Motor Speed Control Kits Using a Microcontroller.

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Abstract
The aim of this project is to make a motor laboratory kits for AC motors. It aims on making affordable kits which are made from locally available materials and applying the obtained knowledge from the four-year curriculum I have undertaken. Initially laboratory equipment's are very expensive and require huge amount of capital for an institution to purchase or acquire them. The methods used before used resistance rheostat to control the input voltage. The method we have used has a great advantage, since it doesn't involve use of variable resistors to control the high-power input side of a motor. It uses the method of PWM technique to vary the speed of motor. The PWM has high and low pulses which in turn sample the input voltage hence varying the frequency of the applied voltage high power input side. The implemented idea can even be applied in industries to control AC motors. It can also be applied in training institutions to practically educate the trainees on the field of AC motors and enable them to enhance acquired skills on the field of motors and machine drives. Arduino mega Microcontroller is used to produce the PWM for the speed control and also to interface with other components like IR, voltage and Current sensors and the LCD. The method is quite efficient and accurate in precision and also cheap to maintain.
Keywords: PWM; Affordable Laboratory Kit; Speed control; Load Voltage; Load Current.

1. Introduction

Frequency Drives are power electronic devices that are used to control the dynamic characteristics of electric motors based on the demand of the load. At that instant, Frequency Drives control the basic parameters of the motor example the frequency and speed to control the main characteristics like flux and torque. It attains it by use of a rectifier-inverter circuit. The rectifier converts incoming source power from AC to a DC and this DC is used by the inverter section to generate a three-phase AC needed depending on the load. The main objective is to design and implement a laboratory low-cost kit to help students gain and learn practical skills from the achieved knowledge in the field of motor and control systems. It will also introduce them to the use of a microcontroller/ microprocessor. However specific objectives of the project is controlling the speed of an AC three-phase induction motor through frequency control, to display input current of the controlled motor, observe the voltage input of the load and to ensure learners can calculate and learn different motor characteristics.

2. Literature Review

2.1 Flow Chart

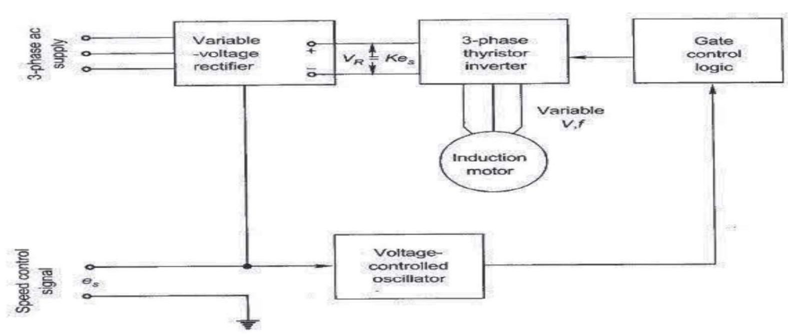

Figure 1: Flow Chart

2.1.1 Voltage Rectifier

Variable voltage rectifier stage converts AC line voltage supplied to the drive to DC. The voltage rectifier is either a silicon controller rectifier (SCR) or a diode. The difference between the two is that the SCR types increases switching gradually thus increasing the voltage applied to charge the DC bus. Diode types rely on a pre-charged circuit to perform the gradual voltage ramp-up of the DC bus capacitors. For drive rectifier stages, most commonly, there is a 6 diode or 6 SCR arrangement that makes up what is called a 6-pulse rectifier.**Invalid source specified.**

The most economical is a diode-based rectifier.

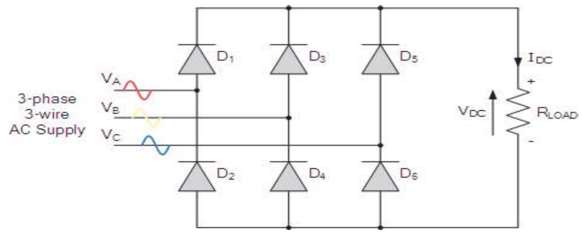

Figure 2 diode-based rectifier.

