

**Sudan University of Science and  
Technology**

**College of Engineering**

**School of Electrical and Nuclear  
Engineering**

**Wireless Control of Speed and Direction of  
Induction Motor Using V/F Method**

**التحكم اللاسلكي في سرعة و إتجاه محرك حثي بطريقة  
الجهد/التردد**

**A project submitted in partial fulfillment for the requirement of  
the degree of B.Sc. (Honor) in electrical engineering**

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**October 2015**

## الآية

قال تعالى :

" سَنُرِيهِمْ آيَاتِنَا فِي الْآفَاقِ وَ فِي أَنفُسِهِمْ حَتَّىٰ يَتَّبِعُونَ  
لَهُمْ أَنَّهُ الْحَقُّ ، أَوْلَمْ يَكْفِ بِرَبِّكَ أَنَّهُ عَلَىٰ كُلِّ شَيْءٍ  
شَهِيدٌ "

فصلت (53)

# DEDICATION

To everyone embraced us with his smile, it was very supportive

To the most trustworthy, delightful and inspiring mentor Ust. Galal  
Abdallahman Mohammed...

To everyone who dedicated part of his time to read this...,

Not forgotten our great parents, gorgeous brothers and beautiful sisters for  
providing everything, they also supported us and encouraged us to complete this  
task so that we will not procrastinate in doing it.

To our good batch (elect 27), wish to them all the best in their life..,

Last but not least; we dedicate it to ourselves for being together through the  
good, and the bad, always believing in each other and for being friends, cheerful  
and unbreakable team until the end.

## ACKNOWLEDGEMENTS

First of all, we would like to say Alhamdulillah, for giving us the strength and health to do this project until it is done. We are grateful and would like to express our gratitude to supervisor Uz. Jalal Abdulrahman for his guidance and support in making and understanding our project. Some difficulties were faced in doing this task, but he taught us patiently until we knew what to do because he tried and tried to teach us until we understand what we supposed to do with the project work.

Also, we would like to extend our heartiest thanks to our college for inspiring us to complete our project successfully.

We wish to take this opportunity to express our deep gratitude to all the people who have extended their cooperation in various ways, especially more thanks to Engineer. Musab (Zeta Company for training) for guiding us and my friends throughout this project.

## ABSTRACT

Induction motors have already become an important drive configuration for many applications across a wide range of powers, speeds and Wide spread (90% of motors in industrial application) and excellent performance of the induction motors will ensure that the number of applications using them will continue increase for the foreseeable future. The aim of developing this project is to achieve full control of induction motor (its speed and direction of rotation). An electronic technique called pulse width modulation (PWM) is used to achieve the speed control; this technique generates high and low pulses; these pulses vary the speed in the motor. For the generation of these pulses a microcontroller (arduino) used. The PWM signal sent to motor driver to out specific values of voltage and frequency supplied to motor to maintain specific speed. In this project we use wireless Bluetooth signal which can be sent from mobile phone from a distance of 15 meters. That it can also control the rotation direction of motor and the system can actually adapt to the requirements of modern technology. This project is practical and highly feasible in economic point of view, and has an advantage of running motors of higher ratings. This project gives a reliable, durable, accurate and efficient way of speed control of induction motor.

## مستخلص

تعتبر المحركات الحثية ذات أهميه عظمى في الصناعة لأنها تستخدم في تطبيقات كثيرة و لعل مجال عملها واسع لإتساع مدى القدرة والسرعة لدى هذه المحركات بالاضافه الى انتشارها الواسع في مجال الصناعة حيث تمثل 90% من المحركات المستخدمة. هذا المشروع يتناول التحكم في سرعة المحركات الحثية بإستخدام المتحكم الدقيق.في هذه الدراسة استخدمت تقنية تعديل عرض النبضة وهي عبارة عن إشارة يتم توليدها في المتحكم الدقيق. في تقنية تعديل عرض الموجة يتم توليد موجة مربعة عبارة بنبضات عالية ومنخفضة وعلي حسب عرض الموجة في النبضة العالية يتم التحكم في سرعة الموتور. في هذا المشروع إستخدم متحكم دقيق من نوع اردوينو للتحكم في العملية الكلية.

في هذا المشروع تم استخدام نظام التحكم عن بعد وذلك بإستخدام تقنية البلوتوث كإحدى تقنيات الإتصال اللاسلكي و هذه التقنية تمكن من ارسال الاشارات عن طريق الهاتف النقال من مسافة تصل الى 15 متر. و يمكن أيضا التحكم في سرعة المحرك و اتجاه دورانه. هذا النظام يمكنه التكيف مع متطلبات التكنولوجيا الحديثة و يحقق قدر عالي من الإعتمادية و الكفاءة للتحكم في المحركات الحثية.

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## LIST OF SYMBOLS

$P_m$	Mechanical Power , kw
$T_g$	Gross Torque, N.m
$N_s$	Synchronous speed, r.p.m
$N$	Actual speed, r.p.m
$S$	Slip
$\phi$	Flux, Wb
$T_{st}$	Starting torque, N.m
$E_2$	Rotor E.m.f per phase at standstill, V
$R_2$	Rotor Resistance per phase at standstill, $\Omega$
$S_b$	Slip at Maximum Torque
$T_{max}$	Maximum Torque, N.m

## LIST OF ABBREVIATIONS

DC	Direct Current
AC	Alternating Current
V	Volt
I	Ampere
Hz	Hertz
PWM	Pulse Width Modulation
e.m.f	Electrical Motive Force
V/F	Voltage/Frequency
I/O	Input/Output
Cu	Copper
i.e.	That is.
CSI	Current Source Inverter
VSI	Voltage Source Inverter
IGBT	Insulated Gate Bipolar Transistor
SVPWM	Space Vector Pulse Width Modulation
PIC	Programmable interface controller
ARM	Acorn Risc machine
VCR	Video cassette recording

