ISSN: 2277-5536 (Print); 2277-5641 (Online)

# PIC BASED SPEED CONTROL OF THREE PHASE INDUCTION MOTOR VIA SINGLE PHASE SUPPLY

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## ABSTRACT

Most of AC drive uses electric motors because they are controllable and readily available. These drives are based on induction motor because the induction motors are robust, rugged, reliable, durable, and less expensive and maintenance free. When induction motors are directly connected to AC mains, it operates only at the rated speed. However, most of the applications that require variable speed operation. In past, gear systems were used for variable speed operation. But at present, the development in the area of power electronics, microelectronics and control system that controls the speed of induction motor very efficiently. The speed of the induction motor can be controlled by various techniques. The PWM control is one of technique to control the speed of an induction motor very easily using software. The microcontroller based speed control system can be used in various industries such as chemical, textile and cement to operate the motor according to the desired speed.

The proposed technique of single phase to three phase conversion has a wide range of applications where three phase motors are operated on a single phase supply. It is the best option for those applications where three phase supply is not available. The advantages of three phase motor over single phase that they are efficient, economical and require less severe starting current. So single phase to three phase conversion circuit is designed for generation of strong, high quality signals for three phase induction motors using PWM technique with PIC microcontroller. This paper describes the speed control of three phase induction motor using single phase supply with PIC microcontroller. The implemented system converts a single phase AC input into DC. The three phase MOSFET based inverter uses DC voltage and operates on the PWM signals. These PWM signals are generated by the PIC microcontroller. Different PWM techniques are used for firing the three phase inverter and harmonic profile of various PWM techniques are carried out through simulation. The best suitable simulated PWM inverter firing scheme is used for better efficiency. Speed of induction motor is varied by changing the width of the firing pulse of an inverter.

**KEYWORDS:** Induction Motor (IM), Pulse Width Modulation (PWM), Peripheral Interface Controller (PIC), Metal Oxide Semiconductor Field Effect Transistor (MOSFET).

## INTRODUCTION

Power electronics is the branch of engineering which deals with conversion and control of electrical power for various electrical and industrial applications. In 19$^{th}$ century, the development of AC drives took place which led to industrial revolution (Rashid, 2001). These drives were used for the high speed operation. They were heavy and large in size and they require more power for their operation. So small and low power consumption drives were developed in 20$^{th}$ century. Such development had drastic change in the area of industrial atomization (Sen, 1998). In previous few decades, the field of power electronics had rapid development due to the advent in modern technologies such as Digital Signal Processing (DSP), Data Acquisition System (DAS), Microprocessors (µp) and Microcontroller (µc) (Baharuddin, 2008; Welchko and Lipo, 2000; Hackney, 2005). The above mentioned technologies made power electronics applications easier to implement and more accessible.

During last decade, the rapid development in power semiconductor devices led to the increased use of variable speed drives gained the importance in industrial atomization. The automotive industries are highly adopting variable speed drives because they are improving the performance and overall system efficiency (Papafotiou *et al* , 2004; Sreehitha *et al* , 2012). In some applications, the operation of drive is of paramount and continuous operation of the system must be insured. In industrial applications, variable speed drives requires more reliability, so several solutions have been proposed such as parallel redundancy, poly-phase machines, open winding drives, fault tolerant control for classical drives etc. (Pandian and Reddy, 2008; Burroughs, 2004; Jeevananthan *et al* , 2007; Wankhede *et al* , 2011). Simulation and neural network approach are widely used for predicting and studying the steady state, transient analysis of the induction drives (Li *et al* , 2002). There are little efforts made in the digital switching in three phase induction motor drives (Yao, 2000; Filippich, 2002; Muhialdin *et al*, 2001). Now, digital switching devices are made to control the drive easier. So microcontroller based drives are used in industrial applications. With advent in power semiconductor devices, the pulse width modulation PWM technique has been used more frequently to improve the quality of output signal. Use of turn-off device and application of pulse width modulation technique for power converter have brought distinct improvements in the characteristics (Battello *et al*, 2003; Mohanty and Muthu, 2010; Yedamale, 2002). The proposed design describes the development of three phase induction motor drive for variable speed operation. It is based on PIC16F877A microcontroller which is dedicated for motor control applications (Rumzi *et al*, 1999; Visinka, 2003; Parekh, 2004; Khan and Riyadh, 2011; Win *et al*, 2008). The system is designed for low to medium power three phase induction motors and is targeted for applications in both industrial and electrical appliance fields. The designed drive incorporates both hardware and software parts of the system which operates in open loop.

