Microcontroller based Speed Control of Sinusoidal PWM Inverter fed Three Phase Induction Motor

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Abstract- This paper is concerned with Microcontroller based speed control of Sinusoidal PWM Inverter fed three phase Induction Motor. The Work involves design and fabrication of a variable frequency PWM inverter using MOSFET's, operating from a DC source. The objective is to implement variable frequency sinusoidal PWM inverter in order to control the speed of the Induction Motor using Microcontroller. When it is required to provide wide range of speed control covering about 600rpm to 1500rpm, normal three phase supply at 50Hz with voltage control alone is not successful due to the unstable region in the Torque-Slip characteristics of the motor. Hence it is necessary to go in for variable voltage and variable frequency mode of operation. The main focus of the this paper is the design and fabrication of variable voltage and variable frequency sinusoidal PWM inverter for speed control operation of Induction Motor. This drive system is simulated in MATLAB/Simulink and the simulation results are presented. After integrating the hardware and software the whole setup is tested for satisfactory operation. It is found that the three phase Induction motor is capable of running over a speed range from 600rpm to 1500rpm while driving a fixed load.

Keywords- Inverter, PI and PID controller, Sinusoidal Pulse Width Modulation (SPWM), Induction Motor,

I. INTRODUCTION

In many modern adjustable-speed drives, the requirement is for precise and continuous control of speed and torque with long-term stability, good transient and high efficiency. The DC motor satisfies most of this requirement, but its mechanical commutator and the sparking are disadvantages, and regular maintenance is required. Maintenance will be a problem when interruptions cannot be tolerated or when the motor is used at inaccessible locations. AC motors such as the cage-rotor induction motor and the synchronous reluctance and permanent magnet synchronous motor are brushless and have a robust rotor construction, which permits reliable and maintenance free operation at variable speed, but the induction motor and synchronous motor are inflexible in speed, when operated from mains where the synchronous speed is determined by the supply frequency and the number of stator poles.. However efficient wide-range speed control of the synchronous motor or the cage-rotor induction motor is only possible when an adjustable frequency AC supply is available.

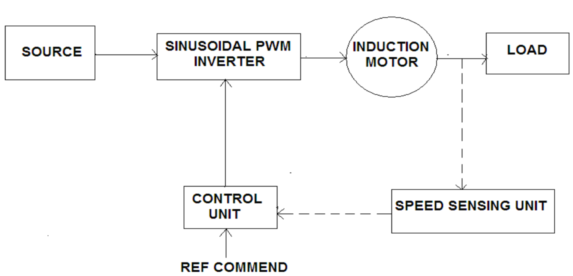

Fig 1 Block Diagram for speed control operation of AC motor

Source: Power sources can be of AC or DC in nature and normally are uncontrollable, i.e. their magnitudes or frequencies are fixed or depend on the sources of energy such as solar or wind.

Sinusoidal PWM inverters: Sinusoidal PWM inverters provide an easy way to control amplitude, frequency and harmonics contents of the output voltage.

Induction Motor: An Induction motor uses electrical energy to produce mechanical energy, very typically through the interaction of magnetic fields and current-carrying conductors. the speed sensing unit measure the speed of three phase Induction motor.

The complexity of the control unit depends on the desired drive performance and the type of motors used.

II. SINUSOIDAL PULSE WIDTH MODULATION (SPWM) VOLTAGE SOURCE INVERTER

The most common PWM approach is sinusoidal PWM. In this method a triangular wave is compared to a sinusoidal wave of the desired frequency and the relative levels of the two waves is used to control the switching of devices in each phase leg of the inverter.

Carrier frequency is preferred for complementary waveform, because it is necessary to keep the symmetry of the output voltage.

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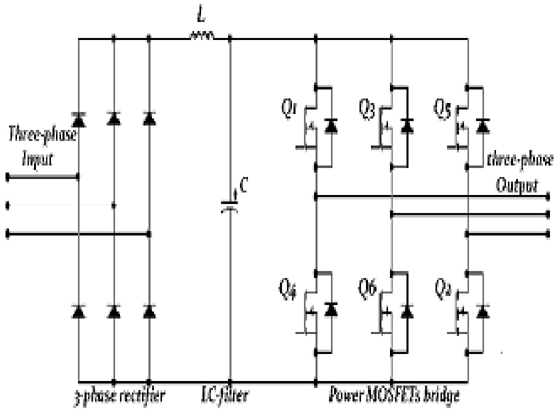