Etc	Et cetera
CD-ROM	Computer Disc – Read Only Memory
OPAC	Online Public Access Catalog
WAN	Wide Area Network
LAN	Local Area Network
PAN	Personal Area Network
WLAN	Wireless Local Area Network
PC	Personal Computer
Mbps	Megabit per second
Wi-Fi	Wireless Fidelity
IEEE	Institute Of Electrical And Electronics Engineering
Rx	Receiver
Tx	Transmitter
TTL	Transistor – transistor logic
USB	Universal Serial Bus
UART	Universal Asynchronous Receiver / Transmitter
Vcc	Voltage controlled clock
GND	Ground
Mcu	Microcontroller unit

CPU	Central Processor Unit
IC	Integrated Circuit
IDE	Integrated Development Environment
OSX	Operating system extension
IOREF	Input/Output voltage Reference
LED	Light Emitting Diode
AREF	Analog Reference
SSR	Solid State Relay
FWD	Forward
REV	Reverse
BJT	Bipolar Junction Transistor
MOSFIT	Metal Oxide Silicon Semiconductor Field Effect Transistor
FET	Field Effect Transistor
CI	Analog Input
HP	Horse Power
KW	Kilo Watt
WCIM	Wireless Control of Induction Motor
APP	Application

# **CHAPTER ONE**

## **INTRODUCTION**

### **1.1 General Concept**

Industry is very important in our life; it plays an important role in development, especially in developing countries. Nowadays, Alternating Current (AC) machines are preferable over Direct Current (Dc) machines in most of industrial applications due to their simple and most robust construction. Induction motors are widely used in industrial and automation applications; hence, they are often called the workhorse of the motion industry. The whole world is going to be automated and computerize in every life sides so that we decided to serve this direction. The following sections discuss the needs of this project, its objectives and methodology to apply it.

### **1.2 Problem Statement**

Usually most of motors are connected by conductors which are used to connect power circuit and control circuit. Generally using of wire-conducting is problematic and complicated and it may raise the temperature in conductors where it increases the power losses which increases the operational cost as a result. In many applications, it is so difficult to control the machine nearly, and also may have been exposed to danger.

### **1.3 Objective**

The main aim of this project is to replace the ordinary switch which is currently used widely to control the operation of an induction motor commonly used in industry by remote control via Bluetooth technology.

## **1.4 Methodology**

The project is designed using microcontroller which acts as master mind of the project to receive input signals, process them according to the program and make decisions and produce out signals. To remotely control the motor; Bluetooth module is used to link the mastermind of the project (microcontroller) to the operator, also we need an AC drive (inverter) to convert signals from microcontroller into suitable values of voltage and frequency required to run the motor by specific speed.

## **1.5 Project Layout**

The project consists of five chapters:

Chapter one demonstrate the problems, the objective and the methodology of the project.

Chapter two talks about the main concepts of the project; such as induction motor, AC driver, control system, microcontroller and wireless connection.

Chapter three shows the components of the circuit and its usage.

Chapter four demonstrates the functions and operation of the circuit.

Chapter five contains the conclusion and recommendations.

# CHAPTER TWO

## GENERAL INFORMATIONS

### 2.1 Electric Motor

The main concept of electrical motors is to transfer electrical power to rotation mechanical power. Motors mostly found in applications as diverse as industrial fans, blowers and pumps, machine tools, household appliances, power tools, and disk drives.

Depending on the type of power supplied; motors are classified into D.C motors and A.C motor. D.C motors contain servo motors, stepper motors and universal motors. A.C motors are classified into synchronous motors and induction motors. <sup>[1]</sup>

#### 2.1.1 Induction motor:

A three phase induction motor is one of an electric motor that converts electrical power into a mechanical power which is then connected with different loads, that's why we described as transformer type. It may be energized directly from a three phase A.C or single phase A.C power grid.

Alternatively it may be energized through a Pulse Width Modulation (PWM) converter at variable voltage and frequency. In induction motors the rotor does not receive electric power by conduction but by induction in exactly the same way as the secondary of a 2-winding transformer receives its power from the primary. That is why such motors are known as induction motors. <sup>[2]</sup>

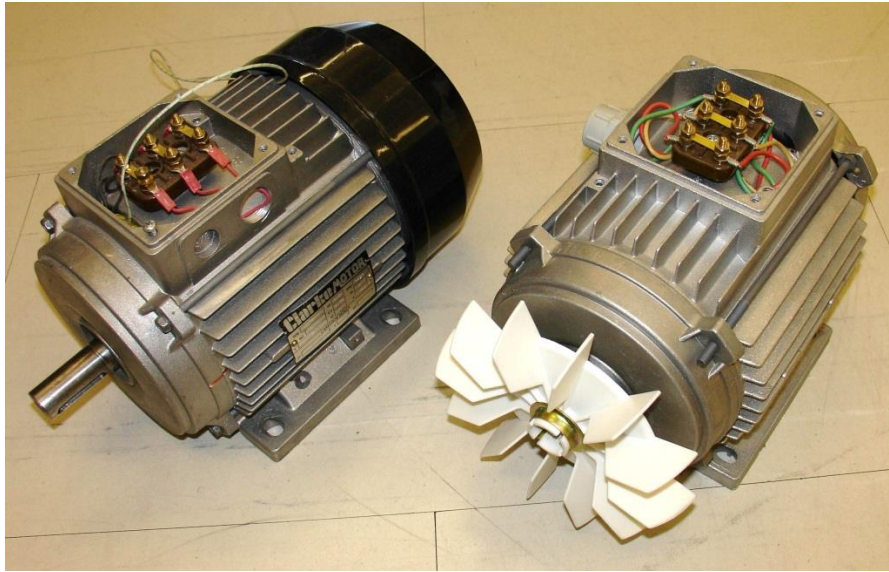


Figure 2.1: induction motor

### ❖ Construction

A 3-phase induction motor has two main parts stator and rotor.

