

## Speed Control of Three Phase Induction Motor by V/F Method with Arduino Uno.

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### ABSTRACT

The induction motors run only at their rated speed when it is connected to the supply, many applications in need of adjustable speed operations. Controlling the induction motor speed efficiently is a main concern nowadays. With the fast advancement in the semiconductor manufacturing technology, the size and price of the semiconductors went down drastically. And this lead to that the motor user can exchange the inefficient mechanical motor drive with the inverter. This paper presents the necessity of induction motors speed control. Out of various methods of speed control of induction motors, method of V/f speed control prove to be the most multilateral. The scheme of implementing V/f speed control presented. The inverter is one of basic requirements for induction motor speed control by V/f method, the inverter traditional control methods is modulated using Arduino Uno which control the whole operation of the proposed scheme, a good control of V/f ratio and smooth speed control been conducted from the scheme, the cost of the modulated scheme is less, the code is easy and can be updated easily to get different results, the scheme can be upgraded to be controlled from distant areas.

**Keywords-** Arduino Uno, three phase induction motor, speed control.

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### I. INTRODUCTION

Asynchronous motors dominate more than 85% of the used motors in industry field and domestic applications, [1]. Induction motors often titled as “workhorse of the industry”. This is due to the fact that it is the most greatly used motors in the world. It is used in industries, transportation, laboratories and household appliances, [2]. The induction motor achieved this popularity because they are cheap when they compared to synchronous and dc motors, in this era of competition, it is the main requirement for any machine, [3]. With reason like handling of procurement, installation and utilization the induction motor considered as the first choice for a machinery process, induction motors with squirrel cage rotor are very tough in construction. There durability let them to be used in different environments of work and for long time durations, [4], they are efficient in energy conversion, very reliable, simple in construction, with low maintenance costs and they have high starting torque, and this is very useful with loads of application are applied before running the motor, [5]. One of the induction motors advantages is the easiness with speed control. To run different applications and loads then different motor speeds are required. In the past, the induction motors are not

used for applications when speed should be kept changed because the traditional methods of speed control is not efficient as compared to dc motor speed control. But, dc motors require maintenance of commutators and brushes. Thus, induction motors are selected. It is very necessary to control the induction motors speed due to various factors like, smooth operation guarantee, torque and acceleration control, the processes with different speeds, in the time of installation, slow speed of the motors is required. The mentioned factors make strong case to implement the speed control or drives with variable speed in induction motors. Various methods are existed to control the induction motors speed like, number of poles changing, adjustable voltage supply control, adjustable rotor resistance control, variable voltage variable frequency (V/f) control, slip recovery, vector control for speed control, [3]. From the mentioned speed control methods, V/f method considered as the most popular the above-mentioned methods, V/f Control is the most favorite and has found recently widespread use in domestic and industrial applications due to the fact of easiness of implementation. However, it has low dynamic performance as compared to vector control. Thus, in applications where precision is desired, V/f Control are not used. Various advantages of V/f Control like, good range of speed adjustment, it gives very good

running and good transient performance, requires low starting current, wide stable operating region, frequency and voltage reach their rated values at base speed, by changing the rate of change of frequency the motor acceleration can be controlled, [6]. Various methods implemented and simulated previously to control the speed of the induction motor using V/f method like, design of real PWM and connect to the inverter to control the output frequency, [7], using PIC microcontroller to send signals to control the frequency of the inverter, [8]. This paper presents a new scheme which is implemented to control the inverter frequency by using the signals of the PWM of Arduino Uno which will fed to the control signals of the inverter and as a result will conduct a smooth control of speed.

## II. MATHEMATICAL MODEL

For the induction motor from the following expression,

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

it is clear that the induction motor speed can be changed by changing the "Ns" or changing the slip (s). Similarly, the induction motor produced torque can be found from the following expression, [3],

$$T \propto \frac{sE_2^2 R_2}{R_2^2 + (sX_2)^2} \quad (2)$$

so, by changing  $R_2$ ,  $E_2$  the torque will be kept constant for constant loads conditions, when the motor slip changes. its speed will change. The synchronous speed is giving by,

$$N_s = \frac{120f}{P} \quad (3)$$

Thus, by controlling the supply frequency smoothly, the synchronous speed can be controlled over wide range this gives smooth speed control of an induction motor. But the expression for the air gap flux is giving by,

$$\phi_g = \frac{1}{4.44 K T_{ph1}} \left( \frac{V}{f} \right) \quad (4)$$

This is according to the e.m.f equation of a transformer which is applied to the induction motor also. It can be seen from this expression that if the supply frequency (f) is changed, the air gap flux value will be affected. This may result into saturation in the stator and rotor cores. Such a saturation leads to the sharp increase in the no load (magnetization) current of the motor. Hence its necessary to maintain air gap flux constant when supply frequency f is changed to achieve this, it can be seen from the above expression that along with frequency the voltage also must be changed to keep the ratio of V/f constant. This insures steady air gap flux gives speed control without impacting the

performance of the motor. Hence for V/f method, the supply to the induction motor required is variable voltage variable frequency supply, [5] [6].