Fig 3 Three phase voltage Source Inverter

The speed of induction motor depends on stator-applied voltage, and so the speed can be varied by varying stator voltage. But if the voltage is varied by keeping the frequency constant, then flux of the machine will also vary, which is undesirable. It can be shown that if the ratio V/f is maintained constant then the flux of the machine will also be constant and so the machine can be operated in constant flux condition. The inverter is constructed using switches, which has to be switched ON and OFF for generation of ac voltage. The switching ON and OFF is usually performed by PWM pulses with fixed ON time, which leads to generation of square/stepped ac wave. The use of sinusoidal PWM will generate an ac wave that closely resemble a sine wave. The output phase voltages

Vao=is the output phase voltage measured to the center of the input D.C.voltage.

Van=is the output phase voltage measured to isolated neural of three phase load such as induction motor.

Where

$$\begin{bmatrix} V_{an} \\ V_{bn} \\ V_{cn} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix} \begin{bmatrix} V_{ao} \\ V_{bo} \\ V_{co} \end{bmatrix} \qquad (1)$$

Modulation index “m” is defined as:

$$m=V_P/V_T \qquad (2)$$

where, V_P = Peak of modulating signal
V_T = Peak of triangle signal

In that m=1 the maximum value of fundamental peak $=0.5V_d$ which is 78.54% of the peak fundamental voltage of the square wave ($2V_d/\pi$) which called the linear modulation region. to further increase the amplitude of the output voltage, the amplitude of the modulating of the modulating signals exceeds the amplitude of the carrier signal which leads to enter into quasi PWM region called over modulating region causing increase in the low order harmonics. Further increasing modulating index tends to obtain square wave at maximum possible output fundamental ($2V_d/\pi$).

III. CONTROL PERFORMANCE

Speed control operation of induction motor is quit complex. In general, the rotor speed is measured by tachometer.slip can be measured by comparing ref speed(w*) and rotor speed (w).the PI and PID controller k_p,K_i,K_d values are selected by Trial and error method. In that PI and PID controller values are k_p= 13, K_i= 26 and k_p= 13, K_i= 26, K_d=0.5.

IV. SIMULATION WORK AND RESULTS FOR SPWM

Simulations are carried out for constant v/f control of induction motor drives using SPWM techniques for closed loop operation. The parameters of the induction motor used for simulation are as follows:
3 HP, 220V, 50Hz

A. Closed loop operation of sinusoidal PWM Inverter

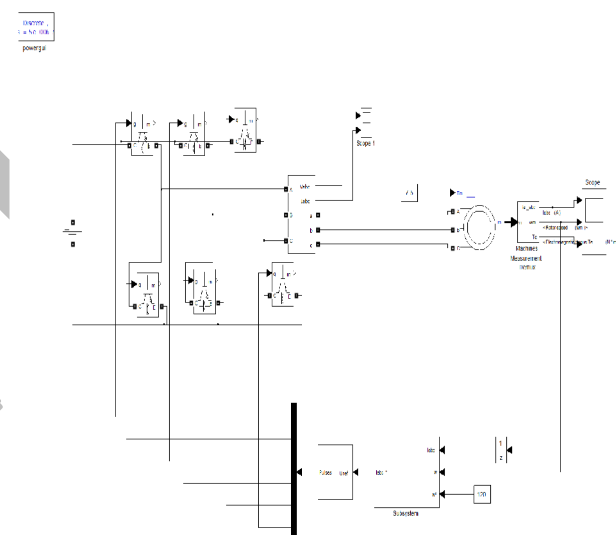

Fig 4.closed loop speed control system

In the simulation 440V Inverter Bridge supplies the input voltage for the three phase induction motor. The rotor speed of the motor is sensed and that has been given to the controller (PI and PID) block as input. When ever the set speed is entered. The controller (PI and PID) generates the required signal to initiate the PWM according to the set speed that has been entered. Once the PWM is initiated .the Inverter Bridge generates the voltage that required for the motor to run as the set speed.

