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11. Advanced Variable Frequency Drive to Drive Three Phase Induction Motor

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Abstract

The core of this paper describes an advanced three phase inverter topology known as the Z-Source Inverter to convert single phase power supply to a three phase power supply. Inverter is controlled through microcontroller 89C52 and use it to drive 3-phase induction Motor. Unique buck-boost feature are obtained through Z-Root inverter as it employs second order filter network at front final stage .Z-Source inverter can be controlled by an outmoded Pulse Width Modulation (PWM) method. For Z-Source inverter control, the improved and extreme constant boost pulse width modulation method is developed. The pulse width modulation pulses generation and control of Z-Source inverter is processed through microcontroller 89C52. The complete hardware is projected to drive the three phase induction motor. Hardware design of advance variable frequency drive includes power supply, Z-Source network, driver circuit, main inverter bridge, the design of control circuit etc. Advance variable frequency drive is implemented and tested to verify the Z-Source inverter concept.

Keywords: *driver; maximum constant boost; microcontroller; PWM; voltage boost; Z-Source Inverter.*

1. Introduction

In most of the industries old-style voltage and current source inverters are used to drive three phase induction motor systems. For effective power operation various new pulse width modulation methods are industrialized and still developing. Impedance-source inverter also referred as Z-Source Inverter is an advanced pulse width modulation inverter topology used in advance variable frequency drive. Z-Source Inverter is more advantageous over old-fashioned inverters with high efficiency, improved power factor and THD, EMI immunity [1] and so on. Nowadays, in power converter applications pulse width modulation control method is commonly used. Analog as well as digital circuit both can be used to generate pulse width modulation signals. Analog circuit for pulse width modulation generation involves large number of isolated circuits such as triangular, carrier and sine wave generator circuit; adder circuits ,comparator, and phase shifters etc. Each of these circuit is designed by joining many isolated components together such as transistors, diodes, resistors, gate drivers, inductors, capacitors, and so on. In addition, accurately designed phase shifter and other circuits are involved in analog method of three phase pulse width modulation generation. Likewise, the output of analog circuit may get affected by environmental conditions, noise, changes in the voltages and current in the circuit and so on.

Thus analog method is critical and escalates difficulty and cost of the circuit. [2] Only microcontroller with minimum configuration is required for Digital method of pulse width modulation generation. With the dawn in the technology now many microcontrollers has in built feature of pulse width modulation generation. Pulse width modulation generation digitally necessitate only knowledge of internal architecture of controller and good programming skill [2]. In this research microcontroller 89C52 is used because of three phase pulse width generation

- Inverter control.

- It reduces the cost of system

2. Block Diagram and Working

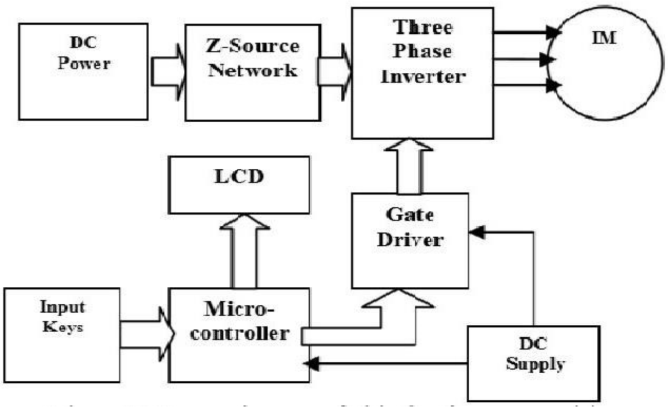

Fig.1.1.Block Diagram [8]

DC voltage source may be a fuel-cell stack, diode rectifier, battery, or capacitor. An impedance network termed as Z-Source is coupled with an inverter main circuit and input power source. In impedance network circuit two inductors and two capacitors are connected in such a way to smoothen dc link voltage and current and forms second order filter. Three phase inverter circuit consists of six switching devices (MOSFET's/ IGBTs) linked in three legs, converts input dc voltage in to consistent three phase AC voltage. Microcontroller 89C52 and gate driver circuit, control switching time of IGBTs/MOSFETs in a proper sequence in a particular time used in the main inverter circuit. Pulse width modulation signals are applied to the gate terminals of MOSFET's/ IGBTs through gate driver circuit. User can easily interface with the system by interfacing LCD and Key-pad with microcontroller. The key-pad is interfaced to microcontroller port pins to set input voltage, shoot-through time control, and to interrupt microcontroller to start and stop sending pulse width modulation signal at port pins.