## III. THE PROPOSED SCHEME

The normal supply available is constant voltage constant frequency AC supply. To get variable frequency variable voltage source an electronic scheme using converter and inverter circuitry is used along with Arduino Uno as shown in Fig. 1. This scheme is connected to a 3-phase induction motor with squirrel cage rotor and the equivalent circuit of the motor shown in Fig. 2, [3].

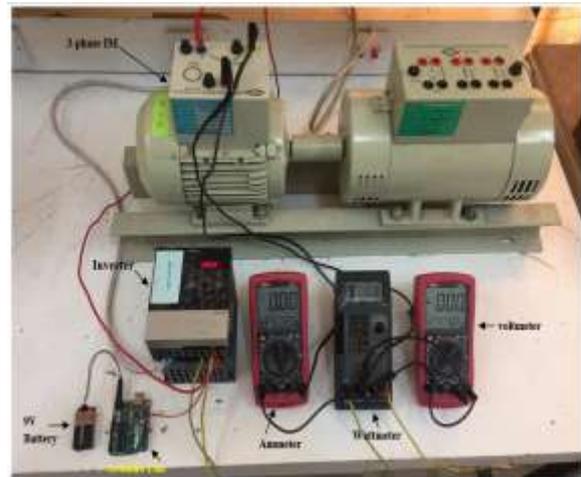


Fig. 1. The proposed scheme

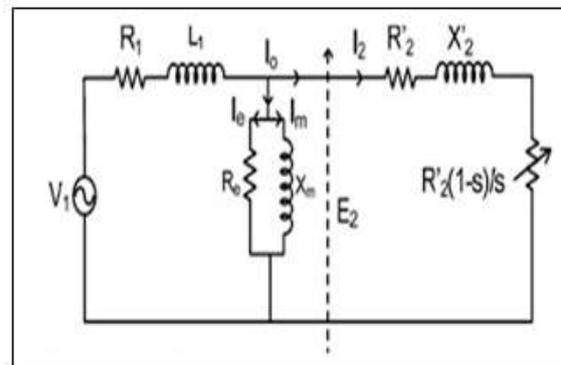


Fig. 2. The equivalent circuit of 3-phase induction motor

### 3.1 Ac Drive (Inverter)

The three phase inverter is connected to three phase induction motor as shown in Fig. 3. The inverter has a rectifier which convert the main single-phase supply to a dc supply. The output waveform ripple of the dc bus is filtered and smoothed by using a capacitor. The filtered output dc bus is then giving to three phase inverter, the output of this inverter is variable frequency variable voltage with constant ratio of V/f. The output frequency of the inverter is in the range of (0.01 to

400Hz) so it's available to operate with different applications, the output frequency can be controlled through different methods available in the inverter like, potentiometer or by the control inputs where there are (4 pin control inputs) in the inverter to control the output frequency by different methods.

