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Speed Control of Induction Motor Using Universal Controller

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Abstract**—** *When connected to main power supply, Induction motors run at their rated speed, however there are many applications where variable speed operations are required. This paper presents the development of an efficient and versatile universal board which is used to control the speed of single-phase or three-phase machines with minor modifications in software and hardware. Although a range of induction motor control techniques are available, generating variable frequency supply is a popular control technique having a constant voltage to frequency ratio in order to attain constant (maximum) torque throughout the operating period. This control technique is called variable frequency control. The complete system consists of an AC voltage input that is put through a rectifier to produce a DC output which is across a shunt capacitor, this will in turn feed the PWM inverter. The PWM inverter is controlled to produce desired sinusoidally voltage at a particular frequency and then through the induction motor.*

Keywords**— *Induction Motor; Microcontroller; Pulse Width Modulation; Inverter; Speed Control.***

I. INTRODUCTION

The synchronous speed of the stator revolving flux (Ns) is given by -

$$Ns = \frac{120f}{p}$$

Where, the supply frequency in Hz is f and the number of poles is p. As the number of poles is fixed varying the supply frequency would result in variation in the speed of induction motor. Variation of voltage should be in proportion to frequency so that the torque developed is constant over the speed range. This in particular what variable frequency (V/f) control attempts to accomplish. For speed control of an electric machine, the AC machine is equipped with an adjustable frequency drive. The speed of the electric machine is controlled by converting the fixed voltage and frequency of the grid to adjustable values on the machine side. This paper interests in three-phase inverter circuit that changes DC input voltage to a three-phase variable frequency variable voltage output. Three-phase inverters are also used in applications in which AC with a controllable frequency is required. In this application, single-phase AC is rectified into DC and then filtered to minimise the ripple content generally, the DC link is used for this purpose. This DC is converted into controlled pulses by means of a voltage to frequency converter. These controlled pulses are fed to the inverter bridge for producing variable voltage variable frequency output. For controlling its speed this output is fed to the three phase induction motor.

II. LITERATURE REVIEW

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The literature search was mainly focused on topics related to the speed control of induction motor. The review of publications and research work revealed the basic guidelines and area of work need to be conducted on an induction motor, where a positive result is expected. New technological development efficiency of the electronic switches is increasing every day and it is becoming cheap also for use in regular day to day use. The system was designed and implemented with the following goals to be completely different from traditional speed control methods of induction motor.

[I]K.Sandeep Kumar et.al:-

In this paper, recent advances in semi-conductor technology and implementation of microcontroller for speed control of induction motor are summarized in detail. The had addressed the variable speed drives of induction motor for constant maximum using V/f method. The proposed system is this paper is designed with closed loop where the actual speed of motor is compared with reference speed and the difference the speed is adjusted by changing firing angles of switching devices and thereby variable speeds.

[II] Puja Talukder et.al:-

This research interests in three-phase inverter circuit that changes DC input voltage to a phase variable-frequency variable-voltage output. Three-phase inverters also used in applications in which AC with a controllable frequency is required. In this application, three phase AC is rectified into DC and then filtered to minimize the ripple content. Thus a variable DC is obtained by employing three phase full controlled power transistors bridge. This controlled DC is converted into controlled pulses by means of voltage to frequency converter. These controlled pulses are fed to the inverter bridge for producing the variable voltage variable frequency output. This output is fed to the three phase induction motor for controlling its speed.

[III] Sachin Hegde et.al:-

In this paper a new speed control approach for ac motor drives that use programmed switching patterns over the complete range of output speed is presented. The propose Provides smooth operation during the require switching pattern changing transitions high quality output voltage and current in the ac motor load and is therefore most suitable for high performance, high efficiency applications.

[IV] Thida Win et.al:-

In this research paper drive schemes of three phase induction motor, principle of operations of components used in constructing variable speed drive and design calculation to construct this drive are included.

III. METHODOLOGY

3.1 Variable frequency AC motor drive

The traditional variable-frequency drive changes the motor's frequency and voltage using solid-state control units.

