

Design and Implementation of IGBT Based Single Phase AC Drive Using PIC 18F452

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Abstract- This paper presents a design and implementation of single phase AC Drive to drive and speed control of an 1-phase induction motor using the PIC 18F452 Microcontroller. The use of this PIC microcontroller yields enhanced operations, fewer system components, lower system cost and increased efficiency. The control algorithm is based on the constant volts-per-hertz principle because the exact speed control is needed. Reflective object sensors which are mounted on concrete frame are used to detect accurate edge position of revolving stage. The PWM control signals are generated by the PIC 18F452 controller to drive the IGBT based single phase AC Drive.

The power section in this includes rectifier (converter) and filter which provide dc output with less distortion from single phase ac input supply. Then the main stage comes is inverter where by controlling the firing of power devices (e.g. IGBT) by pulse width modulation produced by the PIC controller using the control algorithm based on the constant volts-per-hertz principle, the motor is rotated with the load maintaining the volt-hertz ratio constant.

Keywords – PWM, 1-Phase Induction Motor, VSI, IGBT Driver.

I. INTRODUCTION

The word "drive" is used loosely in the industry. It seems that people involved primarily in the world of gear boxes and pulleys refer to

any collection of mechanical and electro-mechanical components, which when connected together will move a load, as a "drive". When speaking to these people, an AC drive may be considered by them as the variable frequency inverter and motor combination.

People in the electrical field and electrical suppliers usually refer to a variable frequency inverter unit alone, or an SCR power module alone (when discussing DC drives) as the "drive" and the motor as the "motor".

It is estimated that 50% of the electrical power produced consumed by electrical motors. More than 50% motors can typically be found in a house, and nearly as many in a car. To preserve the environment and to reduce green-house effect gas emissions, governments around the world are introducing regulations requiring white goods manufacturers and industrial factories to produce more energy efficient appliances. Most often, this goal can be reached by an efficient drive and control of the motor speed. This is the reason why appliance designers and semiconductor suppliers are now interested by the design of low-cost and energy-efficient variable speed drives. Because of their high robustness, reliability, low cost and high efficiency (80%), AC induction motors are used in many industrial applications. However, induction motors can only run at their rated speed when they are connected to the main power supply. This is the reason why variable frequency drives are needed to vary the rotor speed of an induction motor. The most popular algorithm for the control of an induction motor is the V/f control approach using a natural pulse-width modulation (PWM) technique to drive a voltage-source inverter (VSI). The aim of this application note is to show how these techniques can be easily implemented on a PIC based variable frequency drive dedicated to power control applications. The requirements of electrical drive systems increases by the request of more performance, higher integration, easier to program and lower cost.

II. SYSTEM DEVELOPEMENT

The basic circuit diagram of the PIC controlled single phase inverter is shown in Figure 1.

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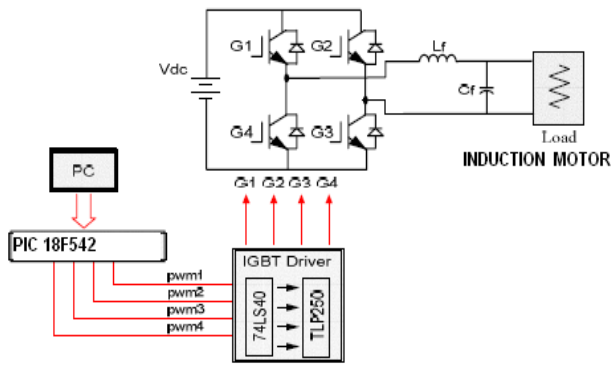


Figure 1. PIC controlled single-phase PWM inverter

Hardware setup procedure can be divided into two sections: the control and power circuit. Electrical isolation between control circuit and power circuit is provided by the optically coupled devices.

CONTROL CIRCUIT DESIGN

The control circuit section is composed of three parts namely PC, PIC board and IGBT driver. PIC 18F452 is programmed to produce gate pulses by comparing a triangular carrier wave in 2-KHz and a sinusoidal reference wave in 50-Hz. The reference wave amplitude adjusts the amplitude of the generated AC voltage and the Reference wave frequency determines the frequency of the generated AC voltage.

1MBH50D-060 coded IGBTs are used in PWM inverter circuit. IGBTs are voltage controlled devices and it requires a minimum gate threshold voltage of about 15-V for establishing the rated collector-to-emitter conduction.

