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3 Phase Multilevel Inverter using Bidirectional Chopper Cell

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Abstract— The paper presents the simulation of the operation of 3 phase multilevel inverter using bidirectional chopper cells. The input provided is a DC supply of 12V which is further distributed into two 6V supplies. To convert DC into AC, configuration of Bidirectional Chopper cell are used two in each phase. Thus 3 phases are working simultaneously to give a 3 phase AC supply using the concept of Multilevel Inverters. . The hardware is broken down into Main and Driver circuits where the main circuit includes the switching circuitry and the driver board comprises of the triggering circuitry.

Index Terms— ***Multilevel Inverter, Bidirectional Chopper, Main circuit, Driver circuit.***

I. INTRODUCTION

Inverter- Inverter is a device that converts electrical power from dc form to ac form using electronic circuits. A single-phase inverter, in which M1 & M2 Conduct for half a period and M3 & M4 conduct for the other half. The output voltage can be controlled by varying the conduction time of the transistors.

Static Switches: Since the power devices can be operated as static switches or contactors, the supply to these switches could be either AC or DC, and the switches are called as AC static switches or DC switches.

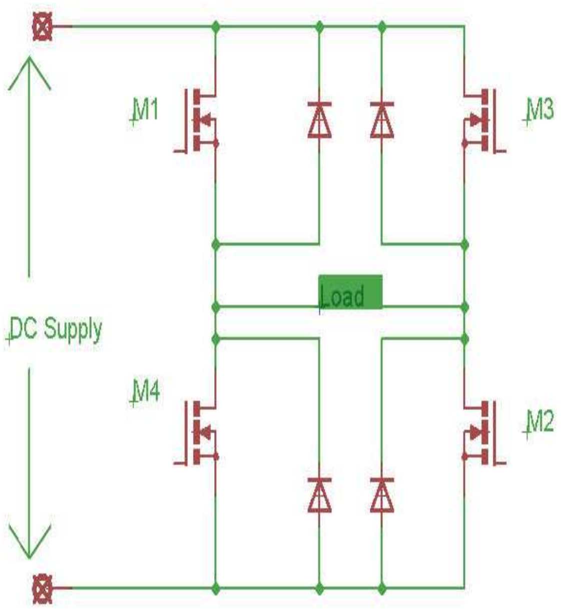

Fig 1 Basic Inverter Configuration

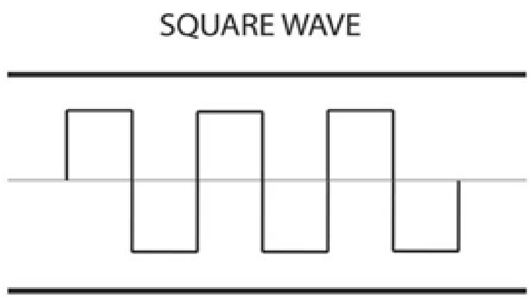

Fig 2 Output Waveform of a basic inverter

A. Multilevel Inverter

A multilevel inverter is an electrical power converter that changes direct current (DC) to alternating current (AC). It provides another approach to harmonic cancellation. They provide an output waveform that exhibits multiple steps at several voltage levels.

The multilevel inverter has gained much attention in recent years due to its advantages in high power with low harmonics applications. The general function of the multilevel inverter is to synthesize a desired high voltage from several levels of dc voltages that can be batteries, fuel cells, etc.

For a three-phase inverter system, as shown in Fig, with an input DC voltage of Vdc given to series connected capacitors, which constitute the energy tank for the inverter. The Multilevel inverter is connected to these nodes. Each capacitor has the same voltage Em which is given by Em = Vdc / (m-1) , where m denotes the number of levels. .

The term level is referred to as the number of nodes to which the inverter can be accessible.