**System Description**

The entire system is divided into two different parts; a power circuit and a control circuit. The power circuit consists of the single phase high voltage bridge rectifier, capacitor filter and MOSFET based three phase inverter. On the other hand, the control circuit consists of the PIC16F877A microcontroller; Opto-Coupler and gate drive circuit. The single phase AC input voltage is fed to a bridge rectifier to produce DC output. But the output of rectifier is pulsating. So capacitor filter is used which assists in stabilizing the DC output voltage. The stabilized DC voltage is fed to the three phase inverter. The three phase inverter consist of six MOSFET's are controlled by PWM signals generated by PIC16F877A microcontroller. A modern strategy used for controlling the AC output in power electronics is pulse width modulation (PWM) technique. The PWM pulses are generated by microcontroller using C language which is executed in the assembly language. The required phase voltage is obtained by changing the duty cycle of PWM signals. This AC output is fed to the three phase induction motor for controlling its speed. It is controlled to produce a desired sinusoidal voltage at constant frequency, which is given to induction motor.

**Gate drives circuit**

The PWM technique is used for controlling the speed of induction motor. The PWM signals are generated by PIC16F877A Microcontroller. These PWM pulses are given to the gate drive circuit through buffer. The gate drive circuit provides the gate signals for firing the MOSFET's which drives three phase induction motor as shown in fig 2.

**Buffer circuit (BC547 & 2N3019)**

The PWM pulse generated by PIC microcontroller is not able to drive the Opto-isolator. To overcome this problem, buffer circuit is used as shown in Fig.3. The output of microcontroller provides the base biasing to BC547. Output voltage of the inverter IC is 5V. The required current to turn on BC547 is = 5mA. Therefore Base resistance of BC 547 is $R_B = 5V / 5mA = 1.0\ K\ \Omega$

Current through BC 147 is, $I_C = V_{CC} / R_C = 15\ V / 1.2\ K$

$I_C = 12.5mA$

$I_C = 13mA$ Approx.

**Opto-isolators (MCT2E)**

Figure 4 shows the internal structure of Opto-isolator. It is the combination of Ga-As Infrared light emitting diode and a silicon NPN phototransistor. The rise time ($t_r$)= 5 µS and fall time ($t_f$)= 5 µS of phototransistor are very small, with typical values of turn-on time $t_{on}$ =2-5 µS and turn-off time $t_{off}$ = 300nS. The turn-on and turn-off times of phototransistor limits the high frequency application.

When input signal is applied to the light emitting diode, it is turned-on and emits the light which falls on the phototransistor. Therefore, photo transistors conduct and output voltage is produced across collector and emitter. The main function of Opto-Isolator is to isolate the power circuitry from the control circuitry.

**Darlington Pair Amplifier (TIP122)**

The TIP122 is popular Darlington pair NPN power transistor rated as 100V, 5A having gain over 1000 with power dissipation of 50W. It intended for use in power, linear and switching applications.

**IR 2110**

IR2110 is a digital logic IC which operates in logical format. It is capable to control two inputs at a time and produces high side and low side output pulses. Typical gating sequences are obtained. These sequences are given to the inverter circuit. The gate drive requirements for a power MOSFET utilized as a high-side switch, the drain is connected to the high voltage rail, driven in full enhancement (i.e., lowest voltage drop across its terminals) is archived by using IR 2110.

The IR 2110 operates on the bootstrap principle. The gate charge for the high-side MOSFET is provided by the bootstrap capacitor which is charged by the 15 V supply through the bootstrap diode during the time when the device is off. Since the capacitor is charged from a low voltage source to the power consumed by the drive .Both the high side and low side channels are controlled by TTL/CMOS compatible inputs.