This requirement makes it difficult to directly interface an IGBT to PIC. For proper operation of IGBTs, correct power levels are required (Vge(th)=15 V and Ic= 50 mA). Voltage and current levels of DSP output signals fail to operate the IGBTs. IGBT driver circuit amplifies PIC output signal to the required level for triggering the IGBTs and isolates the DSP from the power circuit. TLP250 ICs are commonly used driver ICs for IGBTs. However, PIC output signals does not have enough current level to activate the TLP250. 74LS40 NAND gate IC is used to amplify the current value of signals from PIC at a gain of 50/2.

In the buffer circuit (74LS40) if two inverter gates are connected back to back, the two inversion functions would "cancel" each other out so that there would be no inversion from input to final output. DSP output signals

are now ready to activate TLP250. TLP250 consists of a light emitting diode and an integrated photo detector. The output waveform will have the same waveform as the input waveform except the magnitude and power.

POWER CIRCUIT DESIGN

The power circuit section is composed of four parts namely full bridge inverter circuit, DC power supply, LC filter and load(induction motor). PWM inverters include semiconductor devices with nonlinear characteristics and can generate dominant harmonics in the system. The waveform quality of the sensitive load is improved by putting an LC filter at the output of the PWM inverter. In order to design an LC filter, there are many methods available. Optimum performance can be obtained by using [6] in simulation and experimental studies. A rule of thumb in control theory is that the frequencies of such a configuration have to have at least a factor of 10 between them to decouple the effects. According to this rule, for 50-Hz fundamental frequency, resonance frequency has to be at least 500-Hz, pulse frequency of the inverter output has to be at least 5000-Hz. Resonance frequency is determined by the product of L and C.

III.PERFORMANCE ANALYSIS

Principle of speed control The inverter unit controls the speed of a single-phase induction motor by changing the frequency, f, of the voltage applied to the motor. The inverter it changes the frequency, f, by changing the N/OFF cycle of the six switching elements, and the rotational speed (N) of the motor changes in proportion to the expression in formula (1).

$$N = 120 \cdot f \cdot (1-s) / P \dots \dots \dots (1)$$

N: Rotational speed [r/min]

F: Frequency [Hz]

P: Number of poles of a motor

S: Slip

In addition, to make the voltage applied to the winding have a sine-wave shape, the inverter controls the ON/OFF duty cycle as shown in Figure2. The ON/OFF time is controlled so that the average voltage applied to the motor becomes a sine-wave shape by comparing the triangular wave called a carrier signal with the sine-wave shaped signal waveform. This method

The generated torque T of the motor is shown by the formula (2). From this relation, it can be said that the torque will also be constant by making V/f, the ratio of voltage V to frequency f, constant.

$$T = K \cdot I \cdot V / f \dots \dots (2)$$

T : Torque [N•m]

V : Power supply voltage [V]

I : Motor current [A]

f : Frequency [Hz]

K : Constant

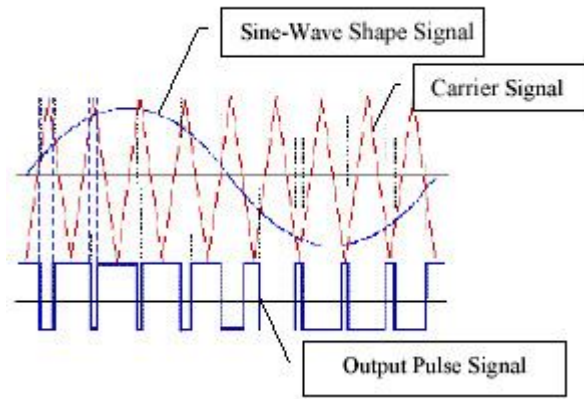


Figure 2. Duty control of ON/OFF

However, the lower the speed is, the more difficult it is to keep constant the input impedance of the induction motor with the change in f . Therefore, to obtain a torque that is constant from low speed to high speed it is necessary to adjust the V/f ratio at low speed in accordance to the characteristics of the motor like the solid line shown in Figure 3.