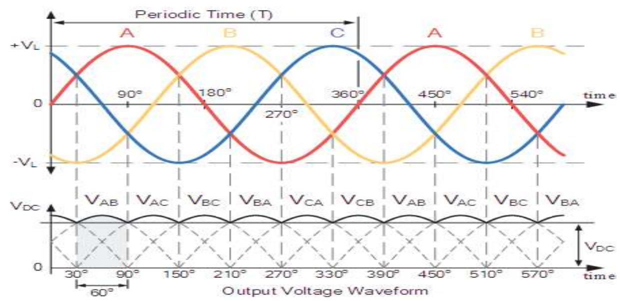

Figure 3 Characteristics of the rectified three-phase supply waveform

Induction motor torque-speed characteristic curves for speeds above base speed, assuming that the stator voltage remains constant.

If the frequency applied to the motor exceeds the rated frequency, the voltage of the stator is held constant at the rated value. Although the applied voltage can be increased above the rated value without reaching saturation, it is limited to the rated voltage. This protects the winding insulation of the motor from burning. As the frequency raises while the voltage remains constant, the resulting magnetic flux and the maximum torque will decrease proportionally.

2.1.2 DC Bus Circuit

This is the second main section of a frequency drive's main power circuit it is comprised of capacitors that store power or charge which is rectified by the converter (tutorialspoint, n.d.)

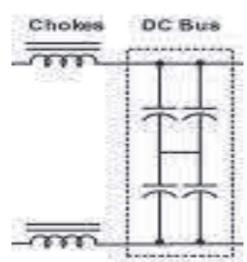

Figure 4: DC Bus Circuit

DC bus chokes help to reduce the negative effects of voltage disturbances especially voltage dips, or sags (are a reduction of the voltage of 10% or more below normal or recommended usage). After the occurrence of voltage sag, the DC bus capacitor is recharged to match the level of the source voltage. But voltage cannot change instantly in a capacitor, so an immediate inrush of current attempts to stabilize the capacitor voltage. The DC choke resists this high current inrush protecting the voltage rectifiers and DC bus capacitors.

The main flaw to a DC bus choke is that its location is after the input diodes. This prevents it from protecting the rectifier against voltage surges from the AC line supply.

2.1.3 Three-Phase Inverter Circuit

This stage converts the DC from the DC bus back to AC, this forms the most critical part of the frequency drive. It consists of microcontroller integrated circuits that are designed and programmed to change the output frequency along with the voltage proportionately. It also creates a three-phase output from a single-phase input. This stage makes frequency drives very unique and most ideal for AC motor speed control (tutorialspoint, n.d.)

