Microcontroller Based 5 Level Converter for Single Phase Induction Motor

Gaurav R Agrawal[1], Vipin V Jais [2], Aman Shahu[3]
Department of Electronics & Telecommunication
[1] Department of Electrical [2, 3]
GWCET, Nagpur[1], GWCET, Nagpur [2], GWCET, Nagpur [3]

Abstract : This paper presents a micro controller based field oriented control 5-level inverter for three phase Induction motor. IGBT is used as power element. Pulse width modulation techniques (PWM), introduced three decades ago, are the most used methods to control the voltage and frequency supplied to electrical AC machines. . A scheme based on 5-level PWM inverter, which control a high performance 8-bit standard microcontroller with gate driver circuit and additional hardware is used, which allows a flexible and economical solution. The output voltage can be varied in a large range and with a good resolution. Experimental data obtained from an induction motor drive will be presented.

***IndexTerms* - FOC, PWM, microcontroller, multilevel inverter, induction motor.**

I. INTRODUCTION

In the last decade, many researches were works continue for improving the performance of the Induction Motor. The various methods are based on the principle of model reference condition system of the field-oriented control of the rotor flux. The induction motor accepted in variable speed drives due to its distinguished advantages of easy construction as well as low cost machine. The asynchronous machine uses some internal parts that need maintenance or replacement. The field-oriented control of rotor flux of voltage applied to the asynchronous machine can transforms the expression of electromagnetic torque of the asynchronous machine to practically the torque of the D.C. machine. In this work, the decoupling V_{ds} and V_{qs} to control the flux particularly in the course of the component I_{ds} and I_{qs}, which sharps to the suggestions of decoupling of the dependent excited D.C motor. The estimators determine the couple, the junction temperature, rotor flux and the stator pulsation. The control of induction motor can transform the expression of electromagnetic torque of to nearly the torque of the DC machine. An application of vector oriented control of rotor flux of asynchronous machine by controlling of induction motor with 5-level PWM inverter. Moreover, with multi level inverter PWM and field-oriented control of rotor flux, the voltage applied to the IM solicits a modulator stage. This stage adds to the signal processing (orders IGBTs of the inverter of the type H) time and consequently limits the reactions of the control system and hence the torque and speed response time. Also a hardware implementation of the field oriented control of 5-level inverter fed Induction Motor system and its implementation in term of programming and code in real time operating system.[5]

II. PROPOSED LOW NOISE AMPLIFIER

The multilevel PWM inverters include an array of power semiconductors and capacitor voltage sources, the output of which generate voltages in stepped waveform. The commutation of the switches allows the addition of the capacitor voltages which reaches the high voltage level at the output, while the power semiconductors withstand only with reduced voltage. A single phase leg of inverter with different numbers of levels by which the action of the power semiconductors is represented by an ideal switch with several position. A five-level PWM inverter generates an output voltage with five values (levels) with respect to the negative terminal of the capacitor. By considering that m is the number of steps of the phase voltage with respect to the negative terminal of the inverter, then the Number of steps in the voltage between two phases of the load k is defined by:

$$K = 2m + 1 \qquad (1)$$

The number of steps p in the phase voltage of a three- phase load in wyes connection is given by:

$$p = 2k+1 \qquad (2)$$

The term multilevel starts with the three-level inverter. By increasing the number of levels in the inverter, the output voltages have more steps generating a staircase waveforms, it results to reduction in harmonic distortion. However, a high number of levels results to increase the complexity and also it introduce voltage imbalance problems.[1]

Three different topologies have been proposed for multilevel inverters as diode-clamped (neutral- clamped), capacitor-Clamped (flying capacitors) and cascaded multi cell with separate dc sources. In addition, several modulation and control strategies have been developed or adopted for multilevel inverters including the following: Multilevel sinusoidal pulse width modulation (PWM), multilevel selective harmonic elimination and space-vector modulation (SVM).

The most attractive features of multilevel inverters are as follows:

1) It can generate output voltage with extremely low distortion.
2) It draws input current with very low distortion.
3) It generates smaller common-mode (CM) voltage, thus reducing the stress in the motor bearings. In addition, by using sophisticated modulation methods, CM voltages can be eliminated [8].
4) They can operate with a lower switching frequency.