**Inverter**

Fig.5 shows the three phase inverter circuit using MOSFETs. It consists of six MOSFET's & six freewheeling diodes connected in three limbs. These MOSFETs are controlled by PWM signals through microcontroller. The waveforms of PWM pulses generated by PIC simulated in Proteus software as shown in fig.6. At a time, only two MOSFET's are conducted. The sequences of conducting the MOSFET's are 1 and 5, 2 and 6, 3&4 and repeats. When any pair of MOSFET is conducted, the current starts flows through motor winding. Motor windings are inductive so it holds the energy in the form of current. The freewheeling diodes are connected across the MOSFET's providing path of current for dissipation while MOSFETs are in the non-conducting state. Upper & lower MOSFETs of the same limb should not be conducted at the same time which prevents DC supply shorted. Above mentioned sequence of conducting MOSFET's, each pair of MOSFET conducts after 120°. Thus we get balanced voltages across the induction motor.

## RESULTS AND DISCUSSION

**Table 1. RPM, Simulated Efficiency and Actual Efficiency**

| RPM | Simulated efficiency | Actual efficiency |
|---|---|---|
| **750** | 65.5 | 64.3 |
| **800** | 67.2 | 65.6 |
| **850** | 69.7 | 67.8 |
| **900** | 72.3 | 70.9 |
| **950** | 74.0 | 72.8 |
| **1000** | 76.8 | 73.3 |
| **1050** | 79.4 | 76.5 |
| **1100** | 80.2 | 78.0 |
| **1150** | 81.4 | 80.2 |
| **1200** | 79.7 | 77.6 |
| **1250** | 77.5 | 74.8 |
| **1300** | 71.6 | 69.0 |
| **1350** | 66.8 | 65.5 |

**Table 2. Load Voltage and RPM**

| Load Voltage | RPM |
|---|---|
| **0** | 0 |
| **25** | 28 |
| **50** | 89 |
| **75** | 171 |
| **100** | 305 |
| **125** | 457 |
| **150** | 596 |
| **175** | 759 |
| **200** | 910 |
| **225** | 1061 |
| **250** | 1262 |