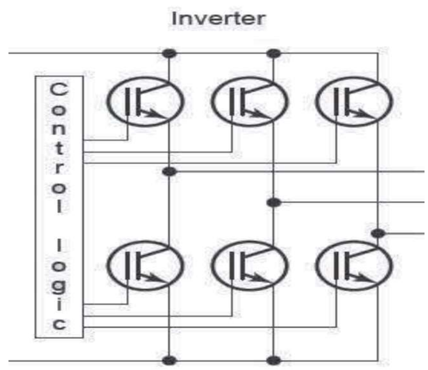

Figure 5: IGBT based inverter circuit diagram

2.1.4 Control Logic Block Diagram

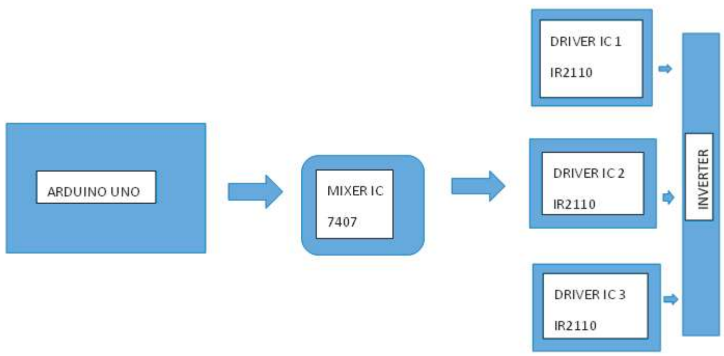

Figure 6: Control Logic Block Diagram

2.1.5 Electronics Components

a. Micro-Controller

Arduino UNO is a suitable microcontroller. Arduino is an open-source electronics platform with easy-to-use hardware and software. The Arduino board can read inputs from a press on a button and turn it into an output - activating a motor, turning on an LED or controlling the speed.

Figure 7 Arduino Uno microcontroller

b. Mixer IC 7408

This IC performs the logic AND function because it contains quad 2 input AND gates using four independent gates. it operates under a power supply ranging from 2-6 volts. It uses advanced CMOS technology to achieve operating speeds with minimum power consumption.

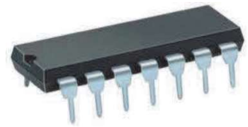

Figure 8: Mixer IC 7408

c. Driver IC IR2110

This is also called an H bridge driver circuit. A three-phase signal is applied across the HIN1/2/3 and HIN1/2/3 of the IC from the mixer IC stage or the signal generator stage. The outputs are conFigured with the drains of the IGBT bridge network which need to control the motor speed.

Figure 9: Driver IC IR2110

d. 1N5804 Schottky Diode

1n5822 is a Schottky diode**,** also known as a hot-carrier diode, mainly used in fast-clamp diode switching applications. It is made up of semiconductor material and carries low forward drop voltage.

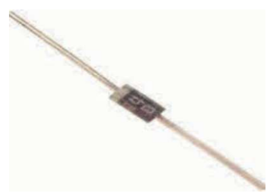

Figure 10: 1N5804 Schottky Diode

e. 600V 370UF Capacitor

Figure 11: 600v 370uf capacitor

f. FGA25N120 Power Transistor

FGA25N120 power transistor utilizes NPT technology which offers very tight parameter distribution, high ruggedness, stable temperature performance, and parallel switching capability. This power transistor is designed for motor controls, inverter

Figure 12: FGA25N120 Power Transistor

g. Hall Effect Sensor ACS756 50A Current Measurement

This is the fully integrated Hall Effect-based linear current sensor ACS756. It provides economical and precise solutions for AC or DC sensing in industrial, automotive, commercial, and communications systems.

Typical applications include motor control, load detection and management, power supplies, and over-current fault protection.

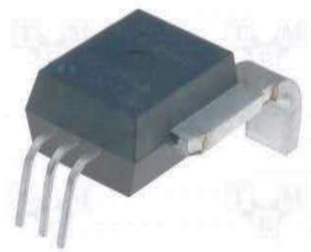

Figure 13 Hall effect sensor ACS756 50A

3. Methodology

3.1 Mathematical Part in Relation to The Project

Three-phase motors are widely used in industry and have become the backbone of many mechanical and electromechanical systems because of their simplicity, reliability, and long life of service. Three phase motors are one example of a type of induction motor, also known as an asynchronous motor, that operates using the principles of electromagnetic induction.

To control the speed of a three-phase induction motor**,** one should be able to understand the basic formulas of speed and torque of a three-phase induction motor. Methods of speed control depend upon these formulas. Synchronous speed

$$N_s = \frac{120f}{P}$$

Where, f = frequency

P - the number of poles

The speed of the induction motor is given by

$$N = N_s(1 - s)$$

Were

N - the speed of the rotor of an induction motor,

N_s - the synchronous speed, S - the slip.