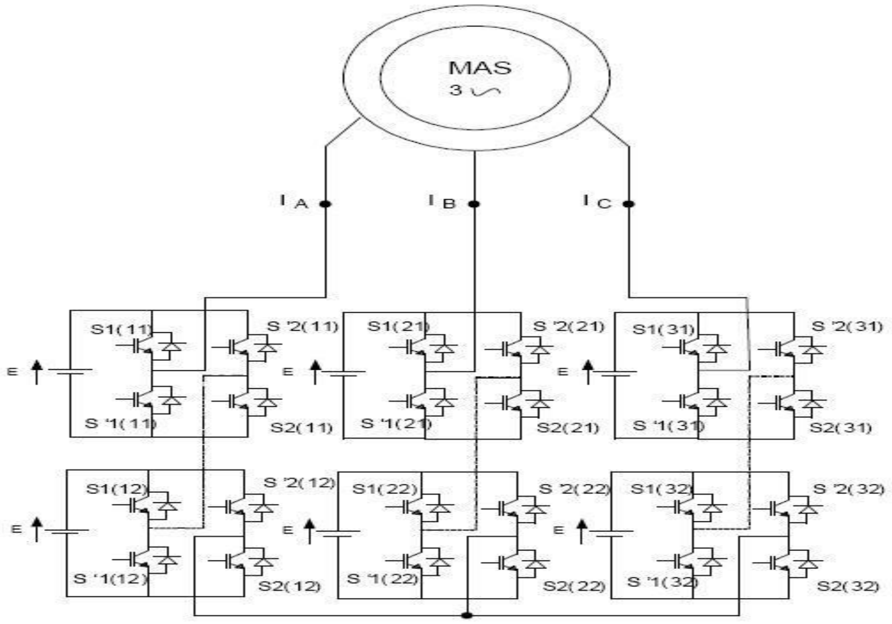


Fig.1 Three-phase cascaded multilevel inverter PWM of the type H

0	0	1	1	1	0	0	1	V_{DC}
1	0	0	1	1	0	0	1	1.5 V_{DC}
0	0	1	1	1	0	0	1	V_{DC}
1	0	0	1	0	0	1	1	0.5 V_{DC}
0	0	0	0	0	0	0	0	0
0	1	1	0	0	0	1	1	-0.5 V_{DC}
0	0	1	1	0	1	1	0	- V_{DC}
0	1	1	0	0	1	1	0	-1.5 V_{DC}
0	0	1	1	0	1	1	0	- V_{DC}
0	1	1	0	0	0	1	1	-0.5 V_{DC}
0	0	0	0	0	0	0	0	- V_{DC}

Table 1:- Conduction Sequence for Asymmetric Cascaded Multilevel Inverter

Three voltage levels can be obtain using 2 voltage sources and two h bridges. If V_{dc} is the voltage of first h bride h1 then second h bride h2 is supplied 0.5 of V_{dc}. appropriate IGBT are switched on in order to get different voltage level. 0.5 V_{dc} , V_{dc} , 1.5 V_{dc} , 0 . Which are repeated continuity and IGBT sequence is inverted for negative values.

III. FIELD ORIENTATED CONTROL

The Field orientated control is the process for obtaining the precise controllability over an induction motor fed with a multilevel PWM inverter by manipulating the angle and amplitude components of the stator field. The actual process involves a number of detailed transformations to obtain a simplified model of an induction motor from a 3-phase time and speed dependent system into a two co-ordinate time invariant system. Basically, it allows an induction motor to be controlled in a similar way to a dc motor by isolating and simplifying the necessary variables for torque and speed control. The basis of the control system is that stator current is referenced with respect to a synchronously rotating frame and the torque (q) and flux components (d) aligned respectively to give instantaneous controllability. Below depicts an ideal vector system for Field Orientated Control is:

$$\psi R \; i_{sq}$$

Where m = Torque

ψ_R = Rotor flux

i_{Sq} = Stator current vector

In essence the above relationship states that m and ψ_R i_{Sq} are directly proportional to each other. Consequently maintaining a constant value of rotor flux will give a direct linear relationship between the torque and torque component (i_{Sq}) allowing precise control by governing the torque component of the stator current vector. [4-5]