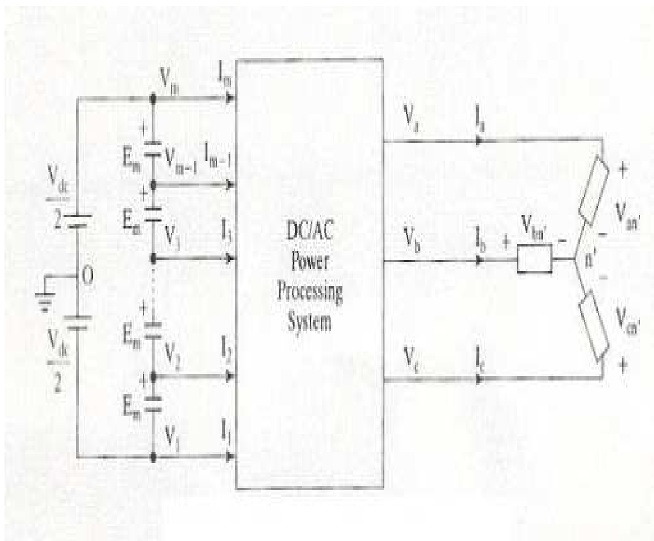

Fig 3 Three-phase multi level power processing system

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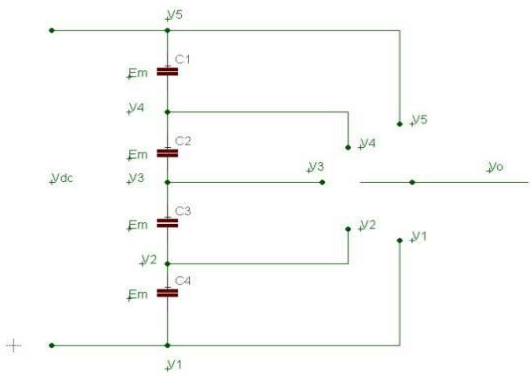

Fig 4 Schematic single pole of multi level inverter by a switch

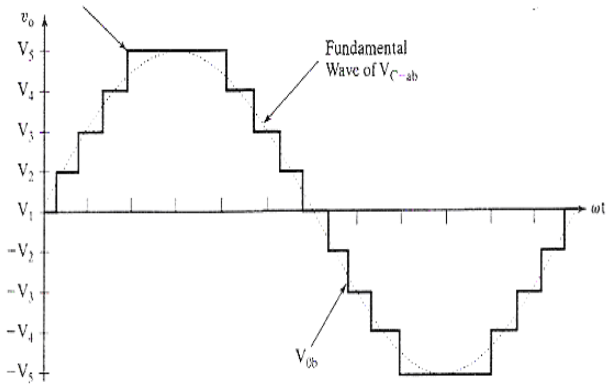

Fig 5 Typical output voltage of a five level Multi Level Inverter

Output phase voltages can be defined as voltages across output terminals of the inverter and the ground point denoted by "0" as shown in Fig 3 Moreover, input node voltages and currents can be referred to input terminal voltages of the inverter with reference to ground point and the corresponding currents from each node of the capacitors to the inverter, respectively. The input node voltages are designated by V1, V2, etc., and the input dc currents by I1, I2, etc., Va, Vb, Vc are the root mean square (rms) values of the line load voltages; Ia, Ib, Ic are the rms values of the line load currents. Fig 4 shows the schematic of a pole in a multilevel inverter, where Vo indicates an output phase voltage, that can assume any voltage level depending on the selection of node dc voltage V1, V2 etc., Thus, a pole in a multilevel inverter can be regarded as a single pole, multi throw switch. By connecting the switch to one node at a time, one can obtain the desired output. Fig 5 shows the typical output voltage of a five level inverter.

The actual realization of the switch requires bidirectional switching devices for each node. The topological structure of Multi Level Inverter must have:

1. Less switching devices as far as possible

2. Must be capable of withstanding very high input voltage for high power applications

3. Have lower switching frequency for each switching device

B. Types of Multi Level Inverters:

The general structure of the Multi Level Converter is to synthesize a near sinusoidal voltage from several levels of dc voltages, typically obtained from capacitor voltage sources. As the number of levels increase, the synthesized output voltage waveform has more steps, which produce a staircase wave that approaches a desired wave form. As more steps are added to the waveform, the harmonic distortion of the output wave decreases, approaching zero as the number of levels increase. As the number of levels increase, the voltage that can be spanned by summing multiple voltage levels also increase.

