWM2

 PWM1_init(5000);                 //set pwm frequency  to 5khz

 PWM2_init(5000);                 //set pwm2 frequency to 5khz

 RB3_bit=1;                     // switch on led to indicate power on

 while(1){                      // endless loop

 RB2_bit=1;                       //output high pulse for square wave1 half cycle

 while(duty<100){

pwm1_set_Duty(duty*2.55);  //set duty cycle for pwm1  first quarter

 delay_us(22);

 duty+=2;

 }

 while(duty>50){
```

```
 pwm1_set_Duty(duty*2.55);          //set duty cycle for pwm1 second quarter
 delay_us(22);
duty-=2; }
 pwm1_set_Duty(0);                //set duty cycle for pwm1 to zero for rest of cycle
 RB2_bit=0;                       //set low pulse for square wave1 second half cycle
delay_us(140);
RB1_bit=1;                        // output high pulse for square wave2
while(duty<100){
pwm2_set_Duty(duty*2.55);          //set duty cycle for pwm2 third quarter
delay_us(22);
 duty+=2;
 }
 while(duty>50){
pwm2_set_Duty(duty*2.55);         //set duty cycle for pwm2  fourth quarter
 delay_us(22);
 duty-=2;
 }
 pwm2_set_Duty(0);                //set duty cycle for pwm2 to zero
 RB1_bit=0;                       //output low pulse for square wave2
delay_us(130);
 }
 }
```