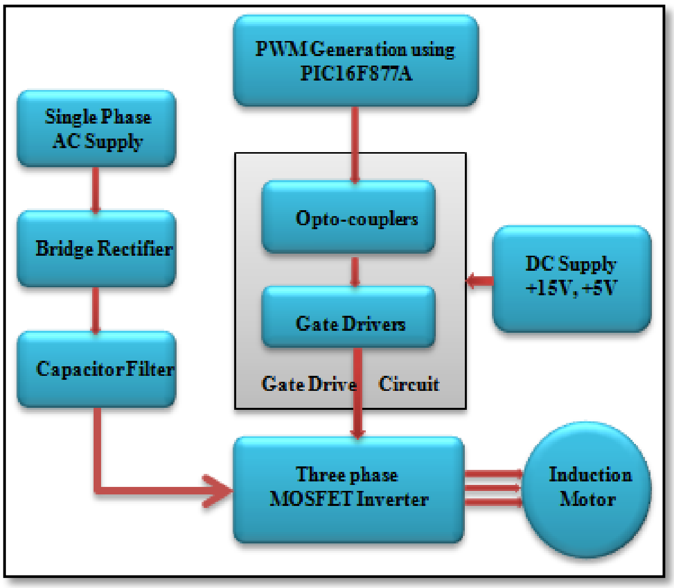


**Figure 1.Block Diagram of Three phase induction motor drive system**

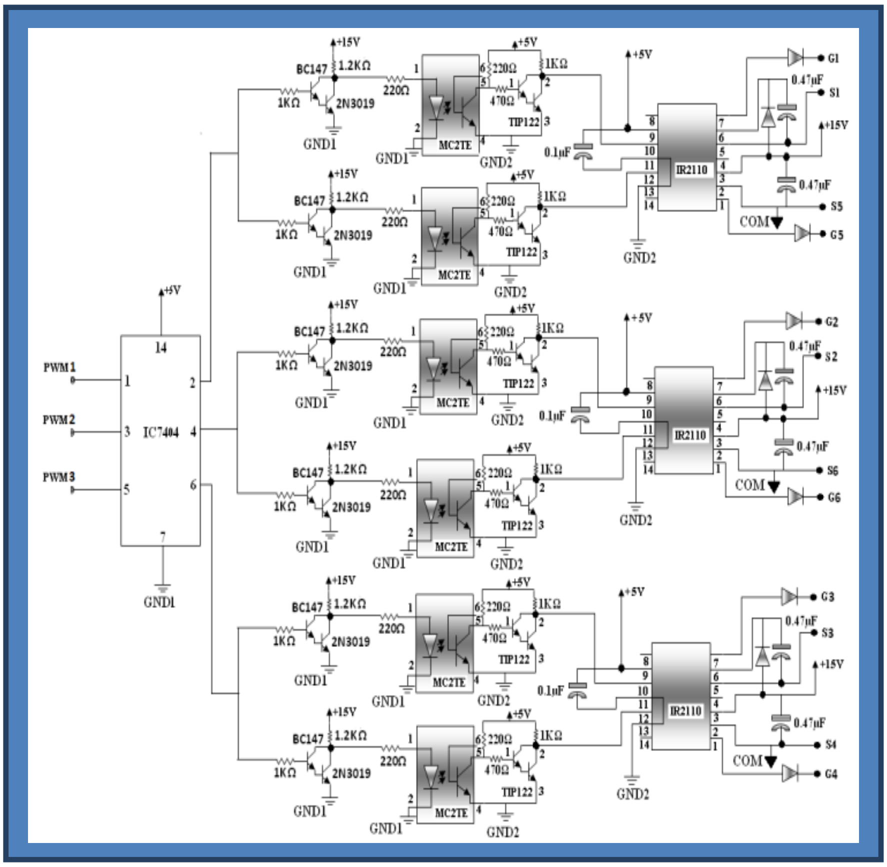


**Figure 2.Gate Drives Circuit**

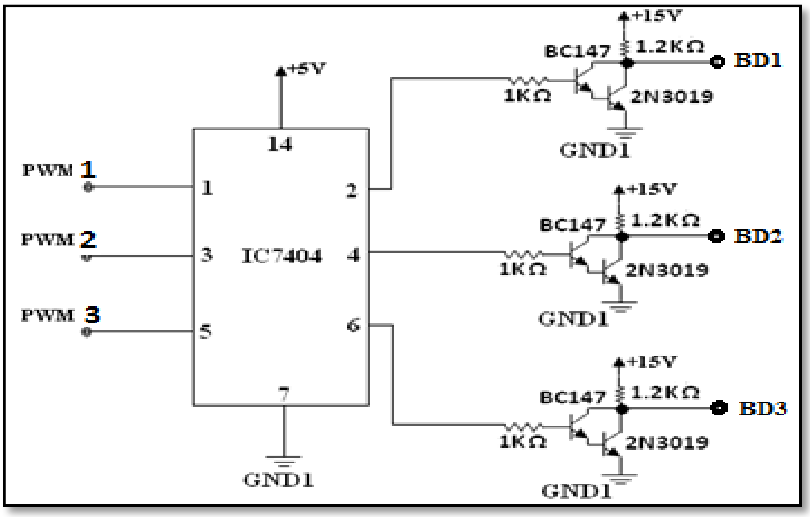


Figure 3.Buffer Circuit

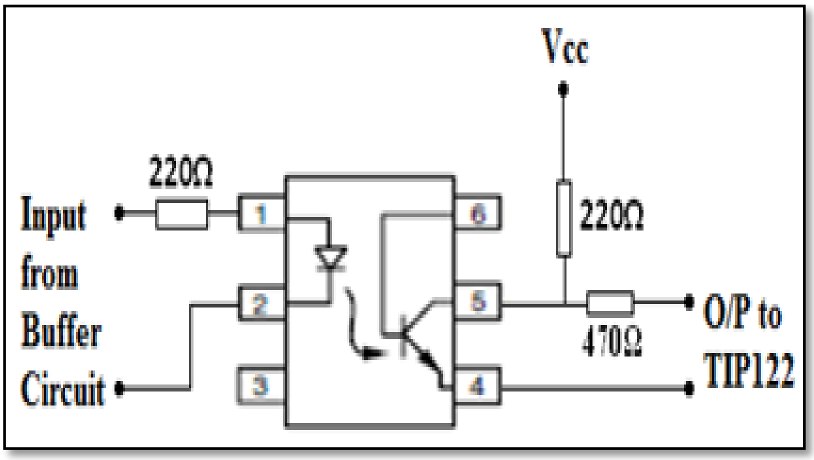


Figure 4. Internal Circuit of Opto-isolator

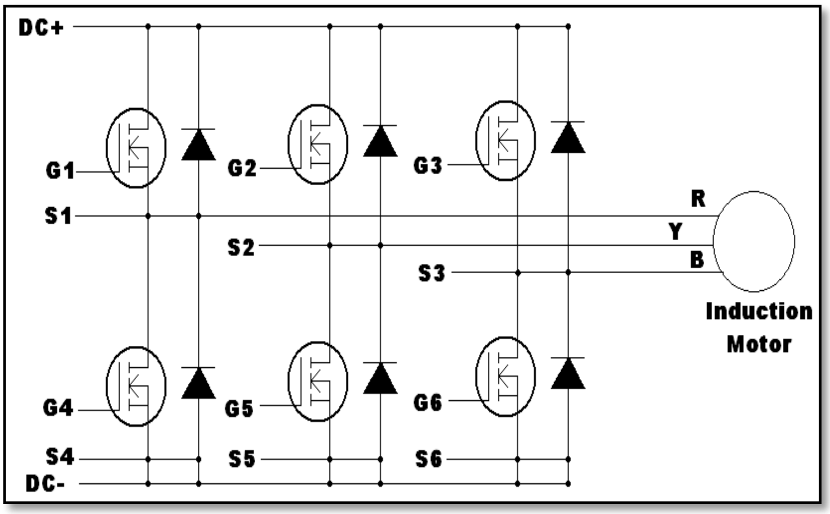


Figure 5. Three Phase Inverter Circuit

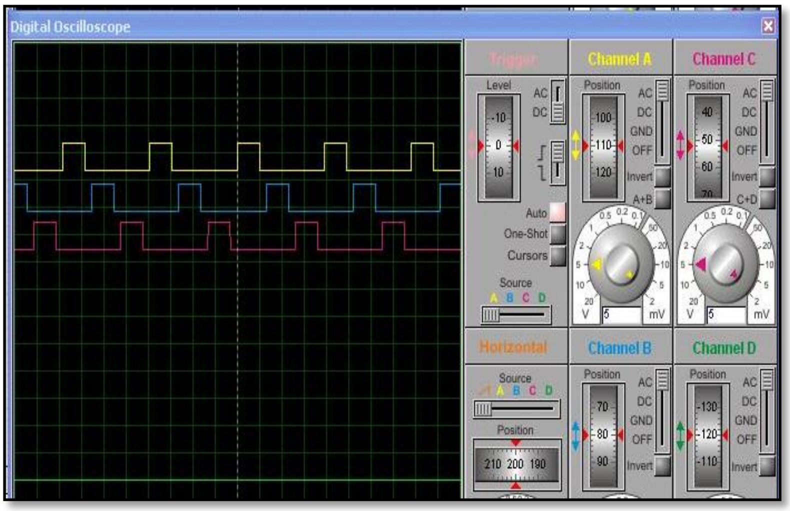


**Figure 6. Input PWM Pulses**

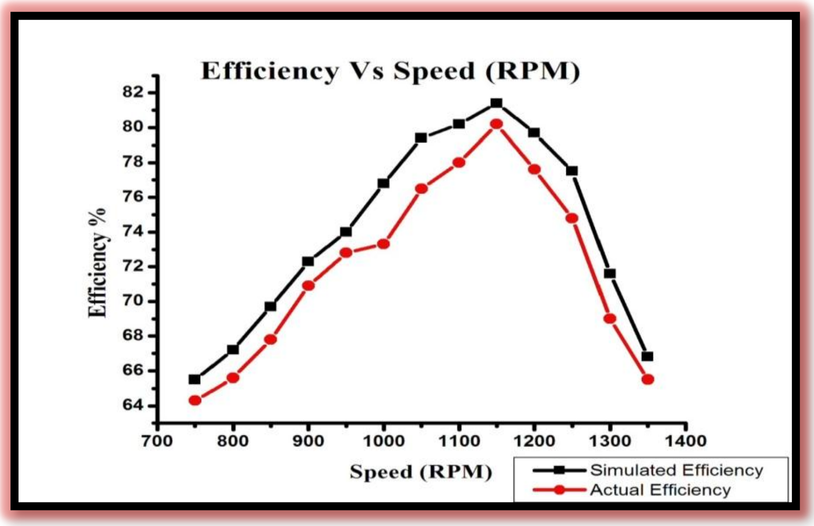


**Figure 7. Graph of Efficiency Vs Speed**

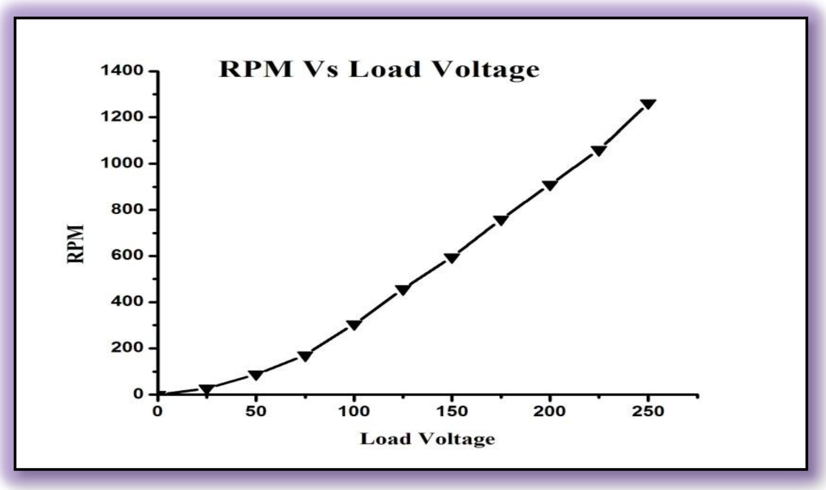


**Figure 8.Graph of RPM Vs Load Voltage**

ISSN: 2277-5536 (Print); 2277-5641 (Online)

**Observations**

The aim of the present work is to develop the PIC microcontroller based induction motor drive and to measure the speed of the induction motor involved. The designed drive is tested for pulse width modulation. The system is simulated and compared with experimental results for different speeds. The experimental measurements of voltage, speed, efficiency etc. are carried out by varying the gate pulse width of inverter. The performance of the motor is tested during the water pumping and data is recorded which is further used in computational module to obtain the performance parameters of the motor. The simulated and the test results under water pumping are similar. The slight differences in the experimental results are due to the losses in the machine and error in the measuring instrument. Therefore, the proposed three phase drive is used for different range of induction motors. Figure 7 shows the graph of Efficiency against speed. It is seen that, initially as the speed increased the efficiency increases and attains maximum value at 1100 RPM and then decreases. This decrease in efficiency is due to the switching losses. Figure 8 shows the graph of RPM against load voltage of motor. From the figure it is seen that as the load voltage increased the speed of motor also increases linearly. Initially the graph is nonlinear and it can be corrected by applying the correction factor through software.

**CONCLUSION**

It is seen that, initially as the speed increased the efficiency increases and attains maximum value at 1150 RPM and then decreases. The simulated efficiency and actual efficiency are nearly equal.

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