The torque produced by the three-phase induction motor is given by

$$T = \frac{3}{2\pi N_s} X \frac{sE_2^2 R_2}{R_2^2 + (sX_2)^2}$$

When the rotor is at a standstill slip, **s** is one.

So, the equation of torque is,

$$T = \frac{3}{2\pi N_s} X \frac{E_2^2 R_2}{R_2^2 + X_2^2}$$

Where:

E_2 - the rotor emf

N_s - the synchronous speed

R_2 - the rotor resistance

X_2 - the rotor inductive reactance

The Speed of the Induction Motor is changed both from Stator and Rotor sides. The speed control of the three-phase induction motor from the stator side is further classified as:

- frequency control.
- Changing the number of stator poles.
- Controlling the supply voltage.
- Adding rheostat in the stator circuit.
- Cascade control method.

- Injecting slip frequency emf into rotor side.

The best option to use the frequency control method is most reliable.

Whenever three-phase supply is given to three-phase inductions motor a rotating magnetic field is produced which rotates at synchronous speed given by (electricalengineeringtoolbox.com, 2016):

$$N_s = \frac{120f}{P}$$

In three-phase induction, motor emf is induced by induction similar to that of a transformer which is given by:

$$E \ or\ V = 4.44\phi K.T.f \ or\ \phi = \frac{V}{4.44KTf}$$

Where:

K - winding constant T - number of turns per phase f - frequency.

If frequency changed, synchronous speed changes. Decrease of frequency increases flux causing saturation of rotor and stator cores which will further cause an increase in no-load current of the motor. So, it is important to retain flux constant and it is possible only if I change the value of voltage. For example, if frequency decreases, it causes an increase in flux but at the same time, if voltage decreases, the flux will also decrease causing no change and hence it remains constant. So, keeping the ratio of variable frequency as constant is important. Hence its name is the frequency control method. For controlling the speed of the three-phase induction motor by frequency control method, variable voltage and frequency are supplied and are easily obtained by using converter and inverter set. (Theraja B. T., 2016).

4. Discussion and Results

Frequency control for an inverter circuit to control three phase induction motor. The diagram below shows a diagram of Proteus simulation of one side of the driver ir2110 to output one phase of the inverter. Frequency control range is 1Hz to maximum of 90Hz. The diagram below shows how to control the induction motor using pulse width modulation. Pulse width modulation is a technique in which amplitude of a digital signal can be controlled using a microcontroller or any source in order to control an electrical device. The PWM is a good method because with help of a microcontroller it generates a digital signal by which can be varied directly from the microcontroller. The method reduces power loss in control of speed of a AC induction motor, unlike the other methods which use a variable resistor to control the voltage entering the armature and the shunt circuit. PWM has two signal period, which are high and low periods. To control the frequency of the PWM one can vary the on and the off states. In my project implementation I have used the generated PWM to control the speed of the motor through delivering the input voltage through succession of pulses rather than varying an analogue signal. By varying the pulse width (on and off time) the speed of motor became controllable by using PWM which sampled the input voltage into as per output frequency of the microcontroller.

