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Speed Control of Induction Motor by V/F Method Using Fuzzy Technique

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Abstract: ***Most of the induction motor drives are based on keeping constant voltage/frequency (v/f) ratio in order to maintain a constant flux in the machine. In this paper method uses a fuzzy logic through pic 16f15355 for high performance of single phase induction motor. The work involves implementation of an closed loop control scheme for an induction motor.***

Keywords: Fuzzy logic, induction motor, real time system

1. Introduction

An induction motor can run only at its rated speed when it is connected directly to the main supply. However, many applications need variable speed operations. This is felt the most in applications where input power is directly proportional to the cube of motor speed. In applications like the induction motor-based centrifugal pump, a speed reduction of 20% results in an energy savings of approximately 50%. Driving and controlling the induction motor efficiently are prime concerns in today's energy conscious world.

With the advancement in the semiconductor fabrication technology, both the size and the price of semiconductors have gone down drastically. This means that the motor user can replace an energy inefficient mechanical motor drive and control system with a *Variable Frequency Drive* (VFD). The VFD not only controls the motor speed, but can improve the motor's dynamic and steady state characteristics as well. In addition, the VFD can reduce the system's average energy consumption.

Although various induction motor control techniques are in practice today, the most popular control technique is by generating variable frequency supply, which has constant voltage to frequency ratio. This technique is popularly known as *VF control*. Generally used for open-loop systems, VF control caters to a large number of applications where the basic need is to vary the motor speed and control the motor efficiently. It is also simple to implement and cost effective.

AC induction motors are the most common motors used in industrial motion control systems, as well as in main powered home appliances. Simple and rugged design, low-cost, low maintenance and direct connection to an AC power source are the main advantages of AC induction motors. Various types of AC induction motors are available in the market. Different motors are suitable for different applications. Although AC induction motors are easier to design than DC motors, the speed and the torque control in various types of AC induction motors require a greater understanding of the design and the characteristics of these motors

2. V/F Control Theroy

A discussion of induction motor control theory is beyond the scope of this document. . The *base speed* of the induction motor is directly proportional to the supply frequency and the number of poles of the motor. Since the number of poles is fixed by design, the best way to vary the speed of the induction motor is by varying the supply frequency.

The torque developed by the induction motor is directly proportional to the ratio of the applied voltage and the frequency of supply. By varying the voltage and the frequency, but keeping their ratio constant, the torque developed can be kept constant throughout the speed range. This is exactly what VF control tries to achieve. Figure 1 shows the typical torque-speed characteristics of the induction motor, supplied directly from the main supply. Figure 2 shows the torque-speed characteristics of the induction motor with VF control.

Other than the variation in speed, the torque-speed characteristics of the VF control reveal the following:
• The starting current requirement is lower.
• The stable operating region of the motor is increased.

Instead of simply running at its base rated speed (NB), the motor can be run typically from 5% of the synchronous speed (NS) up to the base speed. The torque generated by the motor can be kept constant throughout this region.

• At base speed, the voltage and frequency reach the rated values. We can drive the motor beyond the base speed by increasing the frequency further. However, the applied voltage cannot be increased beyond the rated voltage. Therefore, only the frequency can be increased, which results in the reduction of torque. Above the base speed, the factors governing torque become complex.

• The acceleration and deceleration of the motor can be controlled by controlling the change of the supply frequency to the motor with respect to time.