➤ **Stator:** It consists of a steel frame which encloses a hollow, cylindrical core made up of thin laminations of silicon steel to reduce hysteresis and eddy current losses. The insulated connected to form a balanced 3-phase star or delta connected circuit. When 3-phase supply is given to the stator winding, a rotating magnetic field of constant magnitude is produced. This rotating field induces currents in the rotor by electromagnetic induction.

➤ **Rotor:** Construction of rotor depends on type of the specific motor which can be squirrel cage or wound rotor.

#### ✓ squirrel cage:

The rotor, mounted on a shaft, is a hollow laminated cylindrical core having parallel slots on its outer periphery. One copper or aluminum bar is placed in each slot. All these bars are joined at each end by metal rings called end rings. The entire construction (bars and end rings) resembles a squirrel cage and hence the name. The rotor is not connected electrically to the supply but has current

induced in it by transformer action from the stator. squirrel cage rotor shown in figure (2.2)

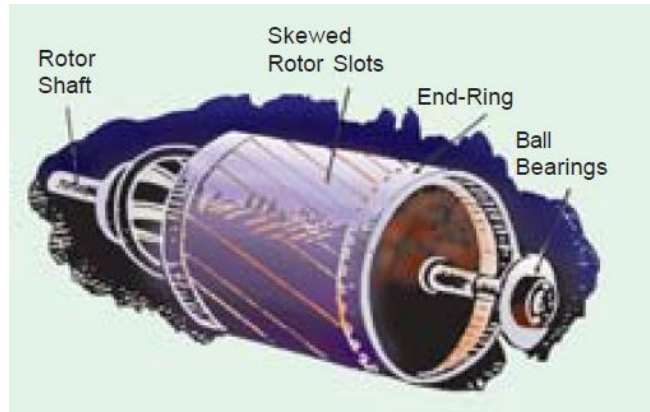


Figure 2.2: rotor in squirrel cage motor

✓ **Phase-wound Rotor:**

This type of rotor is provided with 3-phase, double-layer, distributed winding consisting of coils as used in alternators. The rotor is wound for as many poles as the number of stator poles and is always wound 3-phase even when the stator is wound two-phase. When running under normal conditions, the slip-rings are automatically short-circuited by means of a metal collar, which is pushed along the shaft and connects all the rings together.

Induction motor - in detail- consist of Frame, Stator and Rotor core, Air gap, Shafts and Bearings, Fans, Slip-rings and Slip-ring Enclosures.

When 3-phase stator winding is energized from a 3-phase supply, a rotating magnetic field is set up which rotates round the stator at synchronous speed ( $N_s$ ). The rotating field passes through the air gap and cuts the rotor conductors, which as yet, are stationary. Due to the relative speed between the rotating flux and the stationary rotor, electrical motive forces (e.m.fs) are induced in the rotor conductors. Since the rotor circuit is short-circuited, currents start flowing in the rotor conductors. The current-carrying rotor conductors are placed in the magnetic field produced by the stator. Consequently, mechanical force acts on

the rotor conductors. The summation of the mechanical forces on all the rotor conductors produces a torque which tends to move the rotor in the same direction as the rotating field. The fact that rotor is urged to follow the stator field (i.e., rotor moves in the direction of stator field) can be explained by Lenz's law. According to this law, the direction of rotor currents will be such that they tend to oppose the cause producing them. Now, the cause producing the rotor currents is the relative speed between the rotating field and the stationary rotor conductors. Hence to reduce this relative speed, the rotor starts running in the same direction as that of stator field and tries to catch it.

In practice, the rotor never succeeds in 'catching up' with the stator field. If it really did so, then there would be no relative speed between the two, hence no rotor e.m.f.s., no rotor current and so no torque to maintain rotation. That is why the rotor runs at a speed which is always less than the speed of the stator field. The difference in speeds depends upon the load on the motor. The difference between the synchronous speed ( $N_s$ ) and the actual speed ( $N$ ) of the rotor is known as slip.

$$S = \frac{N_s - N}{N_s} \quad (2.1)$$

$(N_s - N)$  is called the slip speed.

$N = N_s (1 - s)$  is rotor speed.

Where

$S \equiv$  slip

$N_s \equiv$  synchronous speed

$N \equiv$  actual speed

The value of slip must be between 0 and 1; a slip of 0 therefore indicates that the rotor speed is equal to the synchronous speed, while a slip of 1 corresponds to zero speed.

The torque developed by the motor at the instant of starting is called starting torque. In some cases, it is greater than the normal running torque, whereas in some other cases it is somewhat less.

$$T_{st} = \frac{3}{2\pi N_s} \cdot \frac{E_2^2 \cdot R_2^2}{R_2^2 + X_2^2} \quad (2.2)$$

Where

$T_{st} \equiv$  starting torque

$E_2 \equiv$  rotor e.m.f. per phase at standstill

$R_2 \equiv$  rotor resistance/phase

$X_2 \equiv$  rotor reactance/phase at standstill

Torque under running conditions reaches to its maximum at that value of the slip  $s$  which makes rotor reactance per phase equal to rotor resistance per phase. This slip is written as  $s_b$  and the maximum torque as  $T_{max}$ .<sup>[2]</sup>

$$s_b = \frac{R_2}{X_2} \quad (2.3)$$

Where

$s_b \equiv$  breakdown slip

Putting  $R_2 = s_b X_2$  in the above equation for the torque, we get:

$$T_{max} = \frac{k \phi s_b^2 E_2^2 X_2}{(s_b X_2)^2 + (s_b X_2)^2} = \frac{k \phi E_2^2}{2X_2} \quad (2.4)$$

Where

$T_{max} \equiv$  maximum torque

$\phi \equiv$  Flux

### ❖ **Speed Control of Induction Motors:**

A 3-phase induction motor is practically a constant-speed machine. The speed regulation of an induction motor (having low resistance) is usually less than 5% at full-load.