The output voltage during the positive half cycle can be found from

$$v_{ao} = \sum_{n=1}^{m} E_n SF_n$$

Where, SFn is the switching or control function of nth node and it takes a value from 0 to 1.

Terminal voltages E1, E2… all have the same value as Em. Thus, the peak output voltage is Vao[peak] = (m-1) Em = Vdc .

To generate an output voltage with both positive and negative values, the circuit topology has another switch to produce the negative part Vob, so that.

$$v_{ab} = v_{ao} + v_{ob} = v_{ao} - v_{bo}.$$

II. FEATURES

The general features of a multi level inverter are as follows:

- The output voltage and power increase with number of levels. Adding a voltage involves adding main switching device to each phase.
- The harmonic content decreases as the number of levels increase and filtering requirements are reduced.
- With additional voltage levels, the voltage waveform has more free switching angles which can be pre-selected for harmonic elimination.
- In the absence of any PWM techniques, the switching losses can be avoided.
- The fundamental output voltage is set by the dc bus voltage Vdc which can be controlled through a dc link.
- Power factor is close to unity.
- No electromagnetic induction is produced.

In view of the above, the multi level inverters can be applied in the following situations:

- These are meant for high power applications, such as in utility systems for controlled sources of reactive power.
- In steady-state operation, an inverter can produce a controlled reactive current and operates as static volt-ampere reactive compensator (SVC / STATCON).
- These inverters reduce the size of compensator and improve its performance during power system contingencies.
- Because of the use of a high voltage inverter, it can be directly connected to high voltage system (e.g~13 kV) distribution system, eliminating the distribution transformer and reducing the system cost.
- The harmonic content of the inverter waveform can be reduced with appropriate control techniques, and thereby the efficiency can be improved.

Keeping the above in view, the main applications for multi level inverters are

1. Reactive power compensation

2. Back to back inter-tie

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3. Utility compatible adjustable speed drive.

III. MULTILEVEL INVERTERS USING BIDIRECTIONAL CHOPPER CELLS:

Bidirectional Chopper Cells:

This BIDIRECTIONAL CHOPPER CELL has been used in this project for Multi Level inverters. This cell consists of two IGBTs, which are connected through a capacitor, known as "flying capacitor". This is called as bidirectional, since when the firing is allowed to the gates, the IGBT switches act as if they are closed and conduct, else through the capacitor which is charged and discharged. Hence the name is bidirectional.

The stepped wave form of output voltage is in case of diode clamped multi level inverter. The average of these steps is considered as the sinusoidal output.

Due to the floating capacitor in this "bidirectional chopper cell" the steps in the wave for have been eliminated. Harmonic contents used to eliminate the steps that would have been present in the waveform as in multi level cascaded system for which the average output is considered as sinusoidal. But due to this capacitor, even without firing signal for the gates of the IGBTs, the cell is able to send current through the circuit, and hence the steps are eliminated, giving out a complete sinusoidal waveform.

As the levels are increased, the purity of waveform increases, reducing the harmonic content drastically in the output.

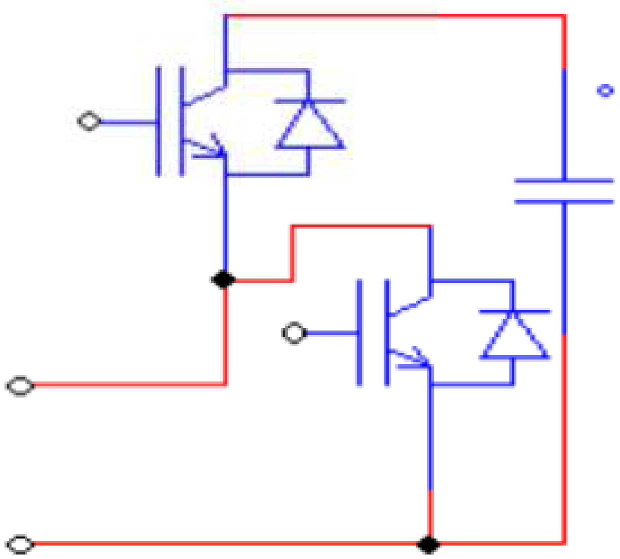

Fig 6 Bidirectional Chopper Cell

The Bidirectional Chopper Cells consists of power transistors. Power transistors have controlled turn on and turn off characteristics. The transistors that are used as switching elements are operated in the saturations region, resulting in a low on state voltage drop. The switching speed of modern transistors is much higher than that of thyristors and they are extensively used in DC to DC and DC to AC converters, with inverse parallel connected diodes to provide bidirectional current flow.

