DESIGN AND DEVELOPMENT OF SPEED CONTROL FOR 3 – PHASE INDUCTION MOTOR USING AT89C52 MICROCONTROLLER

[1]Okpagu P. E., [2]Nwosu A.W., [3]Mbachu C. B. and [4]Onuorah, O. N.
[1,3 &4]Department Electrical/Electronic Engineering, Chukwuemeka Odumegwu Ojukwu University, Uli, Nigeria.
[2]National Engineering Design and Development Institute (NEDDI), Nnewi. Nigeria
E-Mail: [1]ejikeokpagu@gmail.com, [2]talk2nordy@yahoo.com, and [3]dambac614@gmail.com.

ABSTRACT

The reliability, robustness, ruggedness and simple control of induction motors propels their use widely in both industrial and commercial applications. Speed control is of paramount importance as a result of the growing need of industrial drives. The aim of this work is to design and develop speed control for 3-phase induction motor using AT89C52 microcontroller. To actualize the aim, the AT89C52 microcontroller was used to generate PWM signal for switching of the MOSFETs which makes up the power inverter. The power inverter converts DC power generated by the controller to an AC power which was delivered to the induction motor for driving. MOSFETs were used to control the AC voltage that drives the motor. The push button switches attached to the microcontroller were used for either increasing or decreasing the AC power delivered to the motor. The variation of the AC power to the motor resulted in speed variations. LCD display was used to display the speed variations. Experimental results show that the speed of the motor has a linear relationship with the armature terminal voltage as well as the input power to the motor and result also show that the motor torque decreases as the speed increases.

Keywords: 3-Phase Induction Motor, AT89C52 Microcontroller, PWM Pulses, Power Inverter, MOSFET.

1.0 INTRODUCTION

Currently, AC machines are preferable over DC machines due to their simple and robust construction without mechanical commutators. Induction motors are the widely used motors for appliances for industrial control and automation; hence, they are often called the workhorse of the motion industry [1]. As far as machine efficiency, robustness, reliability, durability, power factor, ripples, stable output voltage and torque are concerned, three- phase induction motors stand at the top of the order. Motor control applications span across residential washing machines and fans to hand-held power tools, automotive window lift, traction control systems and various industrial drives. In almost all the applications, there is drastic move away from analog motor control to precision digital control of motors using different processors [2].

Digital control of induction motors results in much more efficient operation of the motor, leading to longer life and lower power dissipation. 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 the V/F control [3].

Induction motors are widely used in control systems and home appliances because of their reliability, robustness, ruggedness and simplicity of control. Before now, the induction motor could be plugged directly to the AC mains or controlled by means of V/F method. When an induction motor is directly connected to AC mains at the given specifications, it operates only at the rated speed. With this method, even simple speed variation is impossible and its system design is totally dependent on the motor design. However, most applications require variable speed operation. The V/F method is able to provide speed variation but does not control transient condition. It is useful only for steady state condition. This method is most suitable for applications where position control is not required or where there is no need for high accuracy/speed control [4, 5].

Microcontroller and DSP based drives are used in industrial applications. With advent of power semiconductor devices, the PWM technique has been used more frequently to improve the quality of output signal. Use of turn-off device and application of PWM technique for power conversion has brought distinct improvements [5]. The proposed method presents the design and development of three phase motor drive for variable speed operation. It is based on the AT89C52 microcontroller which is dedicated to motor control applications where the relationship between synchronous speed Ns, rotor speed Nr and the slip S, is given by:

$$S = \frac{Ns - Nr}{Ns} \qquad (1)$$

or $Nr = Ns\,(1-S)$ and

Rotor speed: $$Nr = \frac{120f}{P}(1-S) \qquad (2)$$

Thus specifying, the speed of an induction motor depends on the slip “S”, frequency of the stator supply “f” and the number of poles for which the windings are wound. The ability of varying any one of the above three quantities will provide methods of speed control of an induction motor. This work uses the 3-phase AC voltage controller along with PWM technique for speed control of the induction motor. AC controllers are MOSFET-based devices which convert DC to AC. By changing the firing angle of the SCR, the output voltage of the AC voltage controller changes. Since frequency remains constant for AC voltage controllers, flux changes in the IM (induction motor) with the change of output voltage in the AC voltage controller and hence torque of IM changes. Since torque is proportional to speed, speed will be controlled.

