DESIGN AND IMPLEMENTATION OF AN IMPROVED QUASI Z SOURCE INVERTER FOR 3 PHASE INDUCTION MOTOR DRIVE SYSTEMS

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ABSTRACT

In this paper a new induction motor drive is designed, which provides a single phase to three phase conversion as well as acts as motor drive. Using effective 4 switch structure and a quasi z-source inverter, voltage boost even greater than the supply voltage can be achieved. The use of input capacitor in the traditional Z source inverters is not present in the proposed topology and also the shoot through duty ratio effectively establishes soft switching of the semiconductor devices. The proposed circuit could also be operated in the bi-directional mode by replacing the input diode with a bi-directional switch. Since 4 switches instead of the traditional 6 switches are used, the costs of the circuit along with switching losses are reduced and the control method for this circuit is much simpler than the traditional 6 pulse circuit.

***Keywords*: Induction Motor Drives , Quazi Z- Source Inverter, Shoot Through Duty Ratio.**

I INTRODUCTION

Three-phase induction motors have been the main consideration in industries more than single phase induction motors due to certain parameters such as; efficiency, torque ripples and power factor. In places like rural areas to be use of rolling mills, machine tools and in low power industrial application for robotics, where by a three-phase utility may not be available, high performance converters must be used to run three-phase induction motor. Low losses and cost-effectiveness of these converters are very important. [1]

II PROPOSED QUASI Z-SOURCE INVERTER

To solve the aforesaid drawbacks in traditional Z-source inverter, Quasi Z-source inverter(qZSI) topology is used. The operation principle and merits of the proposed topology is explained in detail, verified using hardware experiment model and MATLAB simulation is compared with traditional Z-source inverter topology. [1]-[3]

Quasi Z-Source inverters, have been developed which feature several improvements and minimal disadvantages when compared to the traditional ZSIs. The novel qZSI topologies shown in Fig. 2.1a and 2.1 b. in a manner consistent with the voltage fed ZSI, can be made bidirectional by replacing the diode, D1, with a bidirectional conducting switch.

Also due to the input inductor, L1, the qZSI does not require input capacitance, unlike the ZSI and the qZSI shown in figure 2.1.b.The qZSI topologies also feature a common dc rail between the source and inverter, unlike the traditional ZSI circuits. Furthermore, these qZSI circuits have no disadvantages when compared to the traditional ZSI topologies. These qZSI topologies therefore can be used in any application in which the ZSI would traditionally be used. [4]

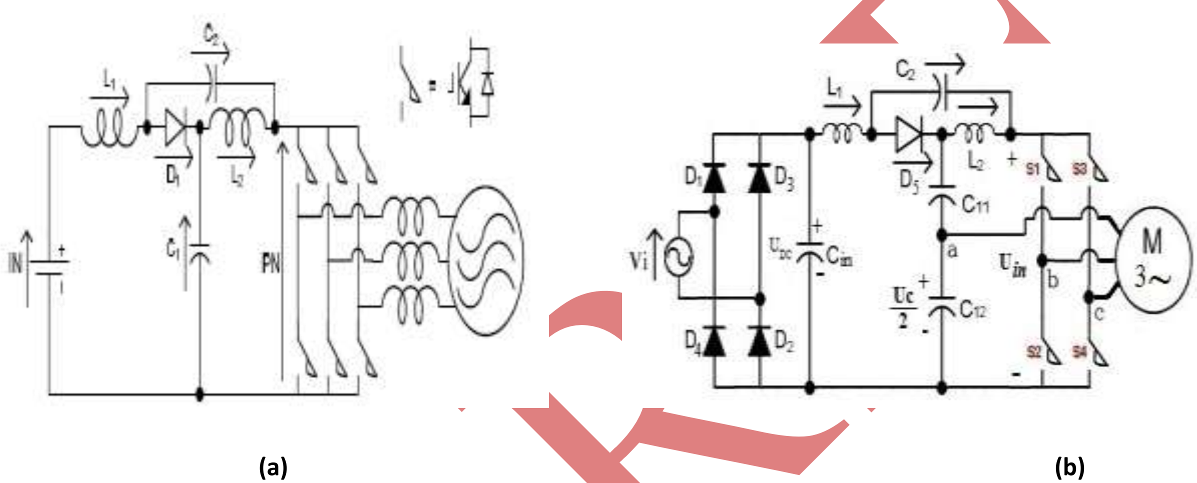


Fig 2.1. Equivalent Circuit Diagram QUASI Z-source inverter for a) open loop. b) Closed loop.