Different methods, by which speed control of induction motors is achieved, may be grouped under two main headings:

- **Control from stator side:** By changing the applied voltage, by changing the applied frequency and also by changing the number of stator poles.
- **Control from rotor side:** Rotor rheostat control, by operating two motors in concatenation or cascade and also by injecting an e.m.f in the rotor circuit.<sup>[2]</sup>

#### ➤ **Volt/Frequency (V/F) Method:**

Of the above mentioned methods, V/F Control is the most popular and has found widespread use in industrial and domestic applications because of its ease-of-implementation. However, it has inferior dynamic performance compared to vector control. Thus in areas where precision is required, V/F Control are not used. The various advantages of V/F Control that it provides good range of speed. It gives good running and transient performance, it also has low starting current requirement, and it also has a wider stable operating region, also Voltage and frequencies reach rated values at base speed, and the acceleration can be controlled by controlling the rate of change of supply frequency. Finally it is cheap and easy to implement.<sup>[3]</sup>

### ❖ **Power Stages in Induction Motors:**

Stator iron loss (consisting of eddy and hysteresis losses) depends on the supply frequency and the flux density in the iron core. It is practically constant. The iron loss of the rotor is, however, negligible because frequency of rotor currents under normal running conditions is always small.<sup>[2]</sup>

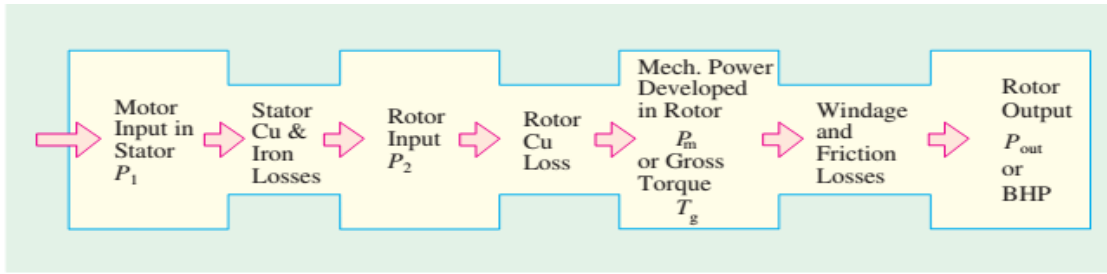


Figure 2.3: power stages in induction motor

## 2.2 AC Drive

AC drives, inverters and adjustable frequency drives all terms that are used to control the speed of AC motor. AC drives receive AC power and convert it to an adjustable frequency, adjustable voltage output for controlling motor operation. The three common inverter types are Current Source Inverter (CSI), Voltage Source Inverter (VSI) and pulse width modulation inverter (PWM).

➤ **Pulse Width Modulation drives (PWM drivers):** A basic PWM drive consists of a converter, DC link, control logic and inverter. A PWM drive is more efficient and typically provides higher level of performance. It can adjust the speed of motor by changing the frequency applied to the motor. Motor speed can adjust by adjusting the number of poles of motor, but this is physical change to the motor.

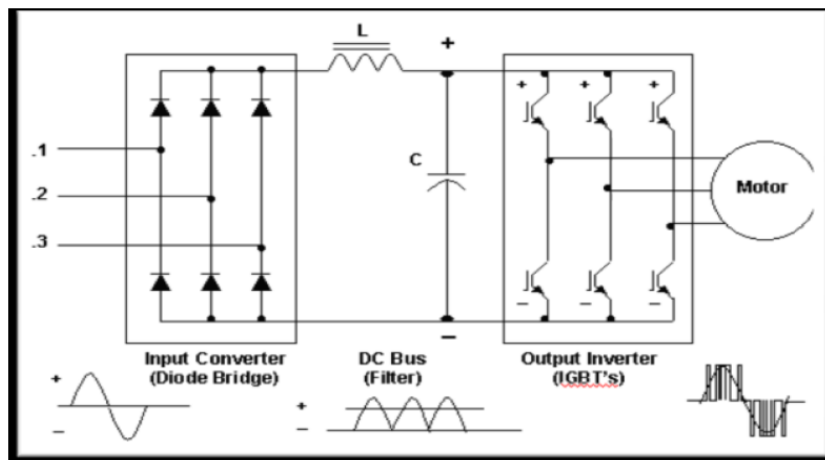


Figure 2.4: PWM drive Block Diagram

Although some drives accept single-phase input power, are going to focus on the 3-phase drive. The input section of the drive is the converter. It contains six diodes, arranged in an electrical bridge. These diodes convert AC power to DC power. The next section-the DC bus section sees a fixed DC voltage. DC bus section filters and smoothies out the waveform. <sup>[3]</sup>

The most widely used PWM schemes for three-phase voltage source inverters are carrier-based sinusoidal PWM and Space Vector Pulse Width Modulation (SVPWM). There is an increasing trend of using SVPWM because of their easier digital realization and better dc bus utilization. <sup>[4]</sup>

## **2.3 Control**

Automatic control has played a vital role in the advance of engineering and science. In addition to its extreme importance space-vehicle systems, missile-guidance systems, robotic systems, and the like, automatic control has become an important and integral part of modern manufacturing and industrial processes. For example, automatic control is essential in the numerical control of machine tools in the manufacturing industries, in the design of autopilot systems in the aerospace industries, and in the design of cars and trucks in the automobile industries. It is also essential in such industrial operations as controlling pressure, temperature, humidity, viscosity, and flow in the process industries Today, control systems find widespread application in the guidance, navigation, and control of missiles and spacecraft, as well as planes and ships at sea. For example, modern ships use a combination of electrical, mechanical, and hydraulic components to develop rudder commands in response to desired heading commands we find control in all industrial application, space research and all robot. <sup>[5]</sup>

### **2.3.1 Control system**

A control system consists of subsystems and processes (or plants) assembled for the purpose of obtaining a desired output with desired performance, given a

specified input. Control system in its simplest form, where the input represents a desired output.