B. Simulation results for closed loop sinusoidal PWM Inverter fed induction motor with PID control

Sinusoidal PWM inverter fed three phase induction motor drive is simulated in Matlab/Simulink software. Current,rotor speed and electromagnetic torque are shown in fig 5,6,and 7

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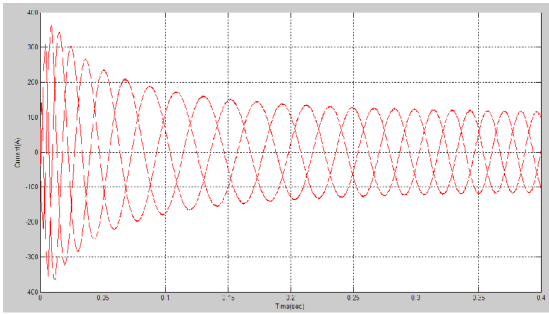

Fig 5 Stator current for set speed of 1241rpm with PID control (T_L = 7.5Nm)

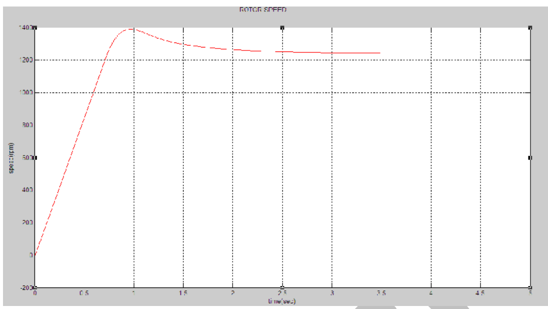

Fig 6 Rotor speed for set speed of 1241rpm with PID control (T_L = 7.5Nm)

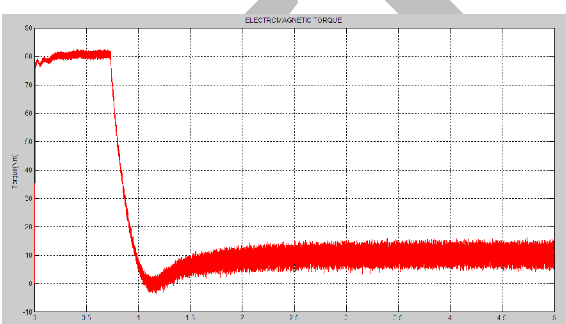

Fig 7 Electromagnetic Torque for a set speed of 1241rpm with PID control(T_L =7.5Nm)

C. Simulation results for closed loop sinusoidal PWM Inverter with PI control

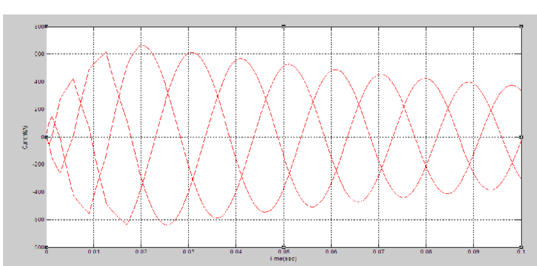

Fig 8 Stator current for set speed of 1241rpm with PI control(T_L = 7.5Nm)

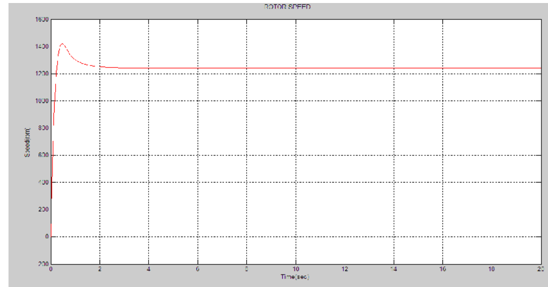

Fig 9 Rotor Speed for set speed of 1241rpm with PI control(T_L = 7.5Nm)

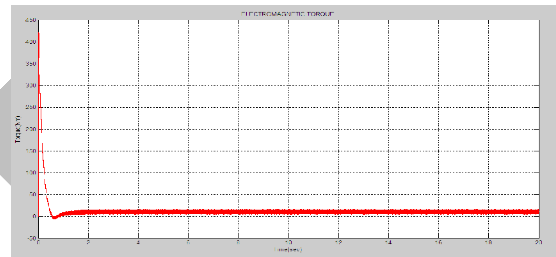

Fig 10 Electromagnetic torque for a set speed of 1241rpm with PI control (T_L = 7.5Nm)

The controller performance is evaluated by measuring rise time, settling time, peak overshoot, steady state error. The simulation results for the above are tabulated. sinusoidal PWM inverter fed three phase induction motor with PI controller is also simulated in MATLAB/Simulink and the simulation results are shown in fig 8,9,and 10.