III BLOCK DIAGRAM

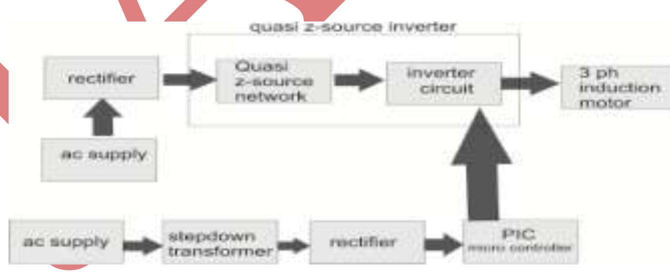


Fig 3.1 Block Diagram of Quasi Z-Source IM Motor Drive

The block diagram of improved Z-source inverter based on the hardware kit model is as shown in the figure 3.1. It consists of AC supply input voltage of 220v-240v. A step down transformer which is used to step down or decrease the input AC supply to 12v. Bridge rectifier is used to convert AC supply to DC supply and also regulate DC supply to 5v. PIC microcontroller is used to generate Pulse Width Modulation (PWM) wave. Driver circuit is used to turn ON or turn OFF power transistor or MOSFET by giving proper gate signals to respective switches on three legs of inverter circuit. Another DC supply or DC link is fed to improved Z-source inverter circuit which will perform buck or boost operation. The driver circuit signal and signal from Z-source circuit is given to three phase inverter circuit which converts DC supply to AC supply and then fed to three phase loads.

IV OPERATION PRINCIPLE AND COMPARISON WITH PREVIOUS TOPOLOGY

The equivalent circuit of the improved Z-source inverter is shown in 4.1

Assuming that

$$L_1 = L_2 = L,\ C_1 = C_2 = C \qquad \text{....(1)}$$

When in the shoot-through state, the inverter side is shorted, as shown in we can get

$$V_L = V_o + V_C \qquad \text{....(2)}$$

When in the non-shoot-through state , the inverter side can be simplified by an equivalent current source (the current value is zero when in null state), as shown in . The following equation can be derived in this state:

$$V_L = -V \qquad \text{....(3)}$$

The shoot-through duty ratio is D_o and the average value of VL over one switching period is zero, so we can get

$$V_C = D_o \qquad \text{....(4)}$$

From this derivation, we can see that in the improved topology, when the shoot-through duty ratio Do is zero, the Z-source capacitor voltage V_c is equal to zero. When the converter is in the soft-starting state, V_c is zero naturally, so if we control the Do increase from zero gradually, V_c can also increase from zero gradually and soft start can be achieved. But this is not the case in traditional topology.

The peak dc-link voltage across the inverter phase legs and peak output phase voltage can be expressed as

$$V_{dc} = V_{C1} + V_{C2} = V_{C3} + V_{C4} = BV_{in} \qquad \text{....(5)}$$

and

$$V_{ac} = M\,\frac{V_{dc}}{2} \qquad \text{....(6)}$$

where $B = \dfrac{1}{1-2D}$ is the boost factor determined by D and M is the modulation ratio. As can be seen from, the output voltage is boosted by a factor B ($B \geq 1$), which is the same as the traditional topology. All the power switches and diodes used in improved and traditional topologies are exactly the same. A comparison is given on the Z-source capacitor, Z-source inductor, and input current ripple.

4.1 Z-Source Capacitor Voltage Stress and Voltage Ripple [4]-[5]

The peak dc-link voltage of the two topologies is exactly the same, as can be seen from one can see that the Z-source capacitor voltage decreases by V_0while maintaining the same voltage boost.

The comparison of V_c/V_oin the two topologies is shown in figure 4.2.As we already know, the Z-source inverter is suitable in applications where the input voltage varies in a wide range, such as the battery, fuel cell and photovoltaic power conditioning systems.