2.0 METHODOLOGY

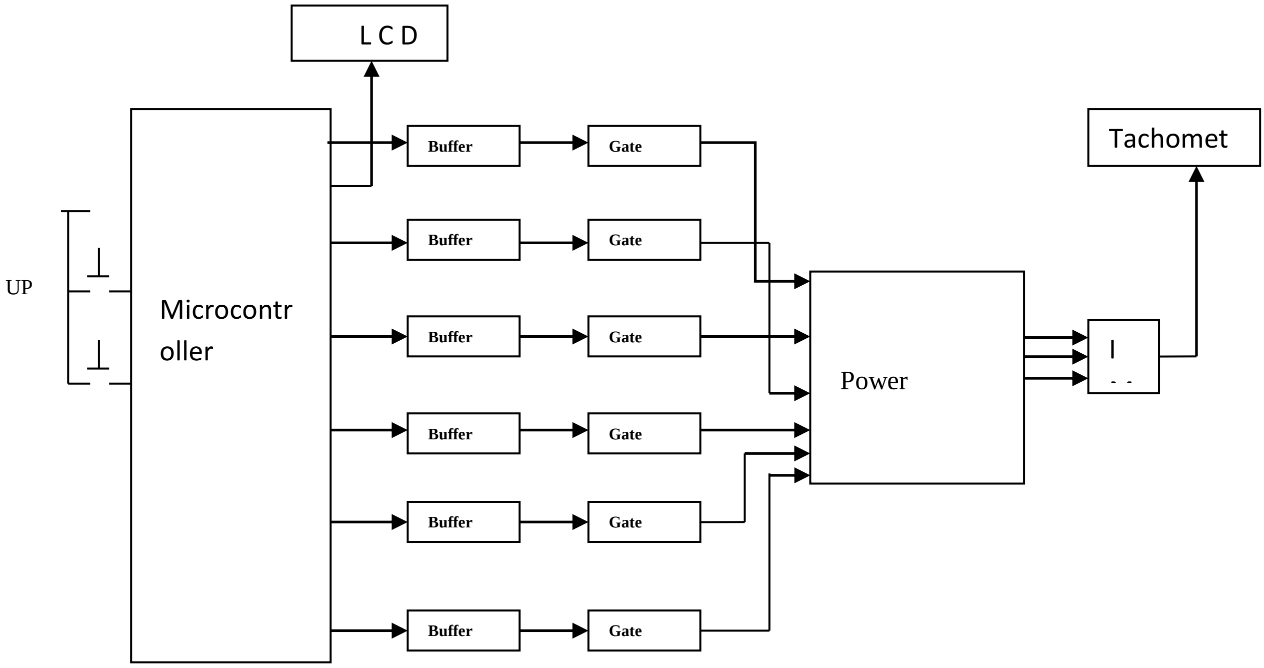

Figure 1: Block Diagram of Speed Control of 3-phase Induction Motor

The block diagram to implement speed control of a three phase induction motor drive system is shown in figure 1. The system consists of the following: (1) push button (up and down) attached to the microcontroller; (2) The AT89C52 Microcontroller; (3) The buffer circuit; (4) The gate drive circuit; (5) The power inverter; (6) The Induction Motor; (7) The Tachometer and (8) The Liquid Crystal Display (LCD).