The power transistors can be classified broadly into five categories:

a) Bipolar Junction Transistors (BJTs): A bipolar transistor is formed by adding a second p- or n- region to a p-junction diode. With two n-regions and one p-region, two junctions are formed and it is known as NPN transistor. With two p-regions and one n-region, it is called a PNP transistor. The three terminals are named as collector, emitter and base. A bipolar transistor has two junctions; collector-base junction (CBJ) and base-emitter junction (BEJ). It is a current-controlled device and requires base current for current flow in the collector.

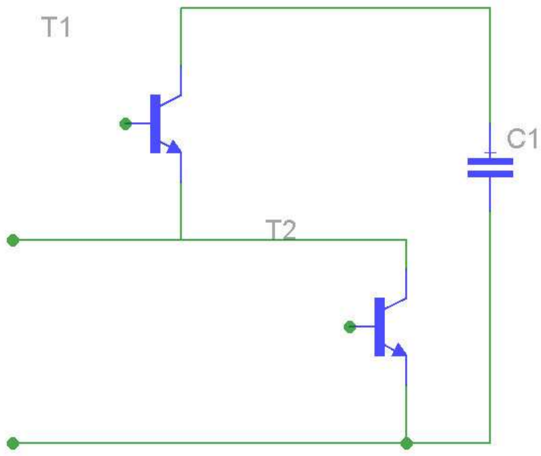

Fig 7 Bidirectional Chopper Cell using BJT

b) Metal Oxide Semiconductor Field Effect Transistors (MOSFETs): A power MOSFET is a voltage-controlled device. The switching speed is very high and switching times are nanoseconds. These do not have problems of second breakdown as in BJTs. These MOSFETS, however, have the problems of electro static discharge. It is relatively difficult to protect the MOSFETs in short circuit fault conditions.

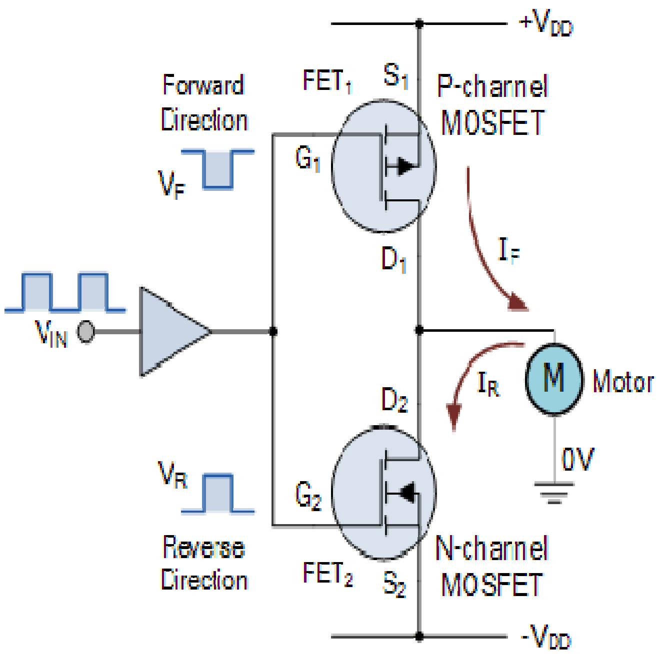

Fig 8 Bidirectional Chopper Cell using MOSFETS

c) COOLMOS: This is a new technology for high voltage power MOSFETS, which implements a compensation structure in the vertical drift region of a MOSFET to improve the on-state resistance. It has a lower on-state resistance for the same package compared with that of other MOSFETs. The conduction losses are at least five times less as compared with those of the conventional MOSFET technology. It is capable of handling two to three times more output power as compared with that of conventional MOSFET in the same package. The active chip area of COOLMOS is approximately 5 times smaller than that of standard MOSFET.

d) Static Induction Transistors (SITs): An SIT is a high power, high frequency device. It is solid state version of the triode vacuum tube. It is a vertical structure device with short multi channels. It is not subjected to area limitation and is suitable for high speed, high power operation.