Consider, for example, the input voltage is 150–300V. In traditional topology, the capacitor voltage stress is decided by the maximum input voltage, so VC is no less than 300V. However, in the improved topology, VC is decided by the minimum input voltage to achieve the maximum voltage boost, the capacitor voltage stress is only 75V to get the required voltage boost under 150V input voltage; thus, low-voltage capacitors can be used. During shoot-through time, the condition for previous and improved Z-source inverters is the same, the Z-source inductor current discharges the capacitors; therefore, the voltage ripple across the capacitors in both inverters can be expressed as

$$V_c = \frac{I_{L(avg)} T_s}{C} \qquad \text{....(7)}$$

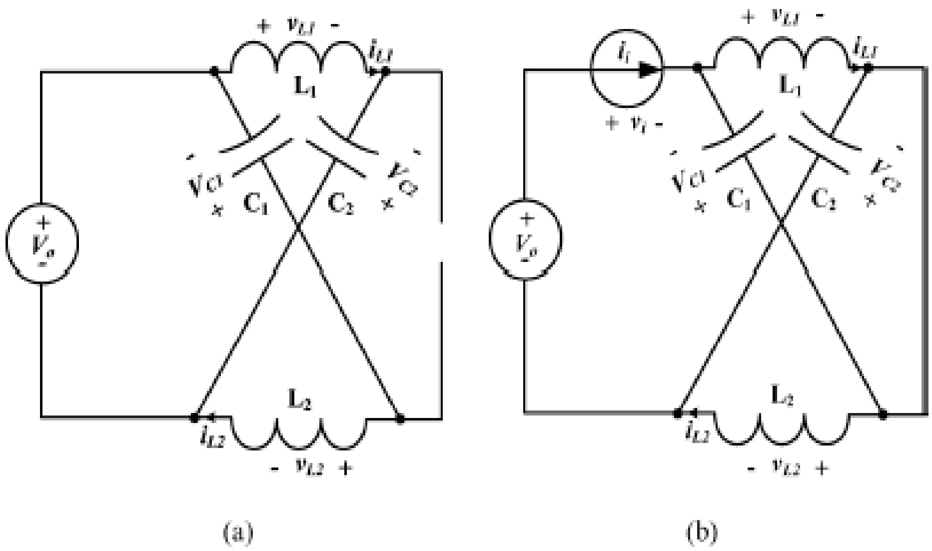


Fig 4.1 Equivalent circuit of Quasi Z-source inverter (a) shoot-through mode(b) non-shoot-through mode

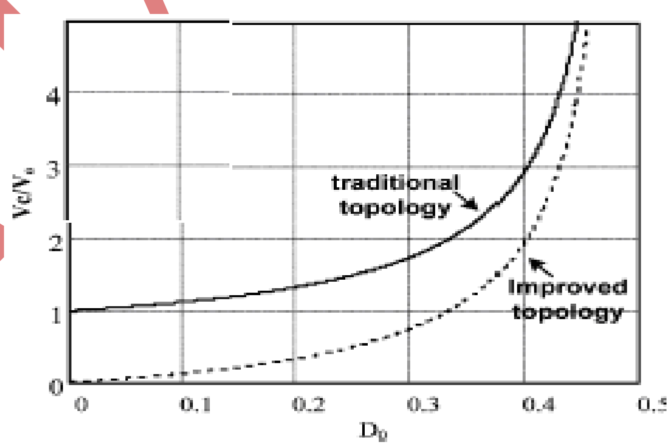


Fig 4.2 V_c/V_o versus D_o of two topologies

4.2 Z-Source Inductor Current Ripple

The average Z-source inductor current equals the average input current; therefore, the average Z-source inductor current in both topologies is the same. For improved topology during the non-shoot-through state, as shown in fig 4.1 (b) the Z-source inductor current decreases and the current ripple can be expressed as

$$I_L = P/V_{dc} \tag{8}$$

The input current for a Z-source inverter is different under different controls, and the following analysis will take the simple boost control as an example. For traditional Z-source inverters, the current to the inverter bridge is i_i, so the input current can be expressed as

$$i_{in} = 2i_L - i_i \tag{9}$$

In shoot-through state, the input current is zero; in traditional zero-state, ii is zero, so $i_{in}$is $2i_L$.In active states 1 and 2, i_i is i1 and i2 , respectively, so $i_{in}$is $2i_L - i_1$ and $2i_L - i_2$, respectively, and the average input current is IL . Ignoring the inductor current ripple, i_L can be represented as I_L.