3. Hardware Overview

The complete hardware circuits (as shown in fig.1) and description is presented in this section. The complete hardware is aimed to drive three phase induction motor from a single phase supply. It involves Z-Source network [2], gate driver circuit, low and high power DC supply, the design of control circuit, and the inverter circuit, selection of switches etc.

Fig.3 Hardware circuit

4. DC Power Supply

DC power supply is designed to control the DC output at 5V and 12V through regulator ICs 7805 and 7812 respectively. To drive MOSFET/IGBT gate driver circuit we used 12 V power supply while 5V power supply is used for the operation of the microcontroller board.

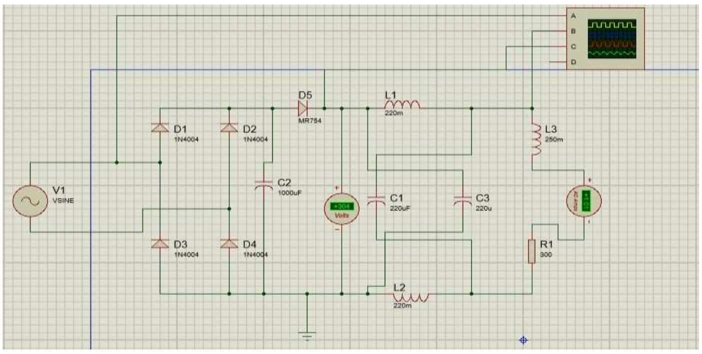

Fig.4 (a) DC Supply Simulation Diagram

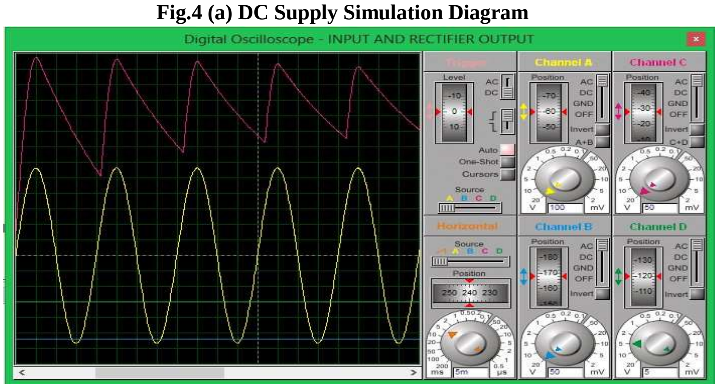

Fig. 4 (b) Simulation Output

5.1 Microcontroller Control Circuit

For pulse width modulation era microcontroller 89C52 is utilized. The control circuit outline is appeared in the accompanying fig.5.1 (a) drawn utilizing Proteus programming. This circuit incorporates LCD interface at port0 of microcontroller, five push catch switches and one drove interfaced to port3 pins, gate way driver circuit not indicated interfaced to PWM yield port2 pins and microcontroller least circuit. LCD showcase is utilized to show readings of RPM and gives UI. It additionally shows hypothetical estimations of yield voltage for given info voltage. Four catches are accommodated uncommon purposes, to hinder microcontroller, increase, decrement shoot-through time and information voltage values and to change the method of operation. Four sorts of edge adjusted PWM waveforms are created utilizing microcontroller. For this four methods of operation are given. One is customary method of operation when engine velocity will be 25%, at second mode Motor rate will be half at third mode it will be 75 % and at help mode it would be approx. 100 %. In conventional method of operation customary PWM is produced, while in help method of operation some a player in conventional zero state is changed over into shoot-through state. The six PWM signs are send at port P2 pins P2.0 through P2.5. The simulations of control circuit are performed utilizing Proteus programming..

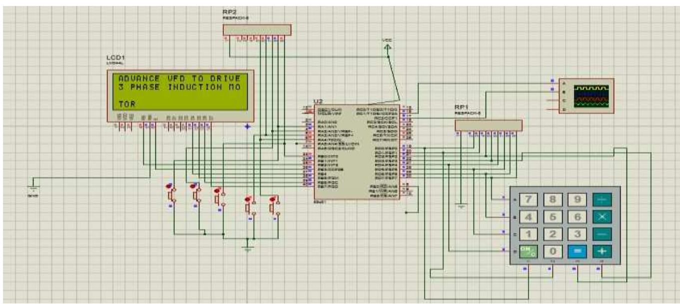

Fig.5.1 (a) Microcontroller interface Simulation diagrams

5.2 Gate Drive Circuit and Simulations

Gate drive circuit for MOSFETs / IGBTs usually covers input opto-isolation, input buffer amplifier and totem pole arrangement of gate driving transistor with high current sink and source capability [1].