We build control systems for four primary reasons; Power amplification, Remote control and also Compensation for disturbances.

#### ❖ **Control system elements**

To achieve full control options; there are many elements must found in control system:

- **Plant:** A plant may be a piece of equipment, perhaps just a set of machine parts functioning together, the purpose of which is to perform a particular operation.
- **Processes:** The Merriam-Webster Dictionary defines a process to be a natural, progressively continuing operation or development marked by a series of gradual changes that succeed one another in a relatively fixed way and lead toward a particular result or end; or an artificial or voluntary, progressively continuing operation that consists of a series of controlled actions or movements systematically directed toward a particular result or end.
- **Disturbances:** A disturbance is a signal that tends to adversely affect the value of the output of a system.
- **Feedback Control:** Feedback control refers to an operation that, in the presence of disturbances, tends to reduce the difference between the output of a system and some reference input and does so on the basis of this difference.

[6]

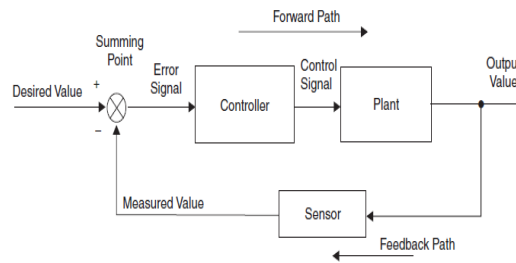


Figure 2.5: Control system elements

❖ **Types of control system:** There are two types of control systems depending on feedback open loop control system and closed loop control system:

➤ **Open loop control system:** Those systems in which the output has no effect on the control action are called open-loop control systems. In other words, in an open loop control system the output is neither measured nor feedback for comparison with the input. One practical example is a washing machine. In any open-loop control system the output is not compared with the reference input.

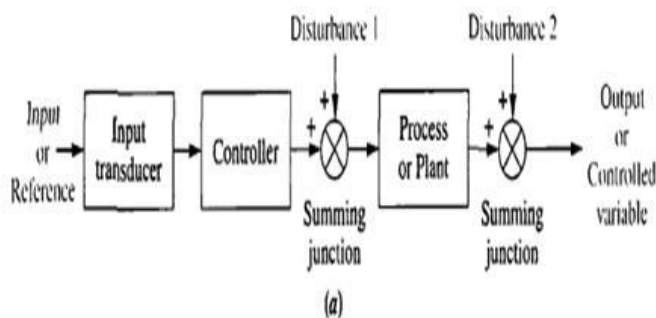


Figure 2.6: open loop system

➤ **Closed loop control system:** Feedback control systems are often referred to as closed-loop control systems. In practice, the terms feedback control and closed-loop control are used interchangeably. In a closed-loop control system the actuating error signal, which is the difference between the input signal and

the feedback signal (which may be the output signal itself or a function of the output signal and its derivatives and/or integrals), is fed to the controller so as to reduce the error and bring the output of the system to a desired value .The term closed-loop control always implies the use of feedback control action in order to reduce system error.<sup>[5]</sup>

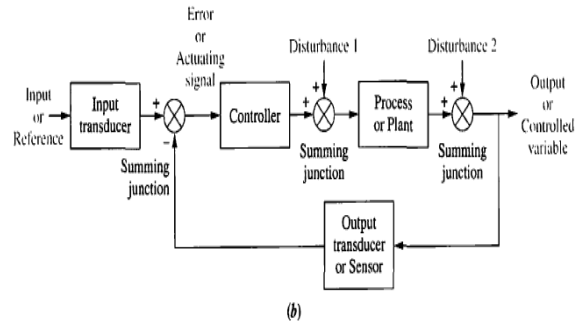


Figure 2.7: closed loop control system

## 2.4 Microcontroller

A microcontroller is a single-chip computer. The device is small, and it is used in control applications. Microcontrollers have many types; like Microchip PIC Microcontrollers, ARM core processors, Rabbit 2000 (8-bit), Microchip PIC Microcontrollers, Free scale Cold Fire (32-bit) and S08 (8-bit) and controlling Arduino. There are many modules typically found in a microcontroller, such as: Processor Core which contains the arithmetic logic unit, the control unit, and the registers, the memory that split into program memory and data memory, Timer/Counter, Analog input/output ports which have integrated analog/digital converters, Digital I/O and Interfaces that used to download the program and can also be used to communicate with external peripheral devices. Other components can be found in microcontrollers; like Interrupt Controller, Watchdog Timer and Debugging Unit according to microcontroller's family.<sup>[7]</sup>

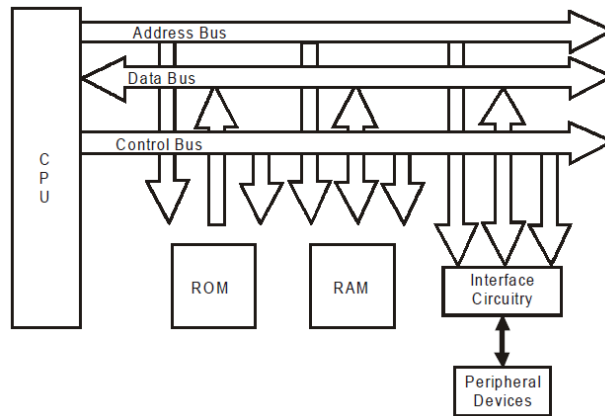


Figure 2.8: microcontroller

There are many families of microcontroller such as 8051 (Intel, Atmel, Dallas Phillips or Siemens), Motorola, PIC, Texas, National, ARM, and also other families which are used in several applications of microcontroller. Microcontrollers have a profound impact in our lives they are used widely at most of the places like Supermarkets in Cash Registers, Weighing Scales, at home in Ovens, Washing Machines, Alarm Clocks, play in Toys, VCRs, Stereo Equipment, and also at office in Typewriters, Photocopiers, Elevators, and it is used mainly in Industrial Automation, safety systems, etc.