2.1 System Operation

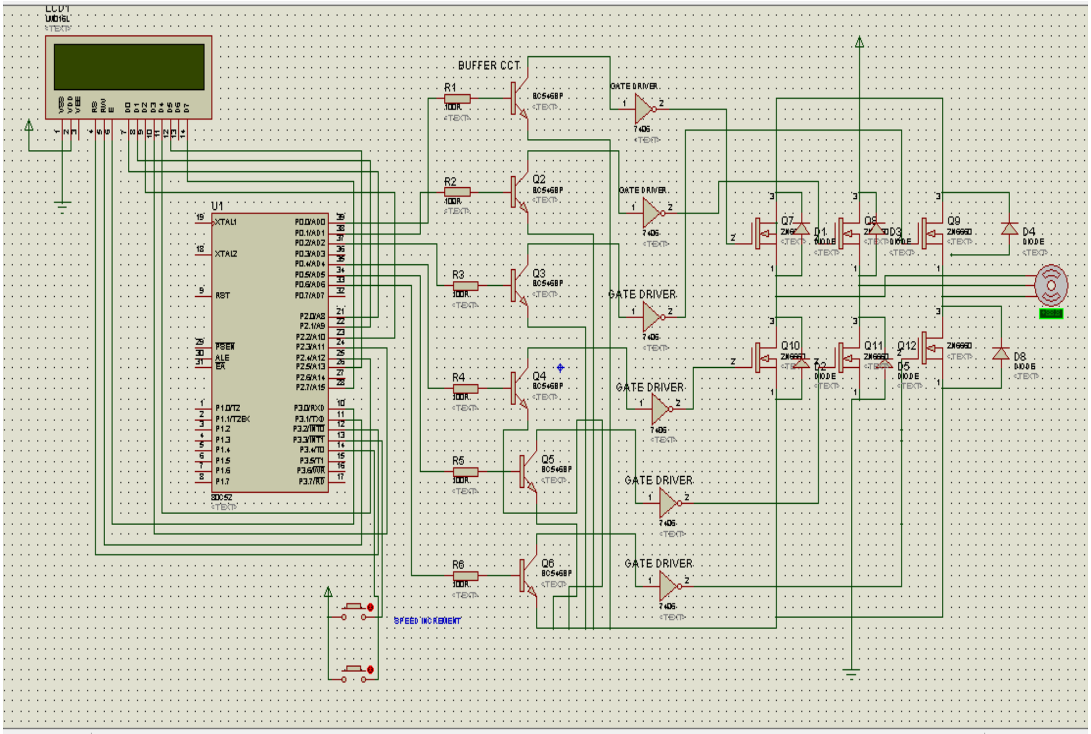

Figure 2: Circuit Diagram of the System

As is in figure 2, the push buttons attached to the AT89C52 microcontroller were used to vary the speed of the induction motor. The up- button was used for speed increment while the down- button was used for speed decrement. As the buttons were pressed, the PWM signals were being generated by the microcontroller. The generated PWM signals were amplified by the buffer circuit and the resulting signals were fed to the gate drive circuit for the purpose of driving the MOSFETs which makes up the power inverter. The Power inverter does the actual conversion of DC to AC for motor operation, the switching ON and OFF of the MOSFETs which make up the power inverter and determines the AC voltage that goes to the motor armature terminal. The power inverter generates AC voltage based on the switching time of the MOSFETs. Switching time was determined by the duty cycle of the PWM signal.
Pressing the upper button generates an increased duty cycle of the firing pulses which were amplified by the buffer circuit. The amplified pulses from the buffer circuit were used to fire the MOSFETs through the gate driver. Then the MOSFETs which make up the power inverter convert the DC voltage to AC voltage which was fed to the armature terminal of the

motor. The tachometer measures the speed of the induction motor and the reverse is the case when the down push button was pressed.