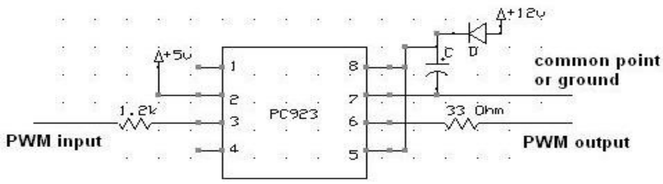

Fig. 5.2 (a) Gate Driver Circuit [1]

There are number of gate driver ICs accessible in the business sector that are intended to drive power transistors, for example, MOSFETs, IGBT. In this venture the door driver IC PC923 is chosen from SHARP Company. It has taking after remarkable elements, for example,

- Worked in direct drive circuit for MOS-FET/IGBT drive (IO1P, IO2P:0.4A).
- Opto-confinement, High separation voltage VISO = 5000 Vrms amongst info and yield.
- Rapid reaction (tPLH, tPHL: max 0.5us).
- Wide operating supply voltage range (Vcc: 15 to 30V, Ta= -10 to 60°C).
- High noise reduction type (CML = MIN 1500V/ µs) (CML=MIN. 1500V/µs).

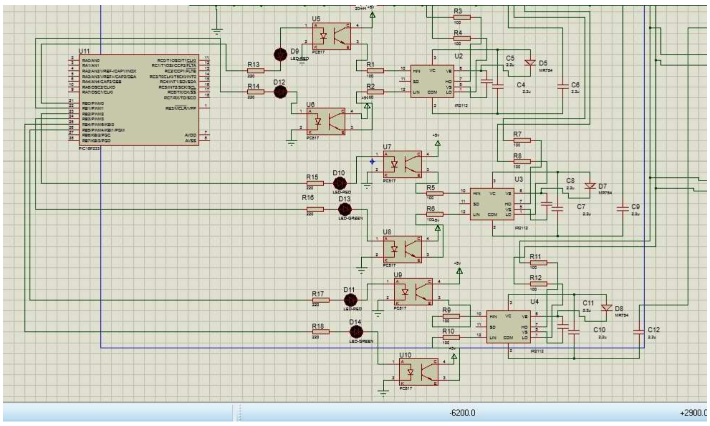

Fig. 5.2 (b) Gate Driver Simulation

Fig. 5.2 (b) Gate Driver Simulation Fig. 5.1 (a) and Fig. 5.2 show typical gate drive circuit using PC923. +5V supply is connected to pivot no.2 (anode) and pin no.3 (cathode) is connected to port 2 pin through a current qualifying resistance 1 .2k.

6.1 DC Source, Z-Source Inverter Circuit and Simulations

The three phase inverter circuit diagram is shown in the fig.6.1 (a) .The comment DC supply is obtained from AC main through using single phase rectifier and dc capacitor of 1000uf.The DC emf is then linked to the Z-Source meshing through reverse blocking ultra-fasting diode MUR460. The turnout dc link voltage across capacitor is then fed Reserve to the three phase inverter. The three phase inverter circuit contains six MOSFETs IRF840 with inbuilt anti-parallel diode. The three phase inverter circuit produces the three phase output ac voltage that is then applied to three phase ac load. The output ac load is a three phase induction motor.