There are many advantages of using microcontrollers; that microcontroller responds to control oriented devices in real time, Microcontrollers are used in small, minimum component designs performing control-oriented activities.<sup>[7]</sup>

## 2.5 Wireless

Wireless connectivity is the new word in computer networks. It involves connecting laptops, mobile libraries and even fridges to computer networks, without physical wire connections. Wireless connectivity means that individuals can potentially access the Internet, CD-ROM networks and office networks from anywhere and at any time. A wireless network is like any other computer network. It connects computers to computer networks but without the need for physical wire connections. A wireless network can provide network access to

computers, databases, the Internet and Online Public Access Catalogs (OPACs), both within and between buildings. The lack of a physical connection means that users are able to roam or work wherever they wish and still have access to the computer network. There are three main types of wireless network; Wide Area Networks (WANs), Local Area Networks (LANs) and Personal Area Networks (PANs).

➤ **wireless LANs:**

A Local Area Network allows computers at one geographical location to share information and devices such as printers. With a traditional LAN each computer physically connects to the network via wires and a network port. A Wireless Local Area Network (WLAN) provides the same services but without the need for physical connections between the computers and the network. A WLAN typically uses radio waves which allow network PC cards plugged into a PC/laptop to connect to a traditional Ethernet LAN. WLANs can usually support data rates of 11 megabits per second (Mbps), and have a range of 30-300 meters, with signals being able to pass through walls.

➤ **Wireless PANs:**

A PAN is a Personal Area Network. This is a network which allows electronic devices within a few meters of each other to communicate and synchronize information. The leading force in PANs is Bluetooth, a short-range radio technology which simplifies communication between different devices. It is based on the idea that a single chip fitted into electronic devices and buildings allows communication between them without wires. Already computer devices are being sold with Bluetooth preinstalled. This means that someone using a Bluetooth enabled laptop will be able to walk into a Bluetooth enabled building and immediately pick up access to its computer network. Wireless connectivity raises a number of issues for libraries:

✓ **Security:** A recent survey highlighted that 25% of organizations not using wireless LANs were held back by security concerns.

✓ **Costs:** Although running costs can be comparable to traditional wired networks, wireless transmission and reception equipment is generally much more expensive than the cost of comparable wired components.

### ❖ **Types of Wireless Technologies**

There are several wireless technologies used in industrial applications and also in home automation, most of these applications use Wi-Fi or Bluetooth technologies.

#### ❖ **Wi-Fi**

Primarily associated with computer networking, Wi-Fi uses the IEEE 802.11 specification to create a wireless local-area network that may be secure, such as an office network, or public, such as a coffee shop. Usually a Wi-Fi network consists of a wired connection to the Internet, leading to a wireless router that transmits and receives data from individual devices, connecting them not only to the outside world but also to each other. Wi-Fi range is generally wide enough for most homes or small offices, and for larger campuses or homes, range extenders may be placed strategically to extend the signal. Over time the Wi-Fi standard has evolved, with each new version faster than the last. Current devices usually use the 802.11n or 802.11ac versions of the spec, but backwards compatibility ensures that an older laptop can still connect to a new Wi-Fi router.

#### ❖ **Bluetooth**

While both Wi-Fi network enable connections to anywhere in the world, Bluetooth is much more local, with the stated purpose of "replacing the cables connecting devices," according to the official Bluetooth website. That's precisely what Bluetooth does; it connects –for example- phones to car stereos, wireless

keyboards and mice to laptops or cell phones to the ubiquitous hands-free earpieces. Bluetooth uses a low-power signal with a maximum range of 50 feet, but with sufficient speed to enable transmission of high-fidelity music and streaming video. As with other wireless technologies, Bluetooth speed increases with each revision of its standard but requires up-to-date equipment at both ends to deliver the highest possible speed. Also, the latest Bluetooth revisions are capable of using maximum power only when it's required, preserving battery life.<sup>[8]</sup>

# **CHAPTER THREE**

## **THE CIRCUIT COMPONENTS**

This chapter consist of a brief explanation and overview about the practical electrical circuit components used in wireless control of induction motor which we are about to implement to achieve the project objectives.

### **3.1 Bluetooth Module**

Abiding by the strict industrial norms and quality standards, we are engaged in supplying and trading Bluetooth Module. Our experts have designed and developed these modules by making use of latest technology as per the prevailing requirements of the industry. These Bluetooth modules offer an option of slave and master mode to the user and are available in variety of specifications at most reasonable prices.

#### **❖ Bluetooth Module HC-05**

Breakout is the latest Bluetooth wireless serial cable this version of the popular Bluetooth uses the HC-05/HC-06 module. These modems work as a serial Receiver and Transmitter (RX/TX) pipe. Any serial stream from 9600 to 115200 bps can be passed seamlessly from your computer to your target. The remote unit can be powered from 3.3V up to 6V for easy battery attachment. All signal pins on the remote unit are 3V-6V tolerant. No level shifting is required. Do not attach this device directly to a serial port. You will need an RS232 to TTL converter circuit or Arduino X-Bee USB Adapter if you need to attach this to a computer. You can either solder a 6-pin header or individual wires. Unit comes without a connector. And now, we provide HC-05/06, HC-05 could be setting to Master or Slave by user. Bluetooth devices use the Universal Asynchronous Receiver/Transmitter (UART) protocol.