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FIGURE 1: TORQUE-SPEED CHARACTERISTICS OF INDUCTION MOTOR

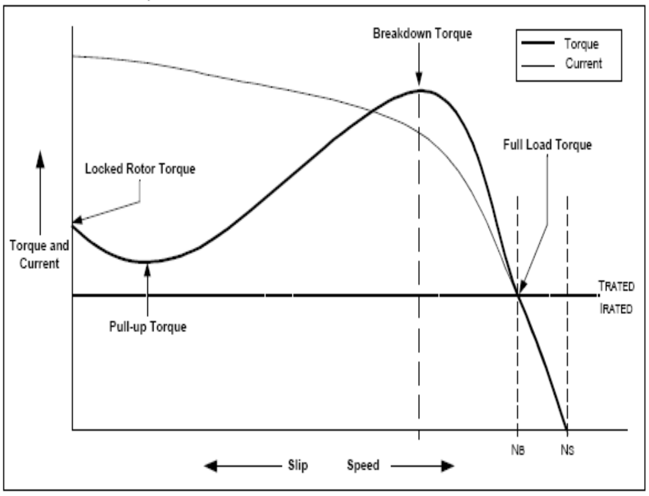
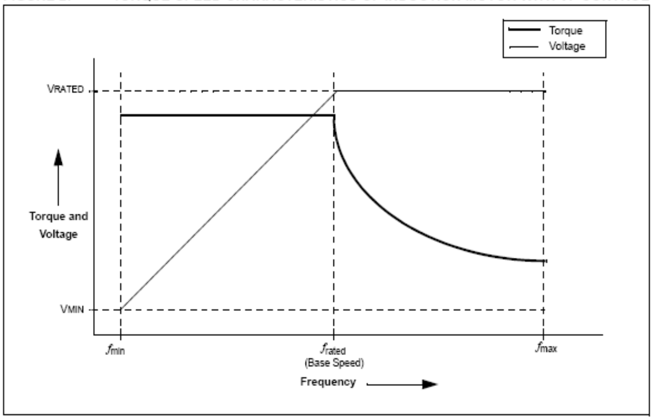


FIGURE 2: TORQUE-SPEED CHARACTERISTICS OF INDUCTION MOTOR WITH VF CONTROL

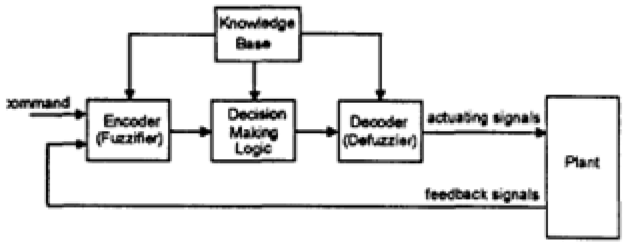


The VFD is a system made up of active/passive power electronics devices (IGBT, MOSFET, etc.), a high-speed central controlling unit (a microcontroller, like the PIC18 or the PIC16) and optional sensing devices, depending upon the application requirement. The basic function of the VFD is to act as a variable frequency generator in order to vary speed of the motor as per the user setting. The rectifier and the filter convert the AC input to DC with negligible ripple. The inverter, under the control of the microcontroller, synthesizes the DC into single-phase variable voltage, variable frequency AC

3. Fuzzy Controller Of Pwm Inverter

Fuzzy set theory first introduced by Zadeh was used to describe inexact information, but after Mamdani's pioneer work on its application to a steam engine control many applications of fuzzy control in industry processes have been developed. The fuzzy controller consists of a set of linguistic rules that describe the operator's control strategies. These rules are based on the experiences of a human operator. Because the detailed dynamics of the controlled process is not needed in the design process, *fuzzy* control possesses an inherent robust property. This paper presents a fuzzy control scheme for the closed-loop regulation of a PWM inverter in application of high performance uninterruptible power supply (UPS) systems.

Different methods for developing *fuzzy* controllers have been suggested in recent years. According to the observed and simulated dynamic behaviors of an ac power source under various load conditions, an innovative fuzzy control scheme is proposed and implemented by using a microcontroller 16f15355. A typical *fuzzy* controller as shown in Fig consists of three major parts: a fuzzifier, a decision making logic, and a d e w i e r . The key to a successful design of a fuzzy controller relies on the suitable selection of *fuzzy* variable and linguistic rules obtained from practical experiences and intuitive tries.