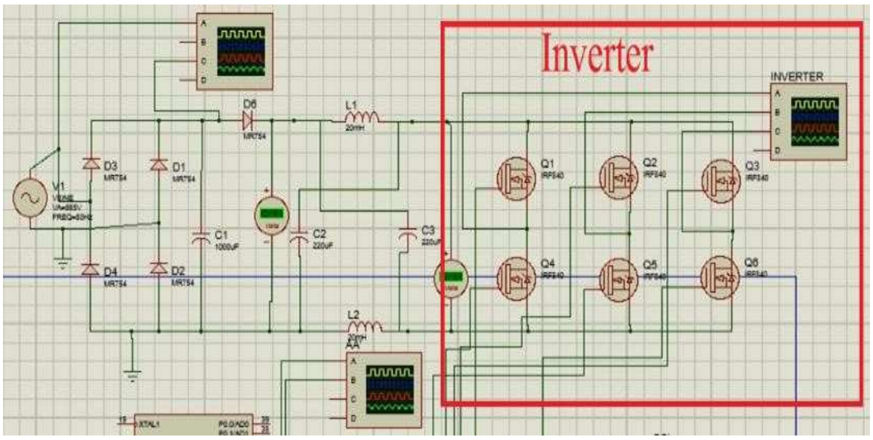

Fig. **6.1 (a) Inverter Simulation**

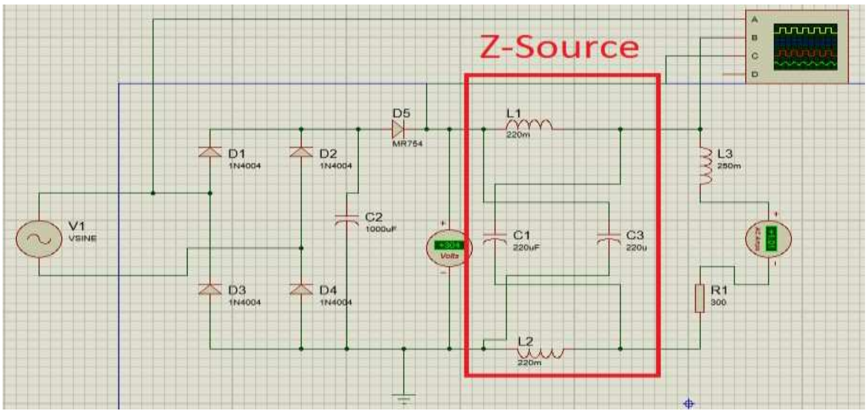

Fig.6.1 (b) Z-source Simulation

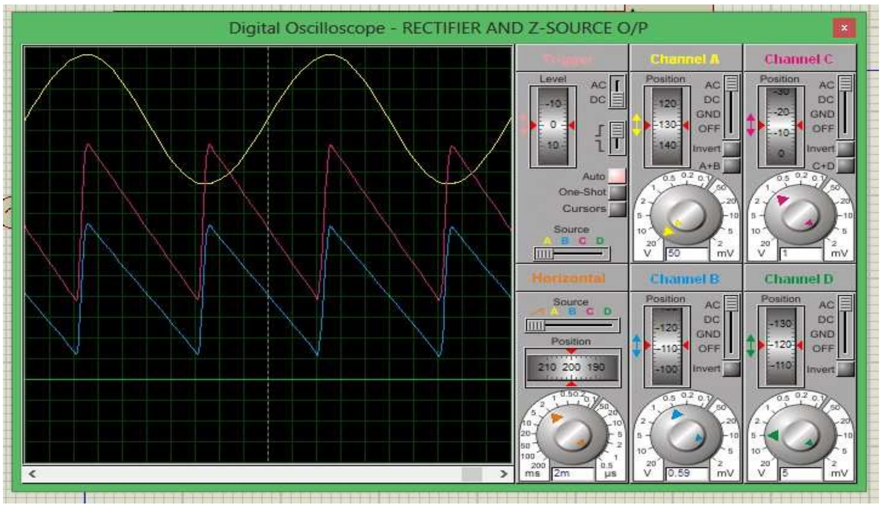

Fig. 6.1(c) Z-Source Simulation Output

6.2 PWM Pattern, generation and Simulation

Table 1.1 PWM Pattern

State	C’	B’	A’	C	B	A	PWM Code (hexa)
State 1	1	0	1	0	1	0	0X2A
State 2	1	0	0	0	1	1	0X23
State 3	0	0	1	1	1	0	0X0E
State 4	0	1	1	1	0	0	0X1C
State 5	0	1	0	1	0	1	0X15
State 6	1	1	0	0	0	1	0X31
ZERO 1	1	1	1	0	0	0	0X38
ZERO 2	0	0	0	1	1	1	0X07
ST	0	0	0	0	0	0	0X00

The three phase waveform are accessed by using three different pointers at PWM pulse width data values corresponding to table. These pointers’ in timers are adjusted so as to point to pulse breadth values that are unity 200 degree form shift apart in time from other. Fc describes number of pulse width inflection heartbeat per cycle. Where fc is known as carrier relative frequency and fm is modulating signal frequency [1]. In rescript to obtain synchronous three phase pulse width intonation waveforms Resultant of fc/fm must be divisible by three.

For example if fc = 3750Hz and fm = 50Hz then number of pulses per cycle is equal to 75. This number is divisible by three 75/3 = 25. So while accessing the pulse width values first pointer points to zeroth location, second pointer should be at 25th location of array and at the same time third pointer should point to 50th location of array.