The following points were used to further explain the working principle of the circuit:

(1) The desired AC voltage was obtained by changing the switching time of the MOSFETs using PWM signals which were generated by the microcontroller. In other words, the controlled phase voltage can be obtained by changing the duty cycle of the PWM signals. The duty cycle can be changed by pressing the push buttons attached to the microcontroller.
(2) Speed variations of the induction motor were recorded by changing the duty cycle of the firing pulse of an inverter and this was done using the push- buttons.
(3) A power inverter circuit converts the DC into the required AC voltage and frequency. Then the required phase voltage is fed to an induction motor.
(4) The inverter has six MOSFETs that are controlled by PWM signal in order to produce the desired AC output from DC bus.

At any given time, only two MOSFET's are in the conducting state. The sequences of conduction for the MOSFETs are 1&5, 2&6, 3&4 and are subsequently repeated. When any pair of MOSFETs is conduct, the current starts to flow from DC bus through one of the motor winding and the motor is rotated. Motor windings are inductive in nature; it holds the energy in the form of current. The freewheeling diodes are connected across the MOSFET's which provides the path for current dissipation while the MOSFETs are in the non-conducting state. Upper & lower MOSFETs of the same limb should not conduct at the same time which prevents DC supply to be shorted. The sequence of the conducting MOSFET's is that each pair of MOSFET conducts after 120°, hence balanced voltages are achieved across the induction motor.

2.2 The Power Supply Circuit

The power supply serves as the main supply of electric power to the system. The supply voltage was 230V that was step down by the 220V/24V, 500mA transformer. The 24VAC voltage was then rectified by a bridge rectifier to have DC output. After the rectification process, the remaining AC ripples were filtered using bypass capacitor. The output from the bypass capacitor is unregulated thereby causing a drastic voltage drop when a load is connected. To solve this problem, an integrated chip (IC) voltage regulator (7805) was used to obtain a fixed output voltage as shown in figure 3.