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CIRCUIT DIAGRAM

A. Level inverter using bidirectional chopper

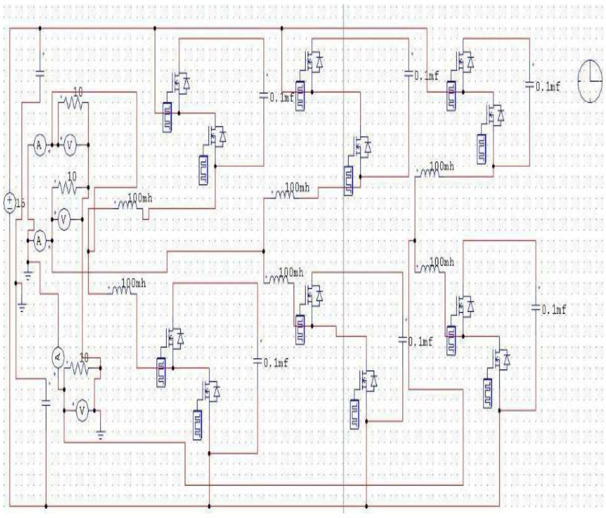

Fig 9 Circuit diagram

B. Description:

- The connection diagram indicates the two level multi level inverter with two bidirectional chopper cells per phase, one level being in positive-half cycle and one level for negative-half cycle.
- The supply input of Vdc =12V is given to two numbers distribution capacitors of 220μF in series. Thus, the applied input voltage is shared equally by them, making the applied DC Voltage of 6V to each half.
- This distributed DC voltage line is connected to three legs of bidirectional chopper cells positive-half (on top side) and negative-half (on bottom side) to form three- phase groups on positive-half and three-phase groups on negative-half.
- Output from each phase-group is connected to a filter inductance of 100 mH in each phase-group on both positive and negative half sides.
- Each phase is connected to R load of 10 ohms.
- After the load, the three phases are joined together to form star point and is connected to the midpoint of the two distributor capacitors as a return path.
- Voltmeters are provided to measure load voltages. Also, the load currents are measured by the ammeters provided in each phase.
- The firing angles are so chosen for bidirectional chopper cells, that each leg contains the two firings which are equal to the level of the multi level inverter.
- The floating capacitor connected across each bidirectional cell is chosen as one 0.1mf. Since the bidirectional cells are connected in series, the connection of floating capacitors in this phase group becomes series connection when the gate signal is in switched off condition. This being a short interval of the firing angles, it is assumed that the floating capacitors are in series.
- Thus, the total effective floating capacitor's capacitance for each leg half (phase group) becomes one half of this capacitance, i.e. 0.05mf.
- To make an equal firing distribution among the cells, when R phase is considered, the firings are chosen with max 2 angles to maintain the level of inverter, which is equal to 2 i.e. 0 /180 means 0 to 180 is on. The negative-half of the R phase firing is chosen as 180 / 360, such that this phase is shifted by 180 degrees with respect to the positive side of sinusoidal wave.
- Similarly, the Y & B phases are selected with a phase difference of 120 degrees with each another. Their corresponding negative halves are chosen by adding further 180 degrees to the respective positive phase groups. Thus, the firing angles have been decided.