The following steps demonstrate the algorithm to obtain the three phase pulse width modulation waveforms using microcontroller 89C52. ·

Use look up table to access the three phase synchronous PWM pulse width data values by using three different pointers. ·

- Send the desired PWM code pattern at microcontroller's pins.
- Initially set the timer value with lowest pulse width value Start the timer and wait until timer flag set.
- Send the next desired pulse width modulation code pattern at microcontroller pins.
- Move the next higher pulse width value at timer value. ·
- Start the timer and wait for timer flag to set. Move the next desired pulse width modulation code pattern at microcontroller pins.
- Set again the timer value with next higher pulse width value. Start the timer and wait for timer flag to set. □ Increment in pointer by one and loop back step 1.

The dead time can be given through system at essential time while sending PWM code design. The beat width qualities are gotten to amid zero state time just with the goal that dynamic state timing would not be bothered.

For acquiring PWM pulse width information for single cycle physically requires huge number of figuring's and a ton of time. To dodge this computation part totally and to get beat width values straightforwardly for any given tweak list and transporter recurrence a C code is composed and utilized. Three stage pulse width modulation waveforms are appeared in the figer. 6.2 (b) This is Edge adjusted three stage PWM to regard to the third harmonics infused three stage major parts with fc 2400Hz and fm = 50Hz. The simulation is performed utilizing Proteus programming.

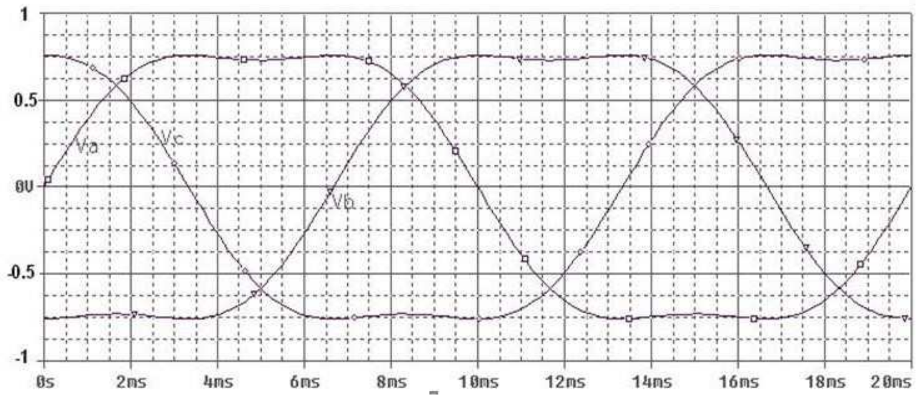

Fig. 6.2 (a) Third harmonic injected sinusoidal signal [1]

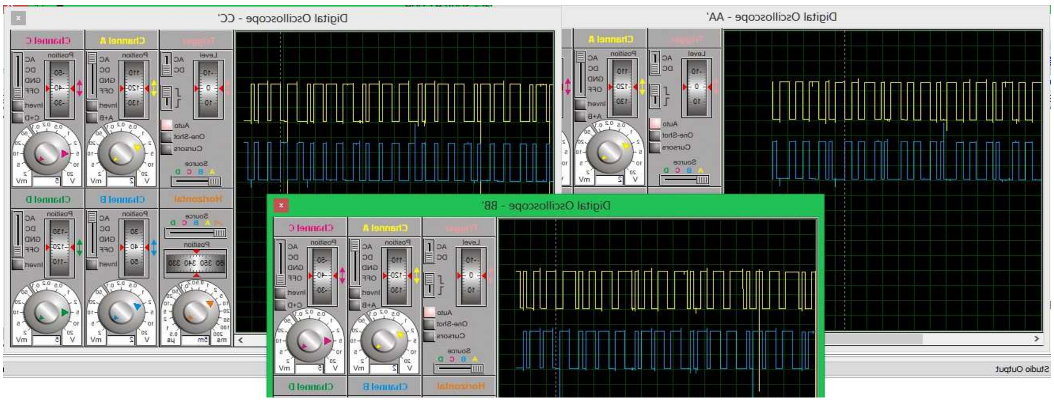

Fig.6.2 (b) Three Phase PWM Waveforms

Three Phase PWM Waveforms waveforms A,B , and C are gate activating pulses for upper three switches while A', B' and C' These pulse width modulation waveforms can be stated as third harmonic injected shoot-through PWM waveforms. The shoot-through state is applied during the traditional zero states only