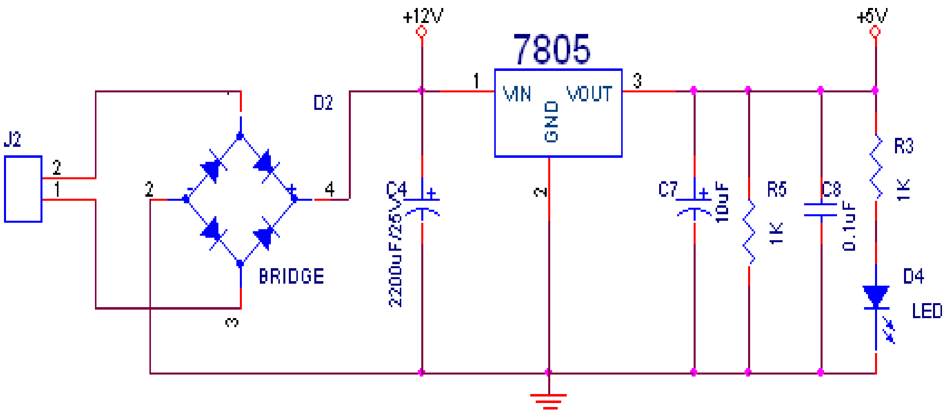

Figure 3: The Power Supply Circuit

2.3 The Buffer Circuit

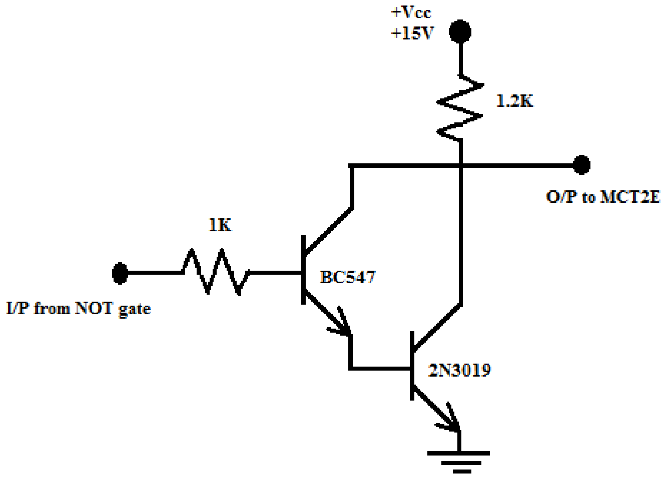

Figure 4: Buffer Circuit

PWM signals from the microcontroller were not able to operate the MOSFETs, so a buffer circuit was used. The buffer circuit consists of BC547 and 2N3019 transistors as shown in figure 4. The microcontroller PWM signal is fed to the base of the BC547 transistor. The output is 180 degree out of phase with respect to the input but the output current is amplified which operates the MOSFETs through the gate driver. The voltage of the inverter IC is 4.8V. The required current to turn ON BC547 is = 5mA. Therefore Base resistance of BC 547 is:

$$RB = 4.8V / 5mA = 0.96K\Omega = 1K\Omega. \quad (3)$$

Current through BC 147 is:

$$IC = VCC / RC = 15\ V / 1.2\ K;\ \ IC = 12.5mA. \quad (4)$$

2.4 Gate Driver

The IR2110 is a high voltage, high speed MOSFET driver with independent high side and low side output voltage channels. It is capable of controlling two inputs at a time and produces high side and low side output pulses. Logic inputs are compatible with down to 3.3V logic. The output driver features a high pulse current buffer stage designed for minimum driver cross the section. The floating channel can be used to drive the MOSFET in the side configuration which operates for up to 500-600V. The gate drive requirements for a power MOSFET is utilized as a high side switch and the drain is connected to the high voltage rail.

2.5 The Power Inverter Circuit

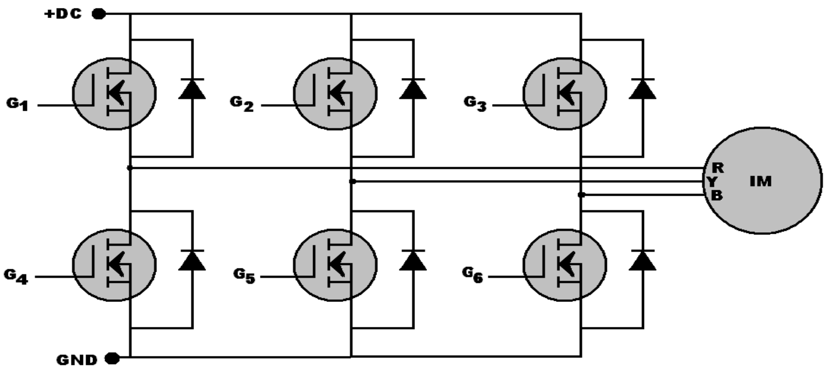

Figure 5: Power Inverter Circuit

Inverter circuit is the main power conversion stage of the system. Figure 5 shows the MOSFET based power inverter circuit. It consists of six MOSFETs & six freewheeling diodes are connected in three limbs. Freewheel diodes in each inverter leg may be internal to the main power switches or may be a separate discrete device in the case of standard MOSFETs which provide path of current for dissipation while MOSFETs are in the non-conducting state. The MOSFETs in the inverter are controlled by PWM signals through driver circuit. At any given time, only two MOSFETs are switched ON. The sequences of conduction for the MOSFETs are 1&5, 2&6, 3&4 and recycled. When any pair of MOSFETs are conducting, the current starts flowing through the corresponding motor winding.

MOSFETs are controlled in order to provide the device current limit, hence controlling the motor torque, to set the direction and speed of rotation of the motor. The torque is determined by the average current in each phase when it is energized. As the motor current is equal to the DC link current, the torque is proportional to the DC input current. The motor speed is synchronous with the applied voltage waveforms and so is controlled by setting the frequency of the inverter switching sequence, therefore controlling the motor speed.