C. Parameters:

Input voltage Vdc

Distribution Capacitances C1 & C2 = 220uf

D. Other Parameters:

Filter Inductances: Lr1, Lr2; Ly1, Ly2; Lb1 & Lb2 = 100 mH each

R phase floating capacitors Cr1 to Cr2: 0.1mf

Y phase floating capacitors Cy1 to Cy2: 0.1mf

B phase floating capacitors Cb1 to Cb2: 0.1mf

Load: Resistance Rr, Ry & Rb = 10 ohms

Phase	Gates	Triggering angles (degrees)
R phase	Gr1, Gr2 : 50 2	0 / 180
	Gr3, Gr4 : 50 4	180 / 360
Y phase	Gy1, Gy2 : 50 2	120 / 300
	Gy3, Gy4 : 50 4	-60 / 120
B phase	Gb1, Gb2 : 50 2	-120 / 60
	Gb3, Gb4 : 50 4	60 / 240

Table 1 Firing Angle

The driver circuit is used to trigger the MOSFETs. There are 12 MOSFETs in the circuit to be triggered.

E. Main Circuit

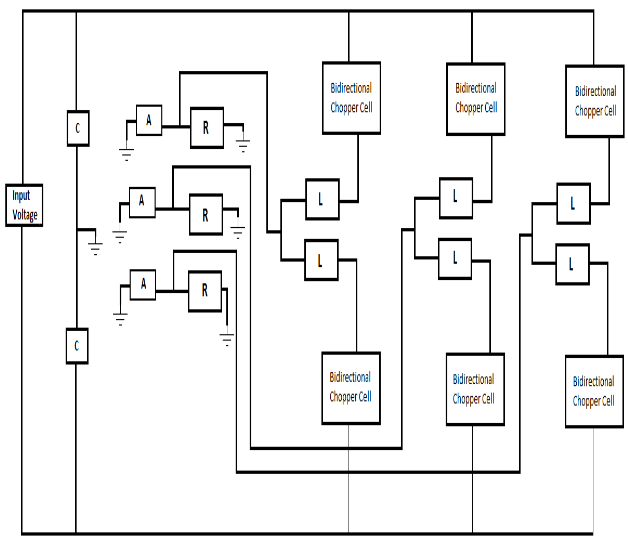

Fig 10 Main Circuit Diagram

This board has inverter circuit along with the 12V power supply. The output of the IC IR2110 is given to the MOSFETs gate terminals. This inverter is a 2 level inverter which takes 12V DC as an input and gives out 3-phase AC.

Inverter circuit consists of 3 legs each representing one of the 3 phases; each leg has 2 bidirectional chopper cells, one on the top and one at the bottom. Top cell is responsible for positive half of the AC output; bottom cell is responsible for negative half of the ac output.

F. Hardware Description

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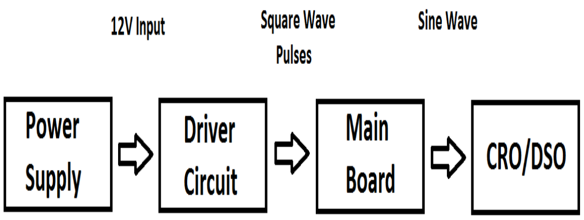

Fig 10 Block Diagram

E. DRIVER CIRCUIT

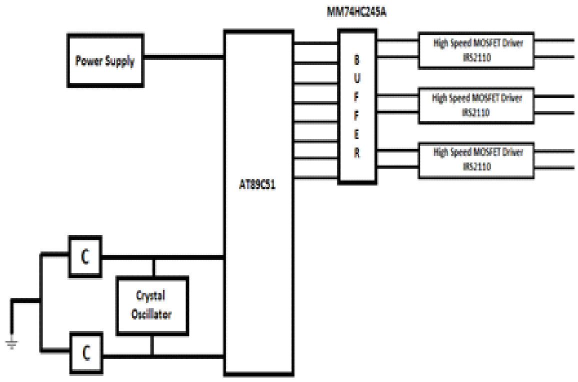

Fig 11 Driver Circuit Diagram

Atmel AT89c51 I.C:

The AT89C51 is a low-power, high-performance CMOS 8-bit microcomputer with 4K bytes of Flash programmable and erasable read only memory (PEROM). The device is manufactured using Atmel's high-density non-volatile memory technology and is compatible with the industry-standard MCS-51 instruction set and pin out. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional non-volatile memory programmer. By combining a versatile 8-bit CPU with Flash on a monolithic chip, the Atmel AT89C51 is a powerful microcomputer which provides a highly-flexible and cost-effective solution to many embedded control applications.