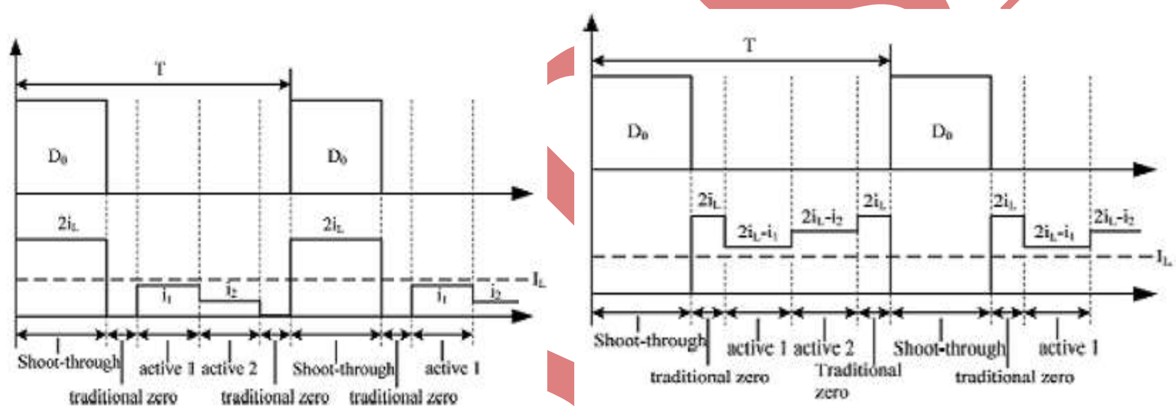


Fig 4.3 Input current for a.) traditional z-source inverter b.)Quasi z-source inverter

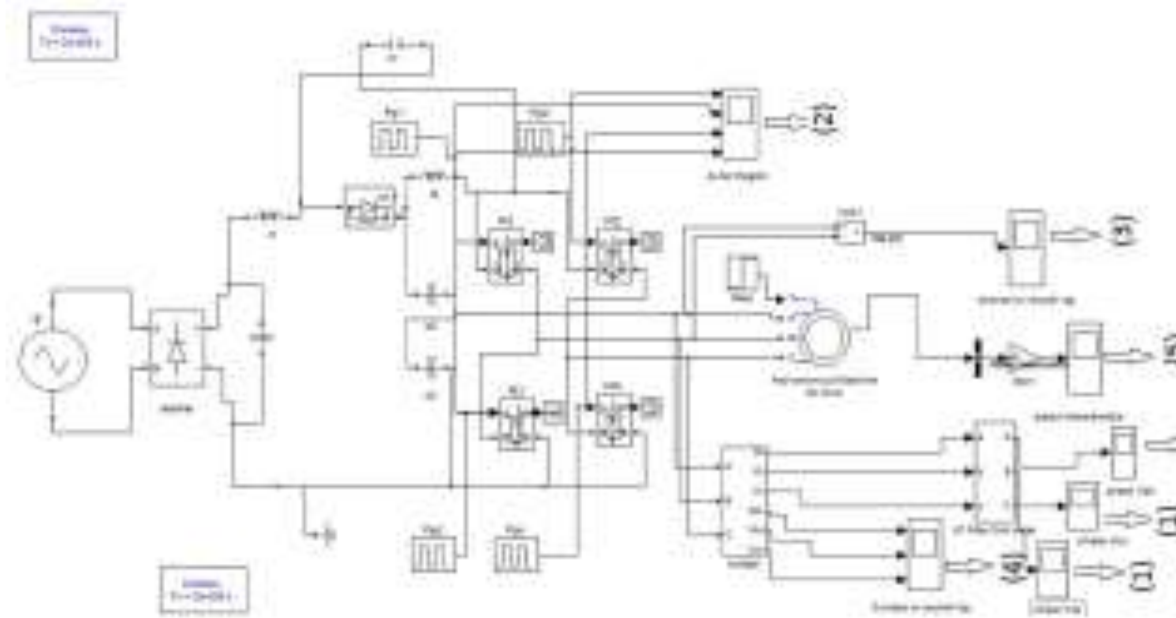
The input current for traditional topology is shown in detail in 4.3.a). The deviation of input current and its average value can be expressed as For improved topology, the input current is actually the current fed to the inverter bridge, so in shoot-through state, the input current is $2I_L$; in traditional zero state, the input current is zero; in active states 1 and 2, the input current is i1 and i2 , respectively, and the averaged input current is IL . The input current for improved topology is shown in detail in 4.3.b). The deviation of input current and its average value can be expressed as