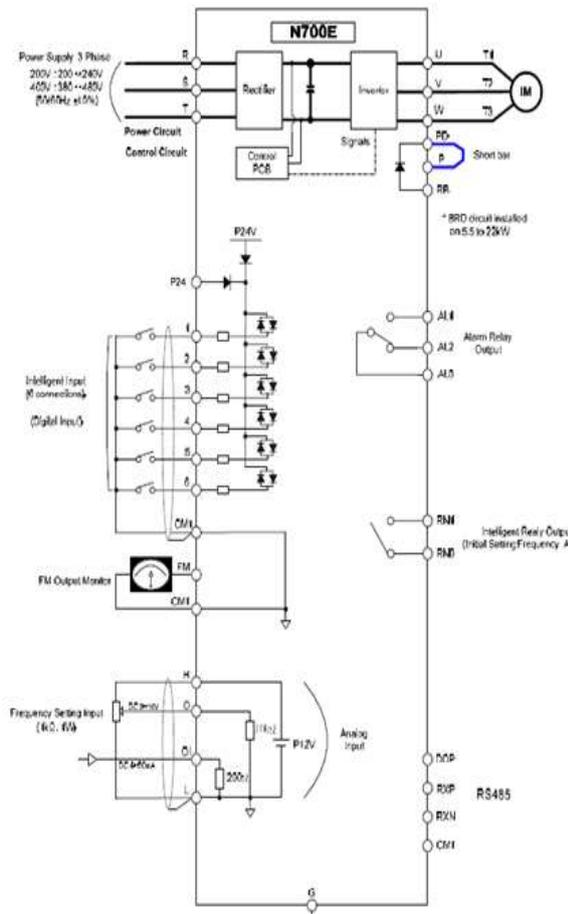


Fig. 3. The electronic scheme using converter and inverter circuitry (Ac drive)

### 3.2 Arduino Uno

It is a microcontroller chipset based on ATmega328. There are 14 digital input and output pins ( 6 of them are used as PWM outputs), 6 analog inputs, one of the features of the Arduino Uno is it has PWM, and this is a technique of obtaining analog results with digital standards. A square wave is created by the digital control, the signal is switched as on and off, and this on-off style simulate voltages between full on (5 Volts) and full off (0 Volts) by changing the part of the time signal expend on versus the time that the signal expands off. The duration of "on time" is called the pulse width, [9]. To get varied analog values, by writing the proper code the pulse width will modulate. Figure (4) shows the PWM signals which is taken from the Arduino Uno, the green lines in Fig. 4 demonstrate regular time period. This time period is

the inverse of the frequency of PWM. Which means, when the frequency of Arduino's PWM about 500Hz, then green lines measure (two milliseconds) each. By writing the command `analogWrite()` with a scale of 0 – 255 which will give in return 0-5volt on the Arduino Uno PWM

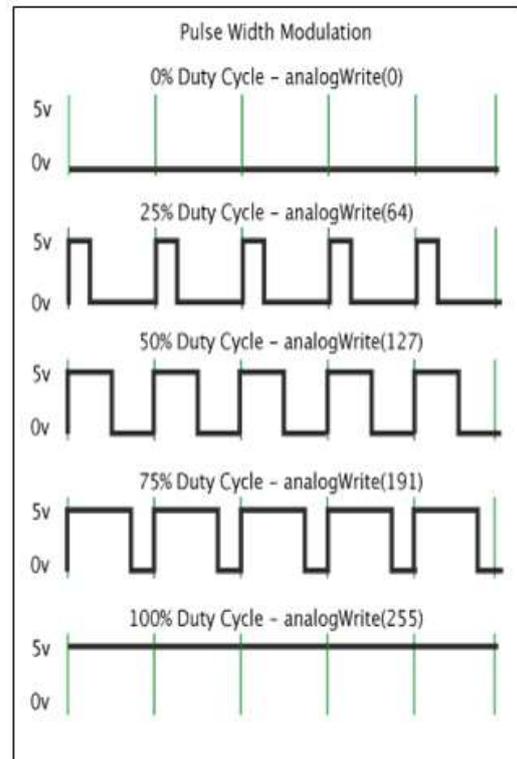


Fig. 4. PWM signals of Arduino Uno

outputs, so that `analogWrite(255)` requests (5V) a 100% duty cycle, and `analogWrite(127)` is (2.5V) a 50% duty cycle.

## IV. IMPLEMENTATION AND EXPERIMENTAL RESULTS

The control signals pins allow to control the inverter by different methods, Arduino Uno is used to control the inverter operation as shown in Fig. 5, Arduino

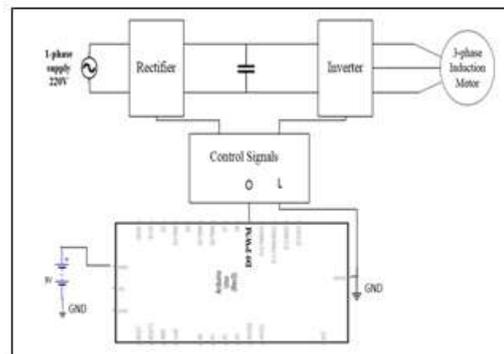
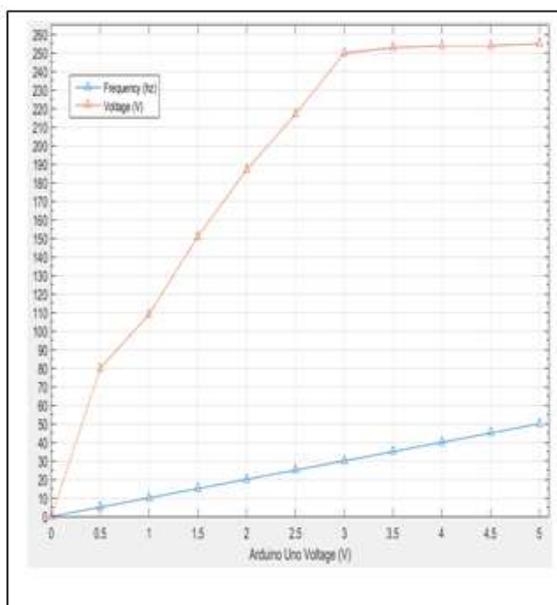