MM74HC245AN Buffer I.C:

The MM74HC245A 3-STATE bidirectional buffer utilizes advanced silicon-gate CMOS technology, and is intended for two-way asynchronous communication between data buses. It has high drive current outputs which enable high speed operation even when driving large bus capacitances. This circuit possesses the low power consumption and high noise immunity usually associated with CMOS circuitry, yet has speeds comparable to low power Schottky TTL circuits. This device has an active LOW enable input G and a direction control input, DIR. When DIR is HIGH, data flows from the A inputs to the B outputs. When DIR is LOW, data flows from the B inputs to the A outputs. The MM74HC245A transfers true data from one bus to the other. This device can drive up to 15 LS-TTL Loads, and does not have Schmitt trigger inputs. All inputs are protected from damage due to static discharge by diodes to VCC and ground.

IRS 2110 I.C:

The IRS2110/IRS2113 are high voltage, high speed power MOSFET and IGBT drivers with independent high side and low side referenced output channels. Proprietary HVIC and latch immune CMOS technologies enable ruggedized with standard monolithic construction. Logic inputs are compatible with standard CMOS or LSTTL output, down to 3.3V logic. The output drivers feature a high pulse current buffer stage designed for minimum driver cross conduction. Propagation delays are matched to simply use in high frequency applications. The floating channel can be used to driver an N channel power MOSFET or IGBT in the high side configuration which operates up to 500 V or 600 V.

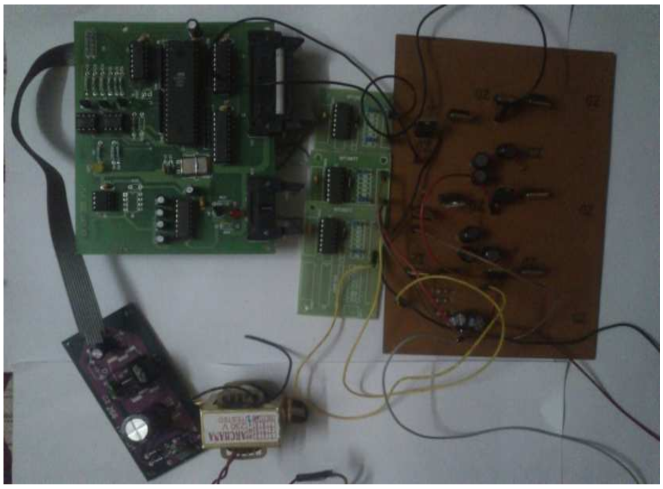

Fig 12 Snapshot of the entire Circuit

III. SIMULATION

A. INTRODUCTION

PSIM is a simulation package specifically designed for power electronics and motor control. With fast simulation and friendly user interface, PSIM provided a powerful simulation environment for power electronics, analog and digital control and motor drive system studies.

This simulation package covers three add-on modules viz.

- Motor Drive Module
- Digital Control Module
- Sim Coupler Module

The Motor Drive Module has built in machine models and mechanical load models for 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 analysis.

The Sim Coupler Module provides interface between PSIM and Matlab/SIMULINK for co-simulation.

The PSIM simulation package consists of three programs:

- Circuit Schematic Program PSIM
- PSIM simulator
- Waveform processing program SIMVIEW

It mainly deals with the following:

- Circuit structure
- Software/Hardware requirement
- Parameter specification format
- Power and control circuit components
- Specification of transient analysis and A.C. Analysis
- Use of schematic program
- SIMVIEW
- Error and warning messages

B. CIRCUIT STRUCTURE

The circuit is represented in PSIM in four blocks:

1) Power Circuit

2) Control circuit

3) Sensors

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4) Switch controllers

The Power circuit consists of switching devices, RLC branches, transformers, and coupled inductors.

The Control circuit is represented in block diagram, This also contains components in s domain and z domain, logic components (such as logic gates and flip flops), and nonlinear components (such as multipliers and dividers) are used in the control circuit.