### ❖ **Universal Asynchronous Receiver/Transmitter (UART)**

The (UART) controller is the key component of the serial communications subsystem of a computer. It is also a common integrated feature in most microcontrollers. It takes bytes of data and transmits the individual bits in a sequential fashion. At the destination, a second UART re-assembles the bits into complete bytes. Serial transmission of digital information (bits) through a single wire or other medium is much more cost effective than parallel transmission through multiple wires. Communication can be “full duplex” (both send and receive at the same time) or “half duplex” (devices take turns transmitting and receiving). The pic 18F4620 has special.<sup>[9]</sup>

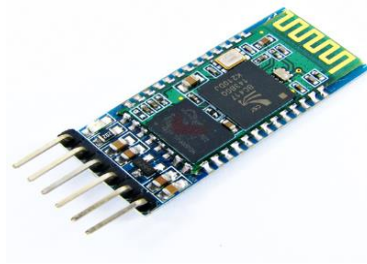


Figure 3.1: Bluetooth Module HC-05

### ❖ **Pins description**

Bluetooth module has six pins described below:

- ✓ **pin1:** key
- ✓ **Pin2:** VCC, voltage supply for logic, the standard voltage is 3.3V, and can work at 3.0-4.2V
- ✓ **Pin3** GND ground
- ✓ **Pin4:** UART\_TXD, Bluetooth serial signal sending PIN, can connect with MCU's RXD PIN.

- ✓ **Pin5:** UART\_RXD, Bluetooth serial signal receiving PIN, can connect with the MCU's TXD pin; there is no pull-up resistor in this pin. But it needs to be added an external pull-up resistor
- ✓ **Pin6:** STATE

The function of Bluetooth module is to receive signals from mobile phone (spp pro application) and translate these signals to arduino using UART protocol.

## 3.2 Arduino

Arduino is an open-source electronics prototyping platform based on flexible, easy to use hardware and software. It is a single board microcontroller, descendant of the open source wiring platform designed to make the process of using electronics in multi-disciplinary projects. The hardware consists of a simple open hardware design for the Arduino board with an on-board input/output support. Arduino hardware is programmed using a Wiring-based language (syntax and libraries), similar to C++ with some slight simplifications and modifications, and a Processing-based integrated development environment. An Arduino board consists of an 8-bit Atmel AVR microcontroller with complementary components to facilitate programming and incorporation into other circuits. An important aspect of the Arduino is the standard way that connectors are exposed, allowing the CPU board to be connected to a variety of interchangeable add-on modules known as shields. Some shields communicate with the Arduino board directly over various pins, but many shields are individually addressable via an IC serial bus, allowing many shields to be stacked and used in parallel. Official Arduinos have used the mega AVR series of chips Most boards include a 5 volt linear regulator and a 16 MHz crystal oscillator. At a conceptual level, when using the Arduino software stack, all boards are programmed over an RS-232 serial connection, but the way this is

implemented varies by hardware version. Serial Arduino boards contain a simple inverter circuit to convert between RS-232-level and TTL-level signals. Current Arduino boards are programmed via USB, implemented using USB-to-serial adapter chips. The Arduino board exposes most of the microcontroller's I/O pins for use by other circuits. Arduino can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling lights, motors, and other actuators. <sup>[10]</sup>

The software consists of a standard programming language compiler and the boot loader that runs on the board. The Arduino IDE is a cross-platform application written in Java, and is derived from the IDE for the Processing programming language and the wiring project. It is designed to introduce programming to artists and other newcomers unfamiliar with software development. It includes a code editor with features such as syntax highlighting, brace matching, and automatic indentation, and is also capable of compiling and uploading programs to the board with a single click. There is typically no need to edit make files or run programs on a command-line interface. Although building on command-line is possible if required with some third-party tools. Arduino embedded devices are inexpensive compared to other microcontroller embedded devices. It can run on Windows, Macintosh OSX, and Linux operating systems. Also it simple, clear programming environment and it is easy to use for beginners. Open source - The Arduino software is published as open source tools, so the user easy to get the information experienced programmers. <sup>[11]</sup>

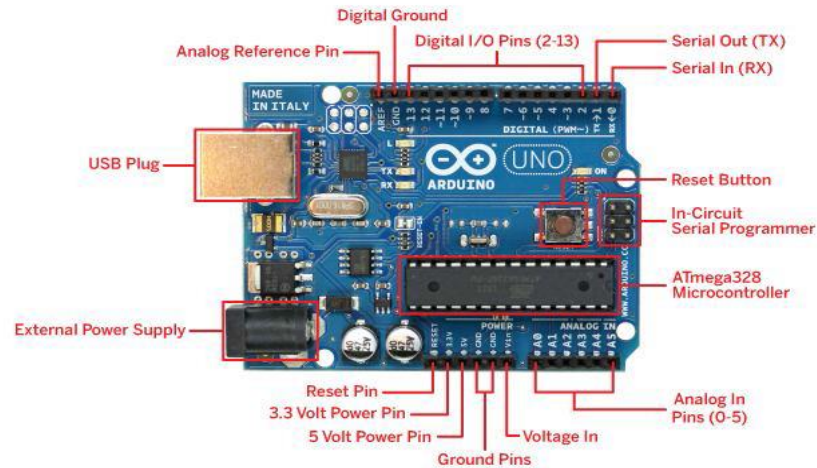


Figure 3.2: Block Diagram of arduino

### ❖ Pin Description

Arduino can be powered using power jack, Universal Serial Bus (USB) port. Apart from this it can also be powered by using an external battery or AC to DC adaptor through pin Vin.