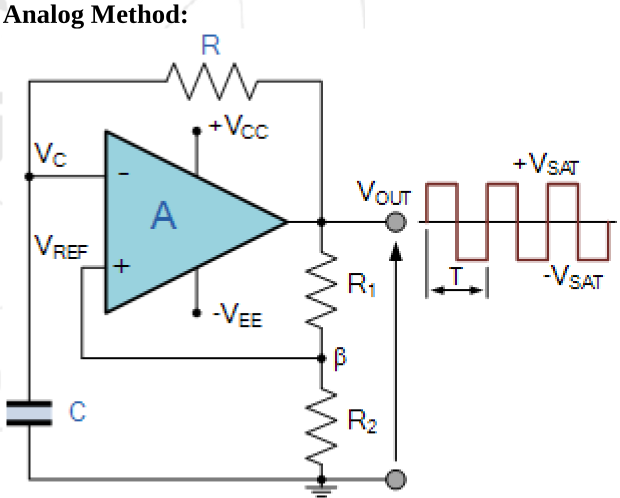


4. *V/f* Speed-Control System Structure

Control of Single Phase Induction Motor-Conventional Methods: The possible methods of controlling the speed of Single Phase induction motors are as follows:

We know that various PWM method are available to control speed of induction motor. SPWM, MPWM, PWMSVM etc. one more point is SPWM is analog method we can also use digital method to generate PWM. We explain here analog method and digital method.

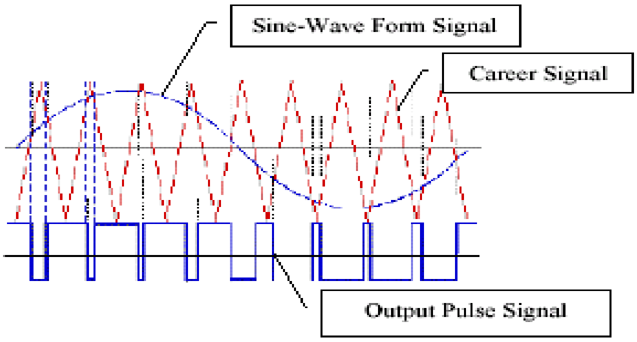
Analog Method:



Here we explain PWM generation using astable multivibrator and zero crossing detectors. So above shown dig is astable multivibrator using op-amp.

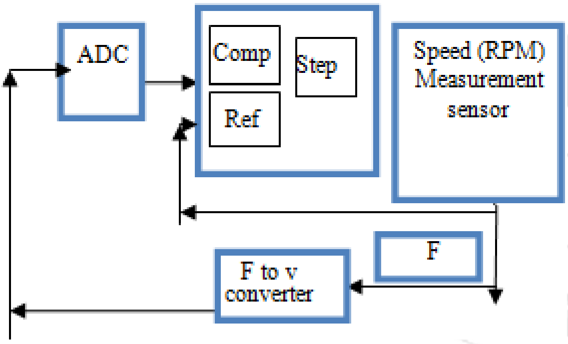
The op-amp multivibrator is an astable oscillator circuit that generates a rectangular output waveform using an RC timing n/w connected to the inverting input of the op-amp & voltage divider n/w connected to the other non-inverting input. An astable multivibrator which has no stable state its output oscillates continuously between its two unstable states without the aid of external triggering. The time period of each state are determined by RC time constant. astable multivibrator input is given to the zero crossing detector. It is used to track the changing in the sine wave from positive to negative or vice versa while it crosses zero voltage.

Whenever that triangular wave crosses zero the output of the op-amp will shift either from negative to positive or from positive to negative. In addition to make the voltage applying (carrier signal) has a sine wave shape the inverter controls the ON/OFF duty cycle. 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 carrier signal with the sine waveform. This method is called PWM control.



When we consider the positive half cycle of the sine wave input. We know that, when the voltage at the non-inverting end is less than the voltage at inverting end, the output of the Op-amp output is Low or of negative saturation. Hence, we will receive a negative voltage waveform. Then in negative half cycle of the sine wave, the voltage at the non-inverting end (reference voltage) becomes greater than the voltage at inverting end (input voltage), so the output of the Op-amp becomes High or of positive saturation

Digital Method



From above block dig we explain how PWM wave generated in digital method. First we sense the speed (RPM) of the motor using speed sensor and that speed is converted in frequency. This frequency is given to the F to V converter. Converter converts the frequency into voltage. Converter working is the circuit charges the capacitor to a certain level. An integrator is connected in it and the capacitor discharges into this integrator or a low pass circuit. This happens for all the cycles of the input waveform. AC output is given to the ADC which converts it into DC voltage. Then it gives to the controller. In that capture mode is a peripheral that allows the user to time and control different events. The compare mode allows the user to trigger an external event when a predetermined amount of time has expired. And the PWM mode can generate pulse width modulated signals of varying frequency and duty cycle. Then using some algorithms we can generate the ratio of v/f constant. Hence we use here digital method to generate the PWM signal.