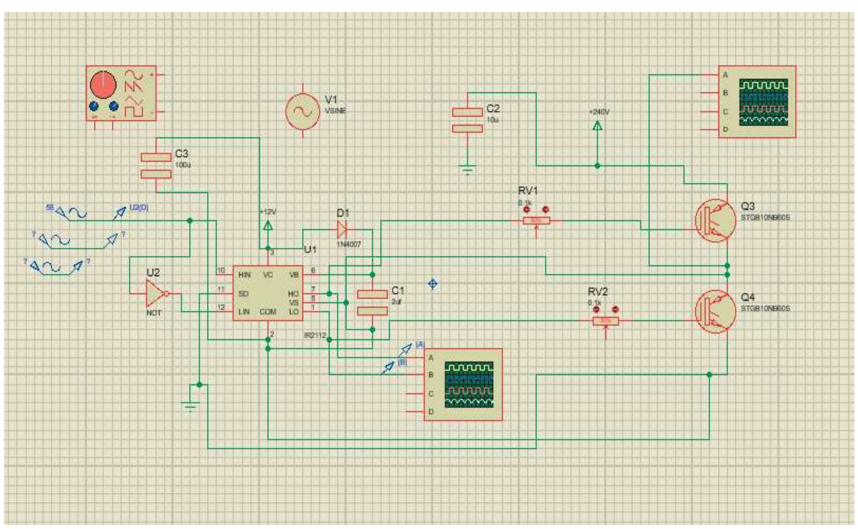

Figure 14 Digital oscilloscope display

Digital oscilloscope display showing the input signals from IR2110 for both high and low side(+12V) to switch and off the inverter side circuit. Smoothened by help of low pass filters using capacitors to help output sinusoidal waveform.

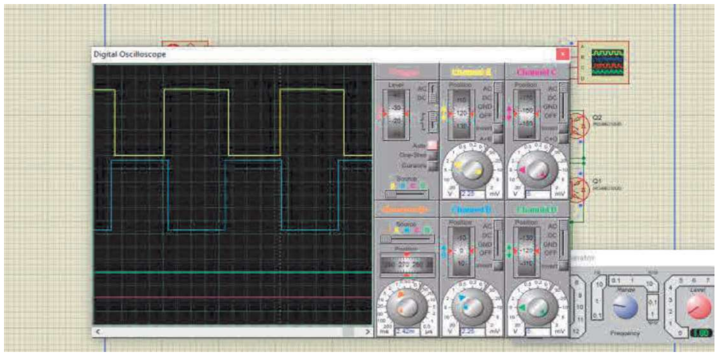

Figure 15 Output waveform on one side of the driver

Output waveform on one side of the driver(ir2110) for both high and low side of inverter (IGBT).

The diagram below shows the output waveforms from microcontroller with 120 degrees out of phase from each other to ensure matching. The signal output from microcontroller achieved is almost +5V.

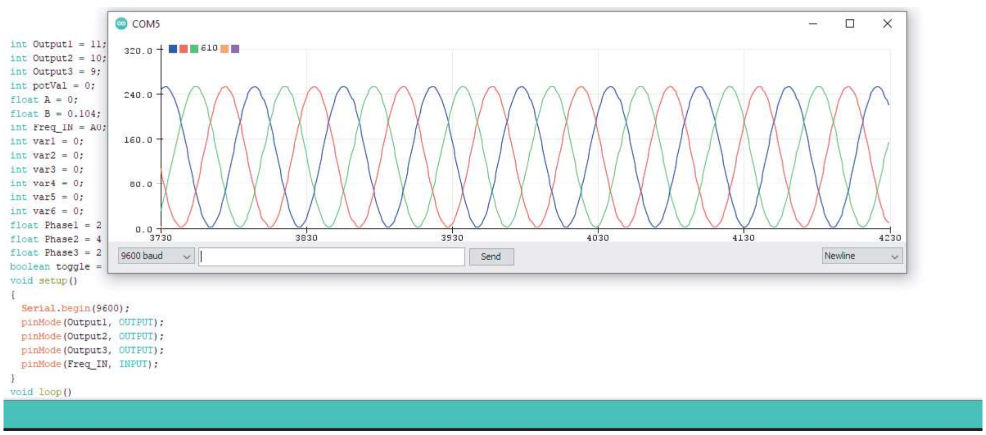

Figure 16 The signal output from microcontroller

5. Concluding Remarks

The conclusion was that at a low-speed work, the motor uses less energy. Therefore, a lot of power is saved by controlling induction motor's speed by through varying the frequency. This drive serves both as speed control and energy saving kit. Energy conservation is the most significant and researched matter globally this encouraged a research that had the ability to control the speed of three phase motors. Hence using this method is economical and reduces electricity bills and at the same time proves to be efficient for motor speed control.

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