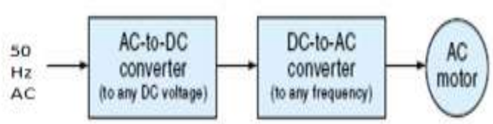

FIGURE 1: A block diagram of a variable-speed-control system.

The basic steps for this process are shown in the block diagram of fig.1. The first step is to convert 50 Hz AC into DC power. The second step is to convert this DC power back into AC at the desired frequency.

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3.2 Transistor based variable-frequency Induction motor drive

The modern strategy for controlling the AC output of such a power electronic converter is the technique known as Pulse Width Modulation (PWM), which varies the duty cycle of the converter switches at a high frequency to achieve a target average low frequency output voltage or current. All modulation schemes aim to create trains of switched pulses, which have the same fundamental volt-second average as a target reference waveform at any instant. The major difficulty with these trains of switched pulses is that they also contain unwanted harmonic components, which should be minimised

3.3 Variable frequency control of induction motor (V/f method)

The synchronous speed of an induction motor is given by,

$$Ns = \frac{120f}{p}$$

Where, f =supply frequency

P=number of poles.

Synchronous speed is directly proportional to the supply frequency. Hence, by changing the frequency, the synchronous speed and motor speed can be controlled below and above the normal full-load speed. The voltage induced in the stator is proportional to the product of the slip frequency and air gap flux. The motor terminal voltage can be considered proportional to the product of frequency and flux, if the stator drop is neglected. Any reduction in the supply frequency without a change in the terminal voltage causes an increase in the air-gap flux. Induction motors are designed to operate at the knee point of the magnetisation characteristics to make full use of the magnetic material. Therefore, an increase in flux will saturate the motor. This will increase the magnetising current, distort the line current and voltage, increase the core loss and the stator copper loss, and produce a high pitch acoustic noise. While any increase in flux beyond the rated value is undesirable from the consideration of saturation effects, a decrease in flux is also avoided to retain the torque capability of the motor. Therefore, the variable frequency control below the rated frequency is generally carried out by reducing the machine phase voltage along with the frequency in such a manner that flux is maintained constant.

IV. IMPLEMENTATION

4.1 Block Diagram

The complete block diagram of speed control of three-phase induction motor is as shown in figure 2.

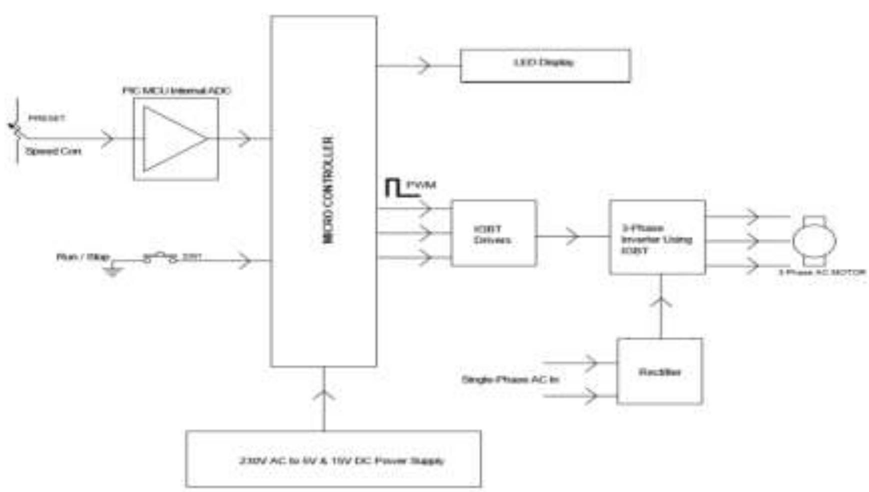

FIGURE 2: Complete block diagram of drive.

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The hardware control system includes squirrel cage induction motor, controlled rectifier, bridge inverter, microcontroller and switches for user interface.