3.0 RESULTS AND ANALYSIS

The system was set up experimentally according to the circuit diagram of figure 2. The experimental measurements of voltage, torque, speed, efficiency etc., were carried out by varying the gate pulse width of the inverter using the push buttons attached to the microcontroller. The measurements obtained are tabulated in table 1.

Table 1: Experimental Results

S/N	Volt (V)	Amp (A)	Power (W)	Torque (Nm)	Speed(RPM)
1	25.0	0.02	0.50	1.0120	127
2	50.0	0.06	3.0	0.8440	166
3	75.0	0.07	5.25	0.7850	398
4	100.0	0.10	10.0	0.6460	535
5	125.0	0.12	15.0	0.5200	668

6	150.0	0.13	19.50	0.4380	803
7	175.0	0.14	24.50	0.3520	942
8	200.0	0.15	30.0	0.2900	1072
9	225.0	0.15	33.75	0.2470	1208
10	240.0	0.15	36.0	0.2200	1345

The results of the experiment were used for virtual implementation using proteus 7 professional. Figure 6 – 10 shows the screenshot of variable speeds obtained at different input voltage (inverter output). It was clear from that the speed of the motor increases as the voltage increase. Mechanical torque decreases with the increase in motor speed.

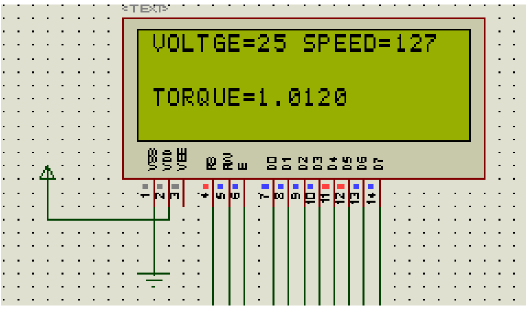

Figure 6: At 25V

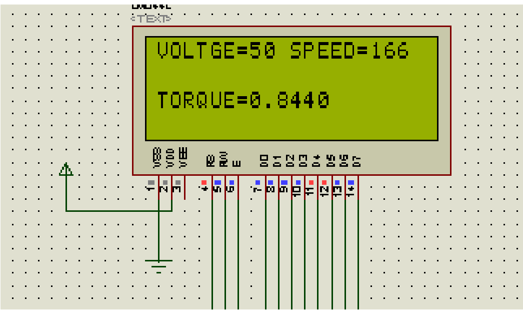

Figure 7: At 50V

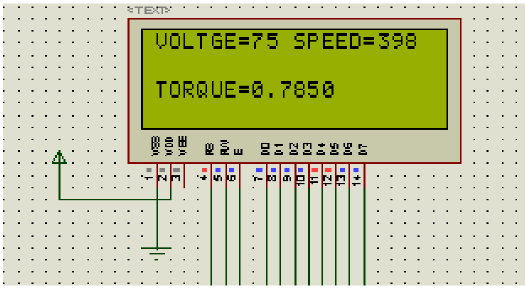

Figure 8: At 75V

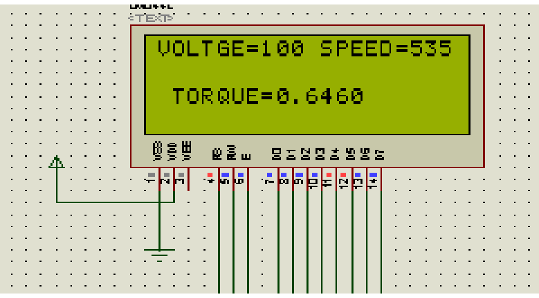

Figure 9: At 100V

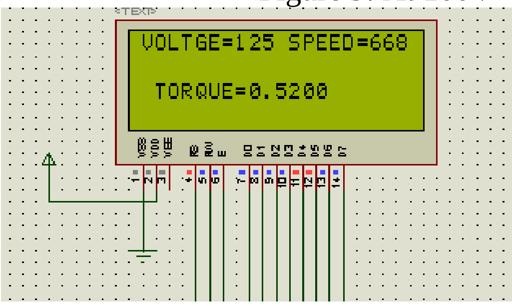

Figure 10: At 125V

It can be seen from the figure 11 that the speed of the motor increases as the armature voltage of the motor increases. In figure 12, there is also a linear relationship between the input power of the motor and its associated speed. Finally figure 13 shows that the torque decreases as the speed of the motor increases.