C. Comparison Tabulation for PI and PID Controller

Controller	**Set Speed= 1241rpm**		**Set Speed= 1336rpm**		**Set Speed= 1432rpm**	
	PI	*PID*	*PI*	*PID*	*PI*	*PID*
Rise Time (sec)	0.17	0.58	0.18	0.65	0.18	0.66
Settling Time (sec)	2.2	2.4	2.4	2.6	2.4	2.7
Peak overshoot Time (sec)	0.5	0.97	1.03	0.48	0.49	1.1
Steady State Error (%)	+2	+7	+3	+5	+4	+7

Table 1 Lookup Table for PI, PID comparison

E. speed comparison Tabulation for PI and PID controller

Controller	**Set speed (rpm)**	**Measured speed (rpm)**
PI	1241	1243
	1336	1339
	1432	1436
PID	1241	1248
	1336	1341
	1432	1439

Table 2 Lookup Table for speed comparison using PI and PID controller

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The comparison of PI and PID controller is tabulated above, from this it's observed that PI controller reaches the steady state bit earlier than the PID controller. The steady state error is also less in the case PI controller which in tern leads to better approximation

V. Hardware Realization

Fig 11 shows the complete hardware circuit, interfacing with Microcontroller and motor operation of the inverter. The speed of induction motor depends on stator-applied voltage, and so the speed can be varied by varying stator voltage. But if the voltage is varied by keeping the frequency constant, then flux of the machine will also vary, which is undesirable. It can be shown that if the ratio V/f is maintained constant then the flux of the machine will also be constant and so the machine can be operated in constant flux condition.

The inverter is constructed using switches, which has to be switched ON and OFF for generation of ac voltage. The switching ON and OFF is usually performed by PWM pulses with fixed ON time, which leads to generation of square/stepped ac wave. The use of sinusoidal PWM will generate an ac wave that closely resembles a sine wave.

The inverter was developed using six MOSFETs as switches, and in this, each pair of series connected MOSFET switches generates the ac voltage of a phase. The system employs two microcontrollers. One controller (AT8920C51) is used to generate six square waves at the desired frequency, which is selected through switch settings. Another Microcontroller (PIC 16F877A) is the master controller which is programmed to generate a single sinusoidal PWM pulses. This sinusoidal PWM pulses are logically ORed with square waves and then amplified and isolated to trigger the MOSFETs.

The rotor speed is measured by an inductive pick-up proximity sensor, which generates pulses and these pulses are signal conditioned and fed to the Microcontroller. The microcontroller computes the actual speed by counting the pulses. The desired speed is entered through keyboard. The Microcontroller maintains the desired speed by modifying the ON time of sinusoidal PWM pulses.

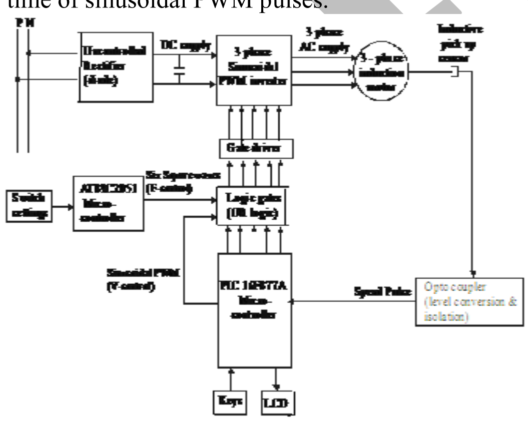

Fig 11 Overall Hardware System Block Diagram

A. Experimental Results

The speed is setup by the operator and then actual speed is measured by the speed sensor and is shown by LCD display