$$\Delta i_{in} = |i_{in} - I_L| = |i_i - I_L| \tag{10}$$

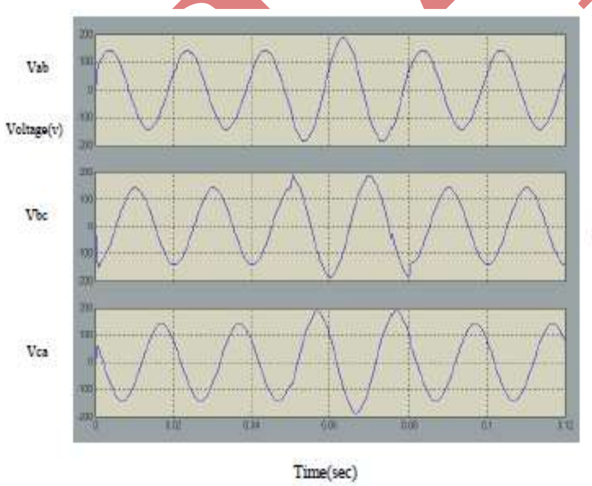
V SIMULATION AND RESULTS

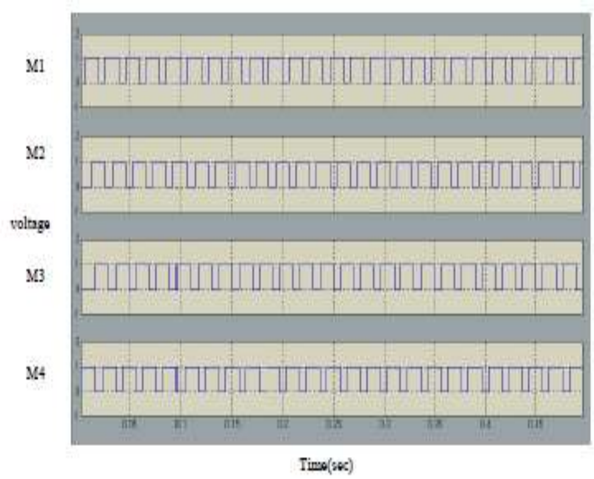
5.1 Open Loop

To confirm the above analysis of impedance source inverter simulation is performed using MATLAB. Fig 5.1 shows the open loop main circuit configuration of impedance source inverter for photovoltaic applications. The impedance network parameters are L1=L2=1000mH and C1=C2=C=2200mF, switching frequency: 10 kHz. The purpose of the system is to boost the input voltage and rotor speed characteristics is shown in fig 5.1.d

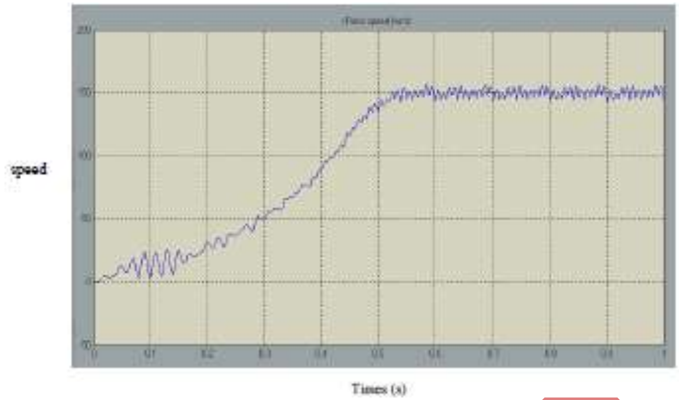


(a)