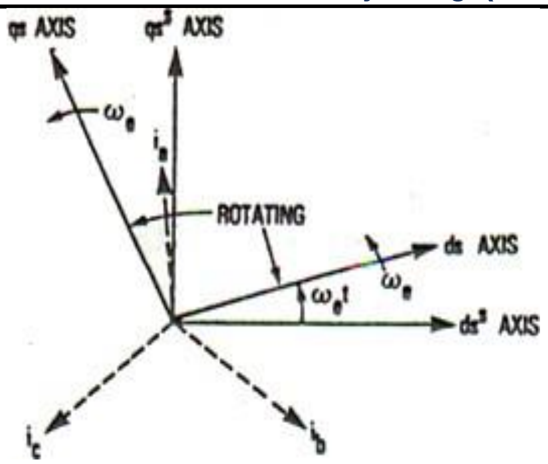


Fig2:-Typical Vector Transformation

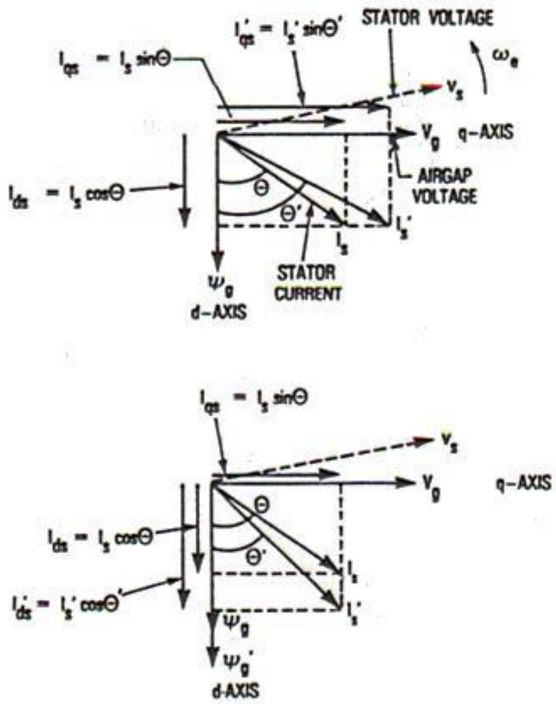


Fig3:- *Phasor representation of a typical Vector Transformation*

IV. HARDWARE IMPLEMENTATION

To Capture and Compare the PWM modules a version of the modulator suitable for the field oriented control, accepts as:

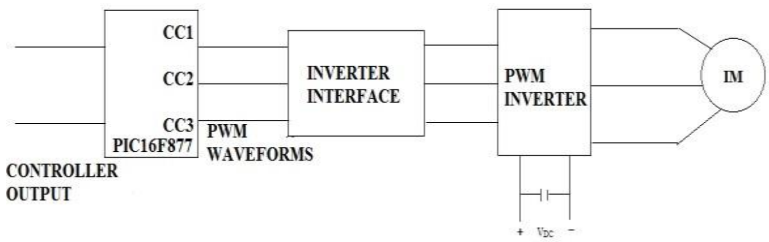
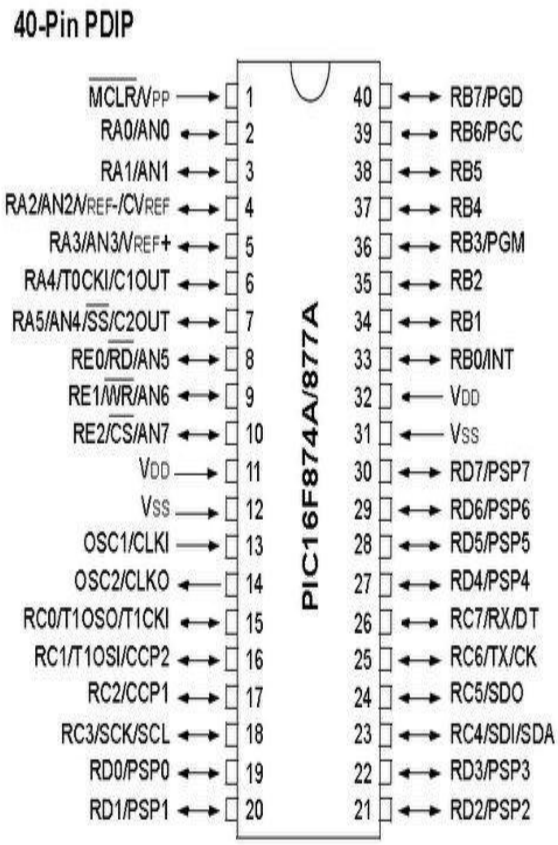