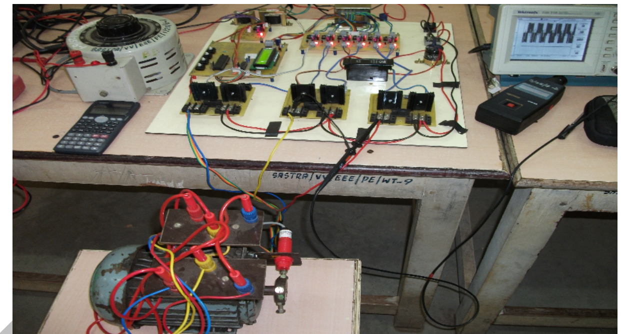

Fig 12 Experimental of Power and Control Circuit connection

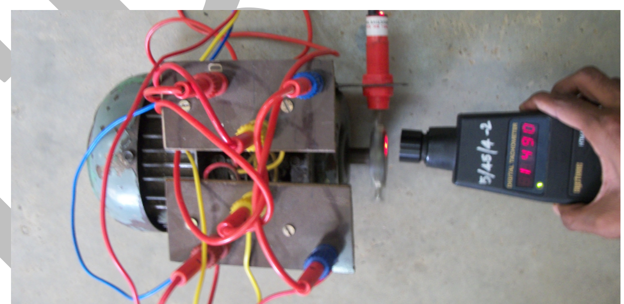

Fig 13 Induction Motor Drive

Fig 14 LCD displaying

Fig 15 Sinusoidal PWM Inverter output waveform

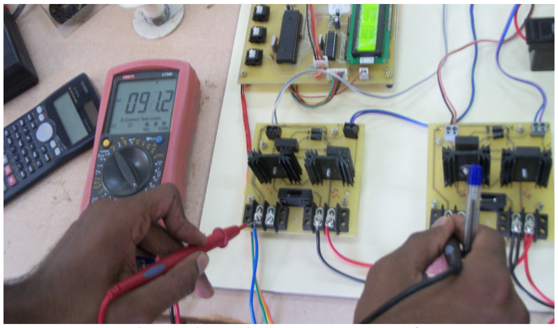

Fig 16 Line voltage measurement of Inverter

B. *Tabulation for Hardware Experimental Results*

v/f ratio = 2

Frequency (Hz)	**Set speed (Rpm)**	**Measured speed (Rpm)**	**Voltage (V)**
25	1500	1493	97
22.5	1350	1340	85
20	1200	1178	78
17.5	1050	1038	69
15	900	870	60
12.5	750	715	51
10	600	543	40

Table 3 Hardware Experimental Results

VI. CONCLUSION

The work as reported in the earlier sections uses the Sine PWM as a modulation scheme for speed control of a three phase Induction motor run from a AC supply. The mode of Voltage Source Inverter used here is 120° of switching between the consecutively operating switches.

Microcontroller is programmed through 'C' programming. The Inverter Switches are triggered through the push pull driver circuit. The V/f ratio is maintained to the constant for all values between the 600rpm to 1500rpm.In that Microcontroller generates the required Sine PWM pulses for the appropriate motor Speed.

REFERENCES

[1] A.Ali Qazalbash, Awais Amin, Abdul Manan and Mahveen Khalid: "Design and Implementation of Microcontroller based PWM technique for Sine wave Inverter"

[2] V. Srinath: "analysis of cascaded three level spwm inverter driven induction motor with active filter using matlab/simulink" xxxii national systems conference, nsc 2008, december 17-19,

[3] K.L.Shi, T.F.Chan, and Y.K.WongandS.L.Ho:"Modelling and simulation of the Three-phase Induction Motor using simulink".

[4] Mazidi, McKinlay & Causey, "PIC Microcontroller", Prentice Hall Inc., 2007

[5] John B Peatman, "Design with PIC microcontroller", Pearson Education Inc., 2000

[6] M.D.Singh & K.B.Khanchandan: "Power Electronics ", TMH, New Delhi,2001.

[7] Bimal K.Bose: " Power Electronics & Variable Frequency Drives Technology & Applications" SPD, Delhi,2000.

[8] The TTL Data book for Design Engineers," TEXAS Instrument Incorporate, First Edition

[9] Muhammad H. Rashid: "Power Electronics Circuits, Devices & Application" PHI, New Delhi,2001

[10] C. Trounce , S. D. Round and R.M.Duke, Evaluation of direct torque control using space vector modulation for electric vehicle applications,IEEE Power Electronics Letters vol. 17, No. 2, June 2005, 76-80.

[11] J Kup-kai Shayu, Flux compensated DTC of induction motor drives for speed operation, IEEE Transactions on Power Electronics vol. 19,No. 6, November 2004,1608- 1613.

[12] Ciro Attaianese, Aldo Perfetto, and Giuseppe Tomasso A space vector modulation algorithm for torque control of inverter fed induction motor drive, IEEE Transactions on Energy Conversion vol. 17, No. 2, June 2002, pp.222-228

[13] S.K.Bhattacharya: " Electrical Machines", TMH, New Delhi,1989.

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