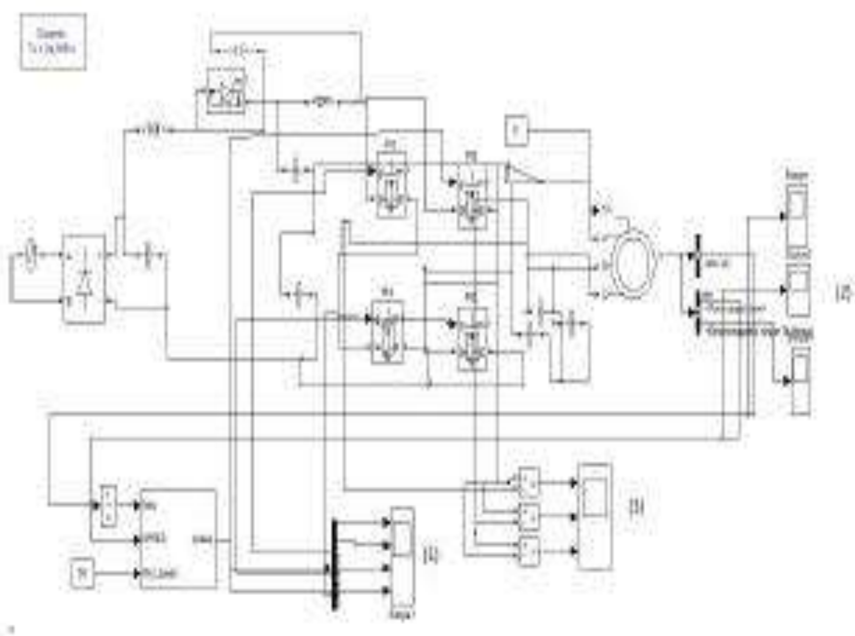
(b) (c)



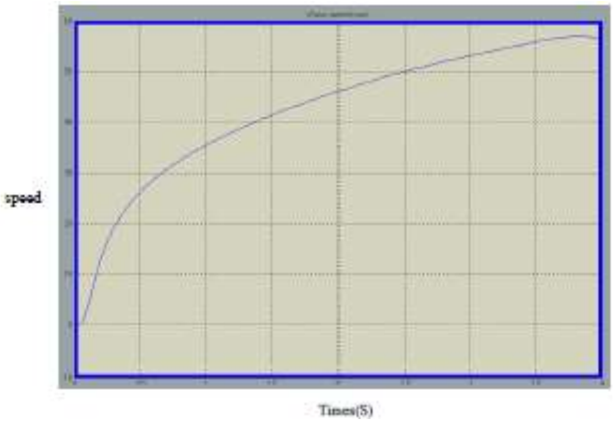
(d)

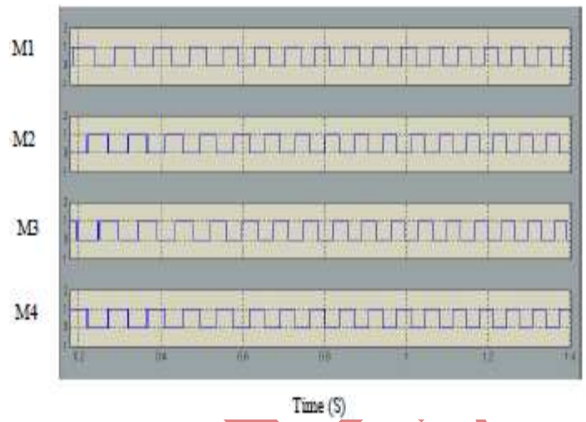
Fig 5.1 Simulation Output a) Open Loop Quazi Z-Source Inverter b) Three phase supply Voltage c) PWM firing scheme d) Rotor Speed.

5.2 Closed Loop



(a)





(b) **(c)**

Fig 5.2 a) Simulation Block of Closed Loop qZSI. b) Simulation Output of PWM firing scheme and c) Controlled Rotor Speed

The main circuit configuration of impedance source inverter is shown in figure 5.2. The impedance network parameters are L1=L2=1000 microHenry and C1=C2=C= 2200microFarad, switching frequency: 10 kHz.

The purpose of the system is to boost the input voltage. The simulation model consists of two parts. One is main system and the other one is subsystem. Main system is used to produce PWM wave by comparing sine wave and oscillatory wave and is given to the subsystem.