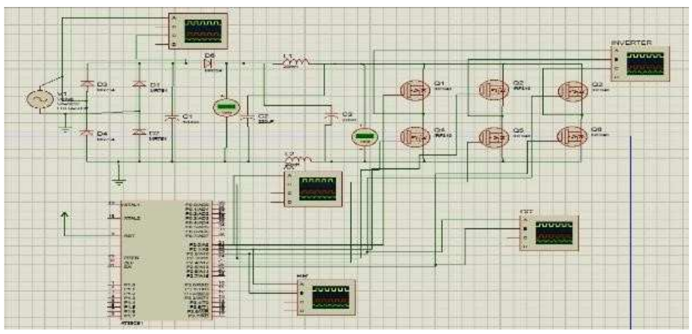

Fig.6.2 (c) Simulation Diagram

7. Hardware Results

Advance Variable frequency drive is executed as per design. The detailed hardware structure and its performance is analyzed in this sections. Test is carried out for motor load linked across the output ac lines. The control circuit, low power dc supply and driver circuit is embedded on separate cards. The Z-Source impedance network and high voltage DC supply for inverter circuit are implanted on the same board as shown. The main inverter bridge circuit and lamp load are implemented on separate boards

7.1. Output Readings of Rectifier:

Input supply 220v RMS
V-peak 282.8 v, V-dc 311 v

7.2. Dc link voltage of capacitor

Approx. voltage 371 v, V-ac 87.1 v (ac component of dc output)
FF = 1.11, Ripple factor = 48%

7.3. In-put Readings of Inverter

Vin = V-dc = 311 V V phase-phase = 207 v V line-line = 358v
Load Current = 1.03 A

7.4. Output Readings of Inverter

V= 308-415 V R.P.M= 1725 I= 2 A Power = .37 KW

8. Conclusion

Advance Variable frequency drive can produce any output voltage greater than the dc input voltage by controlling the shoot-through duty ratio, which is not possible for the old-style ASD systems. In this work, defined the hardware implementation, analyzed the circuit, and validated its concept and dominance practically. Maximum constant boost with third harmonic injection pulse width modulation control method increases output voltage boost while lessening voltage strains across MOSFETs/IGBTs. It allows over-modulation where modulation index can be varied from 0.57 to 1.154. It involves only two reference lines for generating shoot-through pulse times. So it can be easily executed using microcontroller 89C52 using in built timer.

Hardware results are compared with traditional PWM inverter and are consistent with theoretical results. 89C52 is a broadly useful microcontroller. It doesn't have in constructed pulse width modulation generator but pulse width modulation signals can be produced just through programming and utilizing its clock highlight. Microcontroller 89C52 is utilized to produce synchronized three stage PWM flag and speed control of acceptance engine (induction motor).

Additionally, it offers required adaptability in control circuit operation through programming. It offers minimal effort answer for 3 ? induction motor control. For closed loop control ADC can be interfaced to the microcontroller. Other than these favorable circumstances there are a few restrictions that must be considered. Timing overhead due to calculations, function calls, conditional execution, jumps and Interrupt inactivity and so on wastes much of the microcontroller time.

These time overheads puts limits on maximum pulse width modulation frequency generated by microcontroller. Practically it is found that even with 20MHz crystal, maximum three phase PWM frequency is limited to 5 KHz. These time outflows spread in all pulse width modulation pulses evenly.

Thus synchronous pulse width modulation can be attained but covers the pulse width modulation period evenly by some extent of time. These margins can be reduced by using PIC, DSP or advanced microcontrollers which have in built Features of analog to digital converter and PWM generation. Advance Variable frequency drive can produce any output voltage greater than the dc input voltage by controlling the shoot-through duty ratio, which is not possible for the old-style ASD systems. In this work, defined the hardware implementation, analyzed the circuit, and validated its concept and dominance practically.

Maximum constant boost with third harmonic injection pulse width modulation control method increases output voltage boost while lessening voltage strains across MOSFETs/IGBTs. It allows over-modulation where modulation index can be varied from 0.57 to 1.154. It involves only two reference lines for generating shoot-through pulse times. So it can be easily executed using microcontroller 89C52 using in built timer. Hardware results are compared with traditional PWM inverter and are consistent with theoretical results. 89C52 is a broadly useful microcontroller. It doesn't have in constructed pulse width modulation generator but pulse width modulation signals can be produced just through programming and utilizing its clock highlight. Microcontroller 89C52 is utilized to produce synchronized three stage PWM flag and speed control of acceptance engine (induction motor).

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