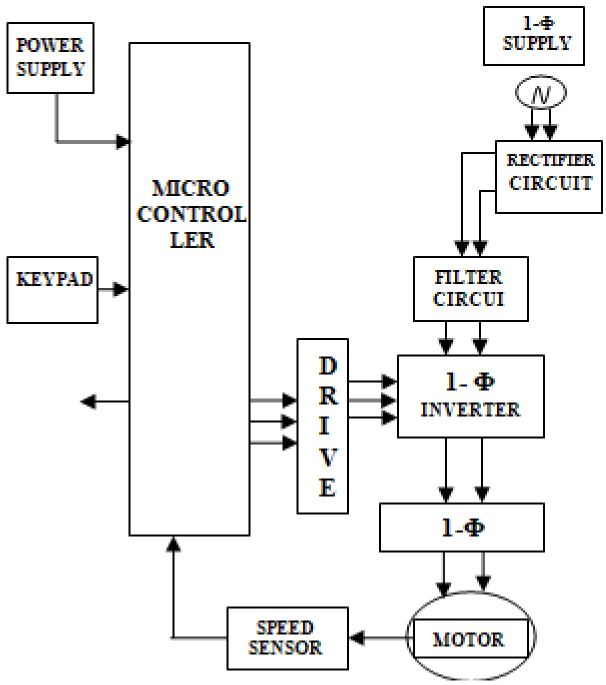
5. Block Diagram

The below block diagram gives an overview of the project in the pictorial form. With the help of the block diagram we will create pre model of the project and analyze the function of the project .The explanation of the project with block diagram over view is given as follows

Microcontroller

In complicated process-control systems. However, because of their small size and low price, Micro-controllers are now also being used in regulators for individual control loops. In several areas Micro-controllers are now outperforming their analog counter parts and are cheaper as well. In this project microcontroller is used to generate different firing pulses applied to inverter. In this project work the micro-controller plays a major role. Micro-controllers were originally used as components

The microcontroller (16F15355) is used as the controller for producing the necessary control signals. The controller is given a speed reference as an input parameter. The three ports of the microcontroller have been utilized for providing the output signal. The output signal is conditioned using a DAC and the required sinusoidal control signal is generated. This sinusoidal signal is then further conditioned to obtain the PWM signal which is given at the gate terminal of the power electronic switches. In order to vary the speed the set reference is varied which changes the frequency of the sinusoidal signal it generates through DAC. This variation varies the duty cycle of the devices. Therefore the voltage also gets varied and a constant v/f ratio is obtained.



<u>**Power Supply Section**</u>

This section is meant for supplying Power to all the sections mentioned above. It basically consists of a Transformer to step down the 230V ac to 18V ac followed by diodes. Here diodes are used to rectify the ac to dc. After rectification the obtained rippled dc is filtered using a capacitor Filter. A positive voltage regulator is used to regulate the obtained dc voltage.

Rectifier Circuit

Rectifier circuit is designed to convert single phase supply to DC supply. Here we are using full bridge rectifier for rectifying AC into DC.

Filter Block

The output of the rectifier block is in the pulsating DC and for getting pure DC we are using filtration block. In filtration block we are using 470 uf/ 470v capacitor.

Inverter

A. Selection of IGBT:-

1) What is the operating voltage? The highest voltage the IGBT has to block should be no more than 80% of the VCES rating. So we selected here VCES=1200v.
2) Is it hard or soft switched? A PT device is better suited for soft switching due to reduced tail current; however a NPT device will also work. So here we use soft switching turn off waveforms.
3) What is the current that will flow through the device? The first two numbers in the part number give a rough indication of the usable current. For hard switching applications, the usable frequency versus current graph is helpful in determining whether a device will fit the application. Differences between datasheet test conditions and the application should be taken into account, and an example of how to do this will be given later. For soft switching applications, the IC2 rating could be used as a starting point. So here we select KGT25N120NDH. Here 25 is a rough indication of the usable current.
4) What is the desired switching speed? If the answer is "the higher, the better", then a PT device is the best choice. Again, the usable frequency versus current graph can help answer this question for hard switching applications.
5) Is short circuit withstanding capability required? For applications such as motor drives, the answer is yes, and the switching frequency also tends to be relatively low. An NPT device would be required. Switch mode power supplies often don't require short circuit capability.