PI controller is used for the closed loop control of the quasi Z-source inverter reference speed is given to the controller and the actual speed is given using the speed sensing unit. The pulse triggers are generated from the above controller using the pi controller. The output pulses are given to the four MOSFET switches. The rotor speed relationship with time is shown in the figure 5.4

VI HARDWARE CIRCUIT BOARD

The Hardware kit for Improved Z-source Inverter is as shown in the above figure 6.1. The Hardware Circuit Board consists of following main parts :230/12V Step DownTransformer ,Rectifier circuit, Controller circuit, Driver circuit, Z-source Impedance circuit

The 230/12v step down transform is used to step down the input ac supply voltage of 230V given in the primary coil is step down to 12v ac supply. The output voltage is taken from secondary coil. In this transformer the primary coil winding is greater than secondary coil winding. These coils are wound over the laminated iron core. The rectifier circuit is used to convert 12 ac supply to 12v dc supply. It also consists of a capacitor, four diodes, voltage regulator, a LED bulb. Voltage regulator is used to convert 12v dc supply to 5v constant dc supply and it is as shown the figure 6.1.

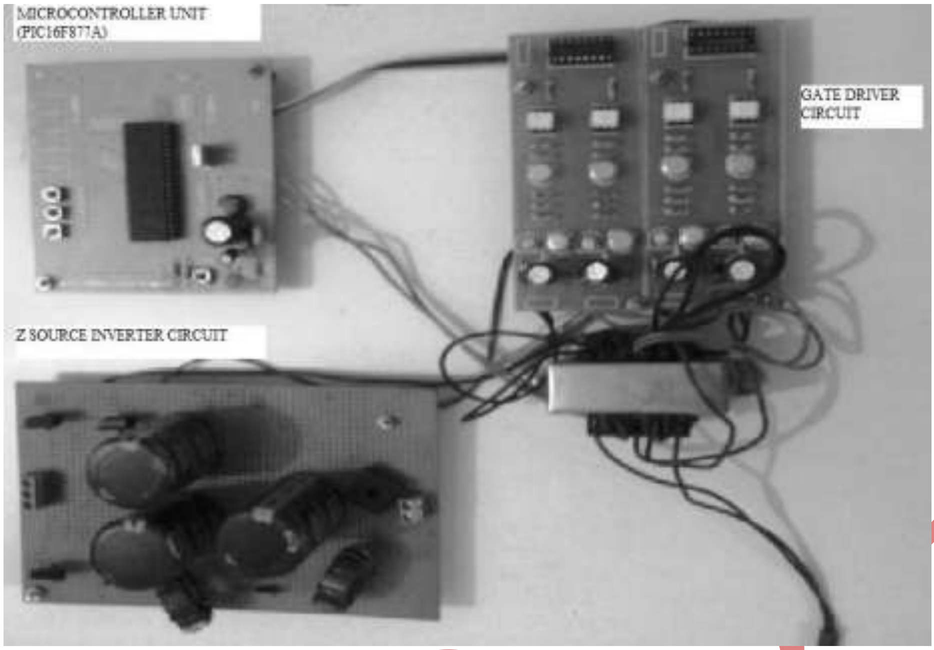


Fig.6.1 Hardware Circuit Board

The LED bulb is used to give indication whether the rectifier circuit is working or not. A voltage regulator is used for converting pulsating dc to fixed dc. A PIC microcontroller shown in fig 6.1.is used for the generation of the trigger pulse. This is achieved using the sinusoidal pulse width modulation from which the output is given to the driver circuit for amplification and optical isolation. In electronics, driver is an electrical circuit or other electronic component used to control another circuit or other component, such as a power MOSFET or high-power transistor. The term is used, for example, for a specialized computer chip that controls the high-power transistors in DC-to-DC voltage converters. The Driver circuit diagram is as shown in the Fig 6.5.In this three driver circuit are used for switching operation of six MOSFET. Each driver circuit controls switching operation for two MOSFET. For this purpose IR2110 IC is used. The IR2110 is a high voltage, high speed power MOSFET driver with independent high and low side referenced output channels. The circuit board diagram of z-source is as shown in the figure 6.1. It consists of two inductors of value 1000microHenry and two capacitors of value 2200 micro Farad.

VII CONCLUSION

A 220v to 50 volt transformer is used in the input side. A tachometer is used for check in the speed of the motor. A half hp squirrel cage induction motor is used for verification of the result. A multi meter is used for checking the output voltage. The input voltage is found to be 50V AC while the output is 3 phase 58V. This is sufficient to drive a 3 phase induction motor with a speed of 900 rpm. The future scope of this paper can be extended for the use in rural areas where 3 phase supply is in high demand. Closed loop of this paper is simulated which can be implemented in places where constant speed is required. It can also be used with DC supply by directly connecting it to the z-source omitting the rectifier circuit

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