Fig 4:- Block diagram of the used system to test the modulator

Inputs the voltage demand in ***dq*** stator coordinates ***(U,*** and *U,)*, and generates the on-line three-phase PWM digital waveforms, which drive the power stages. In the proposed solution, the modulator hardware is just a 8-bit microcontroller with minimum additional logic, which provides the interface with power stage. The microcontroller is a 16F877A microcontroller for specially designed for complex, real-time control applications. It shares a common, register-based architecture core that eliminates the accumulator bottleneck and enables fast context switching. Although the 16F877A microcontrollers are a 8-bit architecture, all devices have bit, byte, word and 8-bit operations. The Motion Control family has peripherals that are optimized for three-phase AC induction motor control and power inverter applications. These devices have a unique peripheral, the capture and compare module (CCM), which greatly simplifies the control with 5 level PWM inverter gate driver circuit and external hardware used for generating three-phase pulse width modulation waveforms. The capture and compare module (CCM) generates three complementary.

Non-overlapping PWM pulses with resolutions of 250 ns (with a 16 MHz oscillator). Once initialised, the CCM require to change PWM duty cycles. The CCM features programmable switching (or carrier) frequency up to 1 kHz**,** duty cycle and dead time. The dead time generator (included in the CCM peripheral) prevents the complementary outputs from being turned on at the same time, in order to avoid a short circuit in one leg of the power inverter. This peripheral also has all programmable high drive capability outputs for each phase. The outputs have programmable polarity, or may be forced high or low. Fig. shows how the CCM produces the PWM waveforms. The CC-COUNTER register determines the switching frequency. The CC-COUNTER register is a 8- bit counter which is clocked every state machine. When the counter is running, it continuously counts up and down between OOOlH and the CC-RELOAD value. When the counter equals the Capture and compare module (CCM)s (there are three Capture and compare module (CCM)s, one for each phase) the outputs are complemented, so, this register set the pulse width. Each time the CC-COUNTER register reaches the CC- RELOAD value, an interrupt is generated (PI-Interrupt). This interrupt is used to change,, the CC-COMP register values (if needed). [2]

Specification of capture and campare module
- Capture is 16-bit, max. resolution is 12.5 ns
- Compare is 16-bit, max. resolution is 200 ns
- PWM max. resolution is 10-bit



-

Fig 5: Pin description of PIC16F877A

V. SOFTWARE IMPLEMENTATION

The general flowchart of the modulator software design is shown in Fig. 6. There are basically two concurrent tasks: the main routine and ISR(Intrrupt Service Routine) Fig. . In the main routine the port c, inputs to the IGBT gate driver circuit produced by the controller, are used, firstly, we determine the IGBT combination to be switched ON and output values to the corresponding port C which is connected too gate driver circuit. After each PWM counter next combination is switched ON. In this way all combination are output too generated multi level wave form for the motor. For other two phase120 phase shifted output is generated. The minimum pulse width resolution is 250 ns, independently of the CC-RELOAD value. The actual resolution depends on the carrier frequency selected: the higher the carrier frequency, the worst the pulse width resolution. The carrier frequency used in the experiments was about 1 kHz**,** which allows a pulse width resolution of 1/256, perfectly acceptable for most applications. With this frequency the switching times are updated within one carrier periods. The modulator synthesises a frequency in the range of 0 Hz to 70 Hz. [3]