Gating signals are then generated from the control circuit and sent back to the power circuit through switch controllers to control switches.

C. INSTALLING THE PROGRAM

- A quick installation guide is provided in the flier PSIM-quick guide and on the CD_ROM.
- Some of the files in the PSIM directory are as follows:

Psim.dll describes PSIM simulator

Psim.exe describes PSIM circuit schematic editor

Simview.exe describes Wave form processor SIMVIEW

Psim.lib, psimimage.lib PSIM libraries

*.hlp Help files

*.sch Sample schematic circuit files

File extensions used in PSIM are:

*.sch PSIM schematic file (binary)

*.cct PSIM netlist file (text)

*.txt PSIM simulation output file (text)

*.fra PSIM ac analysis file (text)

*.smv SIMVIEW wave form file (binary)

SIMULATING A CIRCUIT

- To simulate, for instance, the sample one-quadrant chopper circuit “chop.sch”:
- Start PSIM. Choose OPEN from the file menu to load the file “chop.sch”
- From the SIMULATE menu, choose Run PSIM to start the simulation. The simulation results will be saved to file “chop.txt”. Any warning messages occurred in the simulation will be saved to file “message.doc”
- If the option AUTO-RUN SIMVIEW is not selected in the options menu, from the simulate menu, choose Run SIMVIEW to start SIMVIEW. If the Option Auto run SIMVIEW is selected, SIMVIEW is launched automatically. In SIMVIEW the curves for display are selected.

RESULTS

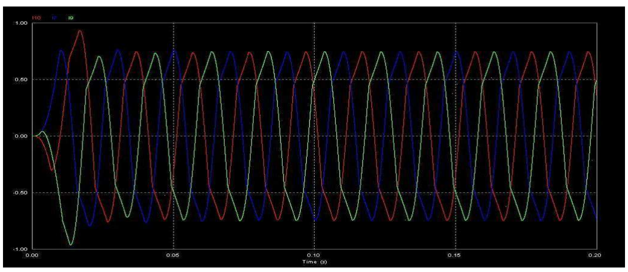

Fig 13 Output Current

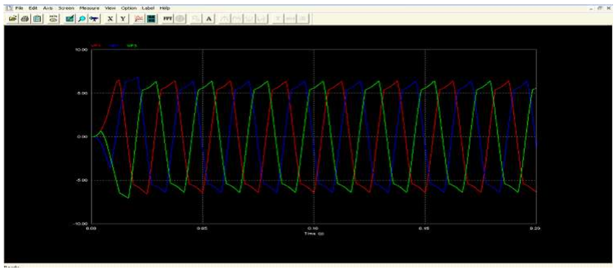

Fig 14 Output Voltage

V. CONCLUSION

It is observed that in multilevel inverter using bidirectional chopper cells sinusoidal output is obtained instead of stepped a output as in case of other types of inverters.

ACKNOWLEDGMENT

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Asawari Dudwadkar, Assistant Professor, Department of Electronics, VESIT, Mumbai Research Scholar, JJTU, Rajasthan Mrs. Asawari Dudwadkar received the Bachelor’s Degree in Electronics Engineering and Master’s Degree in Electronics & Telecommunication from University of Mumbai, India in 1996 and 2007 respectively. She is currently working toward the Ph.D. degree in the Department of Electronics and Communication engineering from JJT University, Rajasthan. Her main research interests include Induction Heating Applications, Inverter modeling and digital control design strategies. She has many publications to her name, some of which are:-Mrs. Asawari Dudwadkar & Dr. Y.S Rao,―Induction Heating: An overview of Digital control Based Systems‖ at National conference at LT COE, Mumbai Sep 2011 Mrs. Asawari Dudwadkar & Dr. Y.S Rao (vice principal SPIT, Mumbai) Published paper in INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH, ISSN No: 2277 8179 on “ Optimisation of Induction Heating system in Simulink..” for July 2013 issue. Mrs. Asawari Dudwadkar & Dr. Y.S Rao, ‖ Contributions to Optimization of Induction Heating System ―.International Journal of Scientific and Modern Engineering (IJISME), Aug2013 , ISSN2319-6386

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