4.2 Controlled rectifier unit

The rectifier unit converts AC signal into DC output, which is adjusted by the delay time of the gate firing pulse to each thyristor from the instant it would have turn ON. In other words adjusting the gate firing pulse with respect to reference instant.

The figure 3 shows DC output of the rectifier, it serves to input of bridge inverter, an intermediate filter circuit will be desirable to minimize the ripples in the voltage.

FIGURE 3: DC output of rectifier

4.3 Motor Drive

The 3-phase induction motor is connected to a 3-phase inverter bridge as shown in Figure 4. The power inverter has 6 switches that are controlled in order to generate 3-phase AC output from the DC bus. PWM signals, generated from the microcontroller, control these 6 switches. Switches IGBTH1 through IGBTH3, which are connected to DC+, are called upper switches. Switches IGBTL1 through IGBTL3, connected to DC-, are called lower switches. The amplitude of phase voltage is determined by the duty cycle of the PWM signals. While the motor is running, three out of six switches will be on at any given time; either one upper and two lower switches or one lower and two upper switches. The switching produces a rectangular shaped output waveform that is rich in harmonics. The inductive nature of the motor's stator windings filters this supplied current to produce a 3-phase sine wave with negligible harmonics. When switches are turned off, the inductive nature of the windings oppose any sudden change in direction of flow of the current until all of the energy stored in the windings is dissipated. To facilitate this, fast recovery diodes are provided across each switch. These diodes are known as freewheeling diodes. To prevent the DC bus supply from being shorted, the upper and lower switches of the same half bridge should not be switched on at the same time. A dead time is given between switching off one switch and switching on the other. This ensures that both switches are not conductive at the same time as each one changes states.

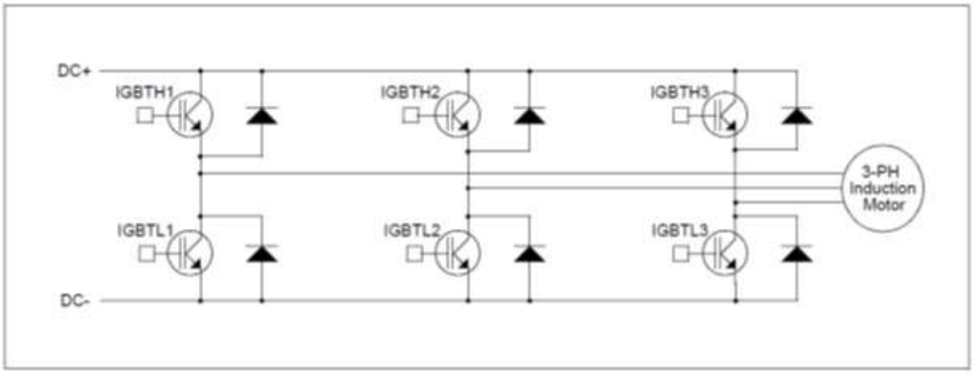

FIGURE 3: Three phase Inverter Circuit

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4.4 Pulse Width Modulation

Pulse-width modulation is a digital technique for varying the amount of power delivered to an electronic component. By adjusting the amount of power delivered to a motor or LED, the speed or brightness (respectively) can be controlled. The simplest and most flexible PWM is generated by a microcontroller.

Pulse-width modulation (PWM), or pulse-duration modulation (PDM), is a commonly used technique for controlling power to inertial electrical devices, made practical by modern electronic power switches.

The average value of voltage (and current) fed to the load is controlled by turning the switch between supply and load on and off at a fast pace. The longer the switch is on compared to the off periods, the higher the power supplied to the load is.

The PWM switching frequency has to be much faster than what would affect the load, which is to say the device that uses the power. Typically switching have to be done several times a minute in an electric stove, 120 Hz in a lamp dimmer, from few kilohertz (kHz) to tens of kHz for a motor drive and well into the tens or hundreds of kHz in audio amplifiers and computer power supplies.