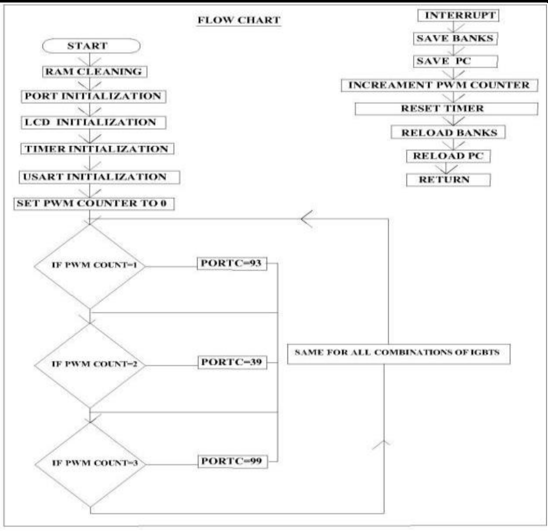


Fig 6: flowchart of software deign

VI. EXPERIMENTAL RESULTS

hp induction motor is connected to the system and successfully run using 5level inverter techniques .the supply voltage under take is 100V maximum in total. The motor is tested under no load condition. The hardware and power components run in under operating temperature in normal and industrial environment. Different input voltages are applied to check the motor performance for suitable running with the help of solar power as input source in further uses.

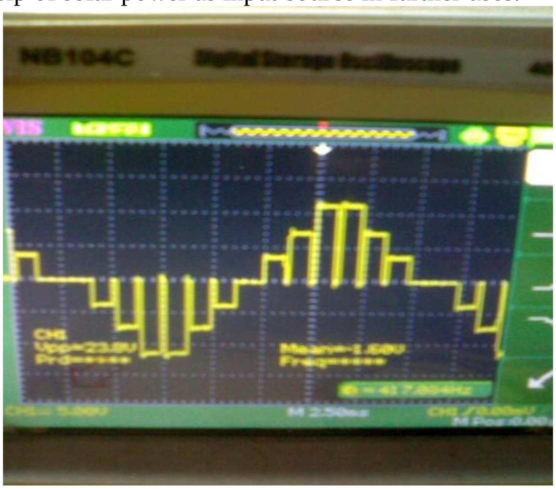


Fig 7:- experimental generated 5-level wave form of PWM inverter

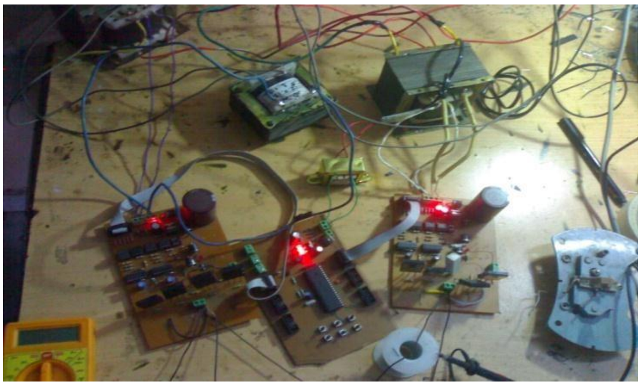


Fig 8: Hardware Setup of Proposed Design

VII. CONCLUSION

A voltage space vector PWM modulator, suitable for field oriented control, was presented and tested with a 0.5 H.P. three-phase induction motor fed by an IGBT 5-level PWM inverter. The proposed solution was based on a high performance 8-bit microcontroller with gate driver circuit and additional hardware. The implemented algorithm is very efficient, leaving enough time to implement other tasks with the same microcontroller, like, **for** instance, **simple** motor control schemes. High switching frequencies can be achieved with fine resolutions within a large output frequency range.