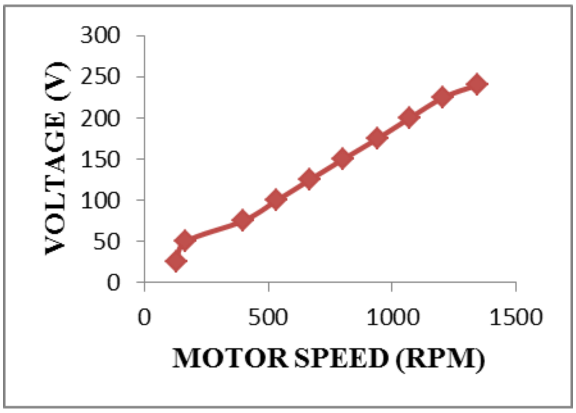

Figure 11: Armature Voltage vs Motor Speed (RPM)

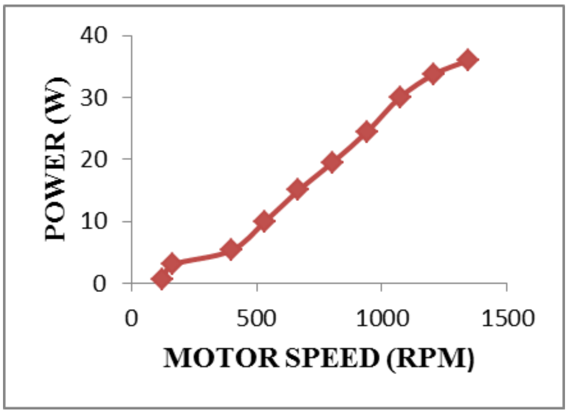

Figure12: Power vs Motor Speed (RPM)

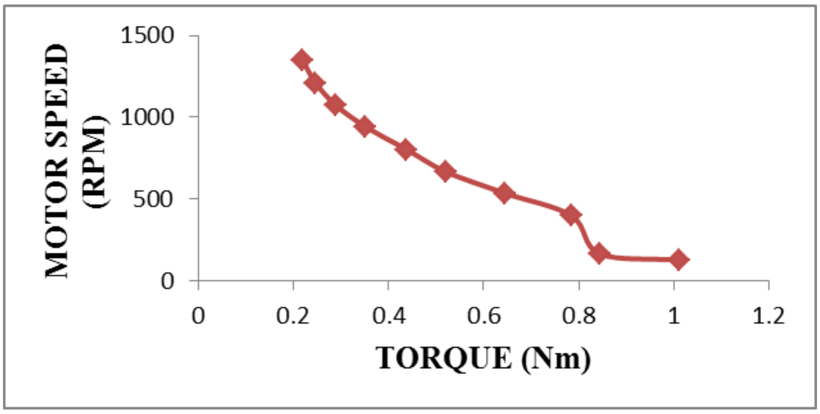

Figure 13: Motor Speed vs Torque

CONCLUSION

This work developed and implemented a 3-phase induction motor drive control mechanism. The experimental measurements of voltage, torque, speed, efficiency etc. were carried out by varying the gate pulse width of the inverter using the two input buttons attached to the microcontroller. It was observed that the speed of the motor has linear relationship with the armature terminal voltage of the motor. Also, mechanical torque decreases as the speed of the motor increases. This shows that in controlling the speed of induction motors, reliability, robustness and efficiency can be enhanced especially for most industrial and basic applications.

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