The term duty cycle describes the proportion of 'on' time to the regular interval or 'period' of time; a low duty cycle corresponds to low power, because the power is off for most of the time. Duty cycle is expressed in percent, 100% being fully on.

The main advantage of PWM is that power loss in the switching devices is very low. When a switch is off there is practically no current, and when it is on, there is almost no voltage drop across the switch. Power loss, being the product of voltage and current, is thus in both cases close to zero. PWM also works well with digital controls, which, because of their on/off nature, can easily set the needed duty cycle.PWM has also been used in certain communication systems where its duty cycle has been used to convey information over a communications channel.

4.5 Microcontroller

PIC (Peripheral interface controller) is the IC while was enveloped to control the peripheral device, dispersing the function of the main CPU. PIC has the calculation function and the memory like the CPU and is controlled by the software. However the throughput, the memory capacity isn’t big. It depends on kind of PIC but the maximum operation clock frequency is about 20MHZ and the memory capacity to write the program is about 1K to 4K words. The clock frequency is related with the speed to read the program and to execute the instruction. Only at the clock frequency, the throughput cannot be judged. It changes with the architecture in the processing parts for same architecture; the one with the higher clock frequency is higher about the throughput. The point, which the PIC convenient for is that the calculation part, the memory, the input/output part and so on, are incorporated into one piece of the IC. The efficiency, the function is limited but can compose the control unit only by the PIC even if it doesn't combine the various IC's so, the circuit can be compactly made.

A potentiometer connected to a 10-bit ADC channel (AN1) determines the motor frequency. The microcontroller uses the ADC results to calculate the PWM duty cycle and thus, the frequency and the amplitude of the supply to the motor. For smooth frequency transitions, the channel AN1 is converted at every 4 ms. The Timer1 reload value is based on the ADC result (AN1), the main clock frequency (FOSC) and the number of sine table entries (36 in the present application). After every Timer1 overflow, the value pointed to by the offset register on the sine table is read. The value read from the sine table is scaled based on the motor frequency input. The sine table value is multiplied with the frequency input to find the PWM duty cycle and is loaded to the corresponding PWM duty cycle register. Subsequently, the offset registers are updated for next access. If the motor direction key is pressed, then PWM1 ~ PWM6 duty cycle values are loaded to PWM1 ~ PWM6 duty cycle registers, respectively. The new PWM duty cycle values will take effect at the next Timer2 overflow. Also, the duty cycle will remain the same until the next Timer1 overflow occurs, as shown in Figure 5. The frequency of the new PWM duty cycle update determines the motor frequency, while the value loaded in the duty cycle register determines the amplitude of the motor supply.

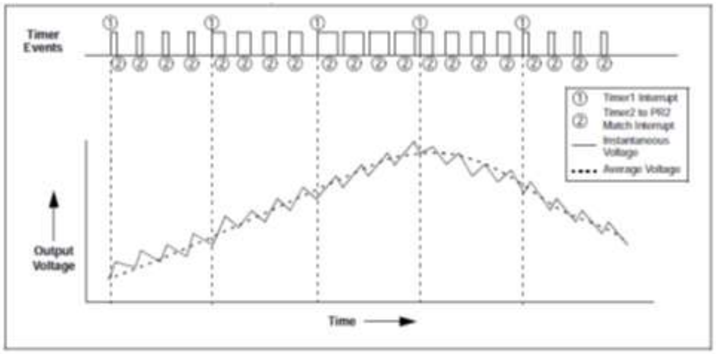

FIGURE 5: Timer events and Output Voltage

V. CONCLUSION

To control the speed of a three phase induction motor in open loop, supply voltage and frequency need to be varied with constant ratio to each other. The method used to control the inverter switches is sinusoidal pulse width modulation (SPWM). The control circuit using microcontroller is developed, therefore the inverter control circuit hardware is reduced modulation ratio, the frequency modulation ratio, dead time period and duty cycle can be easily change through programming without further hardware changes.

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