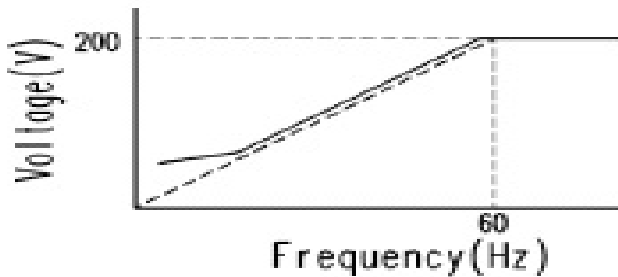


Figure 3. V/f control

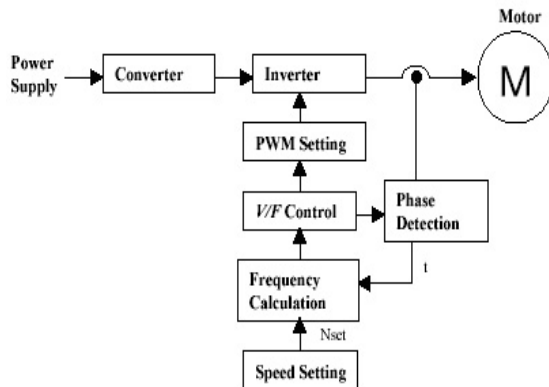


Figure 4. Block diagram of closed-loop control

Figure 4. shows the block diagram configuration of the closed-loop control system used in our implementation. This method detects the phase difference between the voltage of the inverter output block and the primary current, which calculates the driving frequency corresponding to the load using the characteristics data table (Figure 5) prepared beforehand, and controls the inverter frequency without the need for a speed sensor on

motor

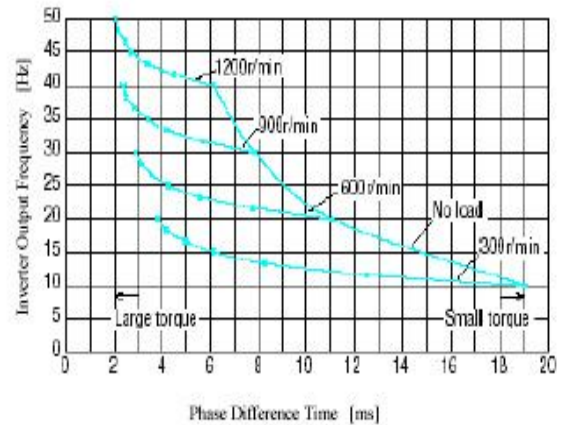


Figure 5. Characteristics data table

With this characteristic table and the detected phase difference time t , the inverter calculates an inverter output frequency that corresponds to the rotational speed command N_{set} set by the speed potentiometer, and outputs it as the inverter output frequency. After receiving the output frequency, the V/f control block calculates the voltage applied to the motor corresponding to the output frequency f , and performs the speed control by driving the PWM inverter.

In Figure 6, the 50-Hz fundamental frequency is compared with 3-KHz carrier signal.

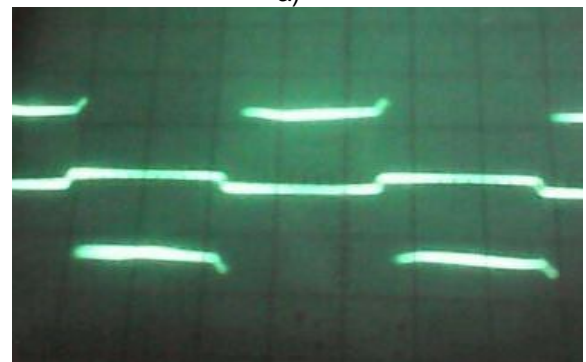
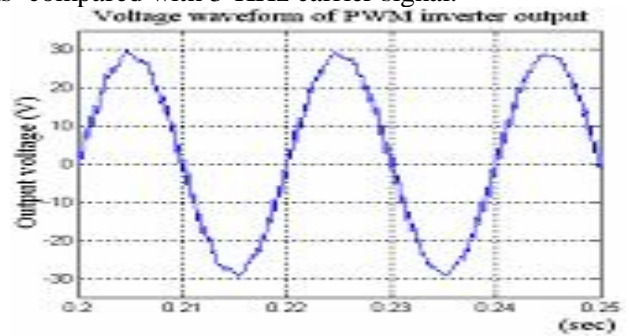


Figure 6. Simulation (a) and experimental (b) results

IV. CONCLUSION

IGBT based AC Drive drives the single phase motor and control the speed of it. By providing the PWM pulses to voltage source inverter, the 1 phase

induction motor rotates maintaining the volt-hertz ratio constant. By changing the frequency the input signal which is given through the hardware knob.(e.g. potentiometer) the period of the PWM pulses changes with respect to it and in correspondence the speed of motor changes providing the volt-hertz principle constant .With the application of the load on motor, the speed of motor decreases then by closed loop the PIC Controller changes and try to bring it in actual applied speed.

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