Features of the selected IGBT:-

- High speed switching
- High ruggedness, temperature stable behavior
- Soft current turn-off waveforms
- Extremely enhanced avalanche capability

B. Selection of inverter circuit

Here we select a half bridge type inverter composed of 4 IGBT's, driving circuit, micro-processor system and DC voltage source. The capacitance C1 and C2 ensure that the point C at the junction of two phase windings has zero potential. In a H-Bridge Driving System reported before, square voltage waveforms whose phase-difference angle is 90°, were supplied to the two phase windings by switching Tr1 - Tr4.

The constant DC voltage is converted into variable AC voltage by using inverter circuit. In this project we are using bridge inverter designed with IGBT'S.

Motor Selection

Single-Phase Induction Motors:

Construction--The induction motor has a rotor that is not connected to an external source of voltage. The induction motor derives its name from the fact that ac voltages are induced in the rotor circuit by the rotating magnetic field of the stator. In many ways, induction in this motor is similar to the induction fields between the primary and secondary windings of a transformer. Large motors and permanently mounted motors that drive loads at fairly constant speed are often induction motors. The stator consists of main winding & a starting winding (auxiliary). The starting winding is connected in parallel with the main winding & is placed physically at right angles to it. The induction rotor is made of a laminated cylinder with slots in its surface. The windings in these slots are one of two types. The most common is the squirrel cage winding. The entire winding made up of heavy copper bars connected together at each end by a metal ring made of copper or brass. No insulation is required between the core & the bars. This is because of the very low voltages generated in the rotor bars. The other type of winding contains actual coils placed in the rotor slots. The rotor is then called a wound rotor. Regardless of the types of rotor used the basic principle is the same.

Torque – If we take stator with a single winding & apply a single phase voltage to it, we will have an alternating current flowing and thereby an alternating magnetic field at each pole. Unfortunately this does not result in rotating fields, one in the forward direction and one in the reverse direction. If we have a short circuited rotor within the stator, it will be two equal and counter rotating torque fields. This will cause the rotor to vibrate but not to rotate.

Torque development – In order to rotate, there must be a resultant torque field rotating in one direction only. If we now add a second stator winding, physically displaced from the first winding and apply a voltage equally displaced in phase, we will provide a second set of counter rotating magnetic fields and the net result is a single rotating field in one direction. If we reverse the phase shift of the voltage applied to the second winding, the resultant magnetic field will rotate in the reverse direction. The Permanent Split Capacitor (PSC) single-phase induction motor is the simplest and most widely used motor of this type. By design, PSC motors are unidirectional, which means they are designed to rotate in one direction. It has a starting and running winding and a capacitor connected permanently in order to produce a 90° electrical phase shift between the two windings. Since capacitor is a frequency dependent component, changing the frequency of the input supply affects the electrical degree of 90° produced by it. If this degree changes, the torque developed also changes. As the input voltage and frequency are fixed irrespective of different operating conditions, the resultant drive performance may also be degraded. Mechanical methods of changing the speed 372 uses gear arrangement causes for a power wastage in the machine. These methods normally do not achieve continuous and instant control of motor speed.

The method proposed in this paper deals with a technique of controlling such a single phase induction motor with the help of microcontroller which enables to control speed of the single phase induction motor as well as its direction of rotation and also the amount of power consumed. By this the starting capacitor can be removed which gives the advantage of employing v/f rule in single phase induction drive system. The starting torque can also be increased which gives faster acceleration. The Pulse Width Modulation technique (PWM) is used to vary the speed of the Induction motor by varying the supply voltage as well as frequency. This PWM technique maintains a constant v/f ratio.