REFERENCES

1. A. Nabae, I. Takahashi, and H. Akagi, "A new neutral- point clampedPWM inverter," *IEEE Trans. Ind. Applicat.*, vol. IA-17, pp. 518–523,Sept./Oct. 1981.
2. M. Doi, G. **Hanis,** ***Application examples using the*** *8XCI* ***96MC/MD microcontroller.*** In "AP- 483". Intel Corporation, 1993
3. M. H. **RASHID,** ***Power electronics: circuits,. devices, and appilcations.*** **2"** ed. Englewood Cliffs, NJ: Prentice-Hall, 1993.
4. B.K. BOSS Power electronics circuit and drives
5. Dr.R.Seyezhai /CARRIER OVERLAPPING PWM METHODS FOR ASYMMETRICAL MULTILEVEL INVERTER International Journal of Engineering Science and Technology (IJEST) Vol. 3 No. 8 August 2011.
6. Keith Corzine, *Member, IEEE,* and Yakov Familiant, *Student Member, IEEE* A New Cascaded Multilevel H-Bridge Drive IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 17, NO. 1, JANUARY 2002.
7. Lotfi El M"barki , Moez Ayadi & Rafik Neji FIELD- ORIENTED CONTROL OF INDUCTION MOTOR APPLIED VIA INVERTER H BY PSPWM AND PDPWM www.arpapress.com/Volumes/Vol8Issue2/IJRRAS_8_ 2_11.pdf IJRRAS 8 (2) ● August 2011
8. Jon Are Suul, Marta Molinas, and Tore Undeland, " STATCOM - Based Indirect Torque Control of Induction Machines During Voltage Recovery After Grid Faults ", IEEE Transactions on power electronics, vol. 25, no. 5, May 2010,pp.1240-1250.
9. G. K. Singh, D. K. P. Singh, K. Nam and S. K. Lim, "A Simple Indirect Field-Oriented Control Scheme for Multiconverter-Fed Induction Motor", IEEE Transactions on industrial electronics, vol. 52, no. 6, December 2005, pp.1653-1659.
10. Julio C. Moreira, , and Thomas A. Lipo,"A New Method for Rotor Time Constant Tuning in Indirect Field Oriented Control", IEEE Transactions on power electronics, vol. 8, no.4.october 1993 ,pp.626-631.
11. M. Ayadi, L. El M"barki, M. A. Fakhfakh, M. Ghariani, R. Neji," A Comparison of PWM Strategies for Multilevel Cascaded and Classical Inverters Applied to the Vectorial Control of Asynchronous Machine „", International Review of Electrical Engineering (I.R.E.E.), Vol. 5, N. 5, September- October 2010, pp.2106-2114
12. Epaminondas D. Mitronikas, Athanasios N. Safacas, , and Emmanuel C. Tatakis," A New Stator Resistance Tuning Method for Stator-Flux-Oriented Vector- Controlled Induction Motor Drive", IEEE Transactions on industrial electronics, vol. 48, no. 6, December 2001, pp.1148-1157.
13. Nash J. N. 1996, *'Direct Torque Control Induction Motor Vector Control Without an Encoder'*, IEEE Conference, May 1993, pp. 86-93.
14. Neacsu., Rajashekara. 2001, *'Analysis of torque controlled IM drives with applications in Electric vehicles'*, IEEE Transactions on Power Electronics , March, Vol 16.
15. Hava A. Kerkman Russel & Lipo T. 1999, „*Simple Analytical and Graphical Methods for Carrier Based PWM-VSI Drives'*. IEEE Transactions on Power Electronics, Vol.14 No.1, pp. 49-61.
16. Benchaib A. Rachid A. & Audrezet E. 1999, „*Sliding Mode Input-Output Linearization and Field Orientation for Real-Time Control of Induction Motors'*. IEEE Transactions on Power Electronics, Vol.14 No.1, pp. 3-13.
17. J.W.L Nerys, A.Hughes and J Corda. 2000,*'Altenative implementation of Vector Control for induction motor and its experimental evaluation*." IEE proceeding electrical power app. Vol 147, no 1, January 2000, pgs 7-13.
18. J Nash, Direct *Torque Control induction motor Vector Control without an encoder*, IEEE, vol. 17 march 2002.
19. Keerthipala W., Chun M. & Duggal B. 1997, *'Microprocessor implementation of field-oriented control of induction motor using ANN observers'*, Journal of Microprocessors and Microsystems, April 1997, no. 21, pp. 105-112.