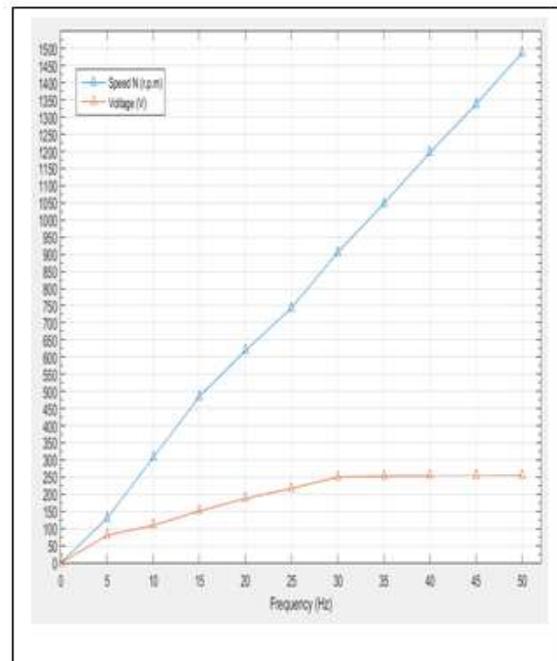
Fig. 5. the proposed scheme (inverter controlled by Arduino Uno)

Uno is added to control the whole operation of supplying variable frequency variable voltage to the induction motor, by selecting the proper frequency and maintaining the ratio of v/f constant, smooth speed control of the induction motor is possible. An experimental test been done by using an inverter which its output frequency set to 50Hz by its human interface monitor, the output frequency of the inverter is controlled through its control inputs which has 10 volt 20mA limit, so by connecting Arduino Uno to the control signals pins of the inverter and using the PWM Arduino Uno output to get a voltage range of (0-5 volt) and this done by writing a code Arduino Uno coding language to control the whole operation and conclude a smooth increment of Arduino Uno output voltage and as a result increment in inverter frequency and voltage. Using (AnalogWrite) command in Arduino Uno coding language control the output voltage in the range of (0-5 volt) by setting (AnalogWrite) command to the values (0-255). the corresponding PWM signals (Arduino Uno output voltage) is supplied to the control signals pins of the inverter. To avoid saturation in stator and rotor cores, the V/f ratio must be constant and the proposed scheme conducted a good V/f ratio as shown in Fig. 6, it



**Fig. 6.** inverter output frequency and voltage with respect to Arduino output voltage

shows that when the Arduino Uno voltage increased the frequency and output voltage of the inverter also increased to keep the V/f ratio constant to avoid saturation. But the when the voltage reached 250v it value didn't change further, and that's due to the fact of the inverter maximum output voltage is 250v. Fig. 7 shows the relation between changing V/f ratio and



**Fig. 7.** V/f ratio with speed

the speed of the induction motor, when the Arduino Uno output voltage injected to the control input of the inverter then the frequency and output voltage will increase simultaneously and as a result the speed of the motor get increased. The results are plotted using Matlab R2015a.

## V. CONCLUSION

Speed control of the induction motors is one of the most trending topics nowadays, through this paper we found a new method to control the speed by frequency variation of the induction motor by using Arduino Uno, this method shows a smooth control of the speed through control the output frequency by setting a code wrote in Arduino Uno coding language. This code will control the whole operation by changing the Arduino output voltage and this will change the output frequency and voltage of the inverter and as a result the speed of the induction motor will be changed, setting a specific time for each speed, the code can be modified easily to get the desired speeds for different applications, it's an efficient method through the following facts, its consume less power as Arduino can operate by connecting 9V battery only, the scheme can be upgraded to connect Ethernet shield to control the operation from distant area.

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#### **APPENDIX:**

three-phase induction motor parameters are:

Rotor type= Squirrel-cage rotor

P=1 HP

N= 1440 r.p.m.

Rated voltage= 415V

Rated current= 2.1 A

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