Specification of motor:
Voltage = 110 v
Frequency = 50/60 Hz
Speed = 2200 rpm
Wattage = ½ HP
Current = 3Amp

6. Calculations

After designing and implementations of this project first decide the total time period of the cycle. Here we consider the total time is 20ms then decide the Ton time and Toff time. From the table we get different no. of speed values on display are as follows:

Column1	Column2	Column3
	observations	
duty cycle in percentage	speed in RPM	Tachometer
10	100	372
12.5	175	500
15	240	800
17.5	290	850
20	360	960
22.5	430	1120
25	530	1280
27.5	680	1400

From the above table here we compare the displayed speed values to the tachometer speed values for accuracy. Also we can observe and calculate the minimum and maximum speed values. Min. value 300 and max. Value 900 then we can calculate the lookup table.

Column1	Column2	Column3	Column4
speed value	PWM count	Voltage	v/f ratio
300	0	60	1.2
400	1	80	1.6
500	2	110	2.2
600	3	132	2.64
700	4	117	2.34
800	5	124	2.48
900	6	132	2.64

In above table we calculate a v/f ratio
i.e

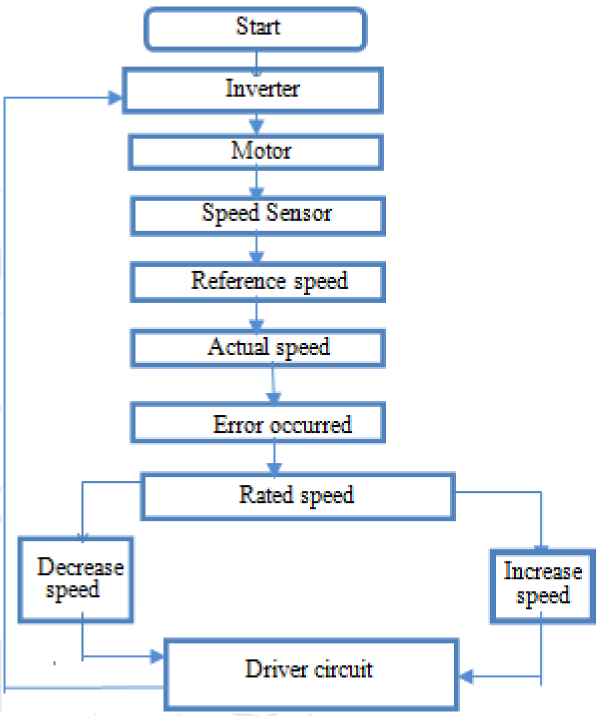
Stator Voltage (V) ∝ [Stator Flux(ϕ)] x [Angular Velocity (ω)]

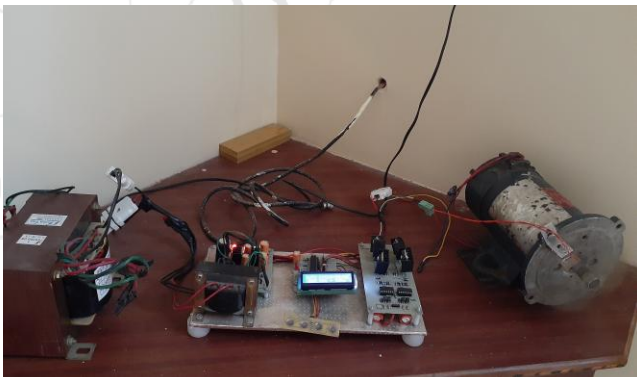
$V \propto \phi \times 2\pi f$

$\phi \propto V/f$

From above formula we calculate v/f ratio.Then above table is converted into fuzzy logic using if else condition then we get correct results. Hence we can control the speed of single phase induction motor by v/f method.

7. Flow Chart





8. Conclusion

The Speed control of induction motor by v/f using fuzzy technique has been successfully designed and tested. Integrating features of all the hardware components used have developed it. Presence of every module has been reasoned out and placed carefully thus contributing to the best working of the unit. Secondly, using highly advanced IC's and with the help of growing technology the project has been successfully implemented.

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