- ✓ 5V, 3.3V: there is an inbuilt regulator on the board. Through this regulator a constant DC supply of 5V, 3.3V is provided.
- ✓ Reset: This pin enables to reset the micro controller.
- ✓ IOREF: This pin acts as reference to the inputs given to the Arduino board.
- ✓ There are 6 pins A0 – A5 through which analog input can be given to the Arduino board.
- ✓ There are 14 digital pins 0-13. Among these (3, 5, 6, 9, 10, 11) are PWM pins from which analog output can be taken from the arduino board.
- ✓ There is an inbuilt LED on pin 13.
- ✓ AREF- This pin acts as reference to the analog inputs.
- ✓ RX, TX are used for receiving and transmitting serial data.

Arduino is the mastermind of the circuit receives the signal from the phone via Bluetooth Module who shall process signal and send it to inverter.

### 3.3 Relay

A relay is an electrically operated switch. Many relays use an electromagnet to mechanically operate a switch, but other operating principles are also used, such as solid-state relays. Relays are used where it is necessary to control a circuit by a low-power signal or where several circuits must be controlled by one signal also used to protect electrical circuits from overload or faults.

There are two types of relay the first is solid-state relays control power circuits with no moving parts, instead using a semiconductor device to perform switching. Solid state electronic component that provides a similar function to an electromechanical relay but does not have any moving components, increasing long-term reliability. Every solid-state device has a small voltage drop across it. This voltage drop limits the amount of current a given SSR can handle. The minimum voltage drop for such a relay is a function of the material used to make the device. As shown in figure (3.3). And the second type is solid state contactor is a heavy-duty solid state relay, including the necessary heat sink, used where frequent on/off cycles are required, such as with electric heaters, small electric motors, and lighting loads. There are no moving parts to wear out and there is no contact bounce due to vibration as shown in figure (3.4)



Figure 3.3: Solid –state relay



Transistors have many types and here we mention the most important types are Bipolar Junction Transistor (BJT), Metal Oxide-Silicon Semiconductor Field Effect Transistor (MOSFET) Transistor and Field-effect Transistor (FET).

The function of transistor in this circuit is to pass 5V to the relay according to signal receive from arduino in base. We used transistor (PN 222A NPN)

### 3.5 Resistances

Electrical resistance is a physical property characteristic of metal conductors in electrical circuits. The resistance can be defined as the ability of material to resist the passage of electric current through it. And this phenomenon is measured in Ohm as a unit that allows passing of one Ampere when one volt is applied through the resistor. Figure (3.6) shows the resistance shape and its symbol.

Types of Resistors are the fixed resistance, Variable Resistance, Photonic Resistance and Thermal resistance.

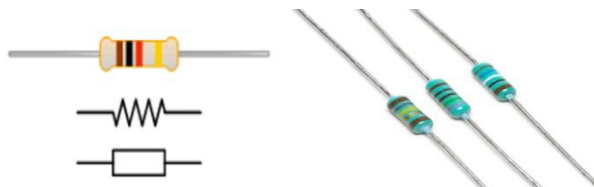


Figure 3.6: Resistance symbol and actual photo

We used fixed resistance in this project to protect the led.

### 3.6 Light Emitted Diodes (LEDs)

It is one of the most popular types of diodes and when this diode permits the transfer of electric current between the electrodes, light is produced. In most of the diodes, the light (infrared) cannot be seen as they are at frequencies that do

not permit visibility. The color of light depends on the energy gap of the semiconductor. Figure (3.7) shows LEDs and its internal construct.



Figure 3.7: LEDs types' actual photo and internal structure

The led's function in this circuit just to indicate and explain what type of process is doing.

### 3.7 VB5 frequency inverter

The inverter receives AC power and converts it to an adjustable frequency, adjustable voltage output for controlling motor operation. Its function in our circuit is interface between control circuit and power circuit. There are many Product technical specifications for this inverter:

✓ **Output:** Rated current (A) = 6.0, Rated voltage (V) = AC 380  
Frequency range (Hz) = 0~500.

✓ **Input:** Rated voltage/Frequency = 380V (3 $\emptyset$ ); 50Hz/60Hz

✓ **Modulation mode:** Optimized space voltage vector SVPWM modulation.

#### ❖ **Setting and wiring of control circuit:**

There are several parameters must be set before operation, as shown in table (3.1) and table (3.2). <sup>[12]</sup>

Table 3.1: Terminals on control panel of inverter

Terminal	Type	Name	Terminal function description	Specification
CI	Analog input	Analog input CI	Analog current/voltage input	Input voltage range: 0~10V Input current range: 4~20Ma
FWD	Running control terminal	Forward running command	Forward/reverse digital command refer to P4.08	Optical coupling isolation input
REV		Reverse running command		

Table 3.2: function code description

Parameter	Function	Range	option Set	Selected mode
P 0.00	Control mode selection	0~1	0	V/F control
P 0.01	Frequency setting channel selection	0~8	6	CI analog input
P 0.03	Running command	0~2	1	terminal control

	channel selection			
P 1.06	Gain of CI channel	0.01~9.99	2.00	CI input value doubled
P 4.08	FWD /REV operation mode selection	0~3	0	two wire control mode -1

### **3.8 Induction motor**

We use in this project 3-phase slip ring induction motor has rated voltage of 415 volt, 50 Hz, rated speed 1400 rpm, rated current of 5.2/3 A, rated power of 1.1 kw equals to 1.47 hp.

# CHAPTER FOUR

## FUNCTIONS AND OPERATION

In this chapter we talk about the implemented circuit which has been done by using the components discussed in chapter three to achieve the objectives of the project. Mainly this project contains two parts; Control Circuit and Power Circuit interfaced using Inverter.

- ✓ **Control Circuit:** represents a master mind of whole system, it process orders according to specific data programmed in microcontroller and sends suitable signals into Power Circuit via inverter. It also contains indicators which illustrates current status. Circuit supplied by low voltage (+5V) using DC power supply as shown in Figure (4.1)

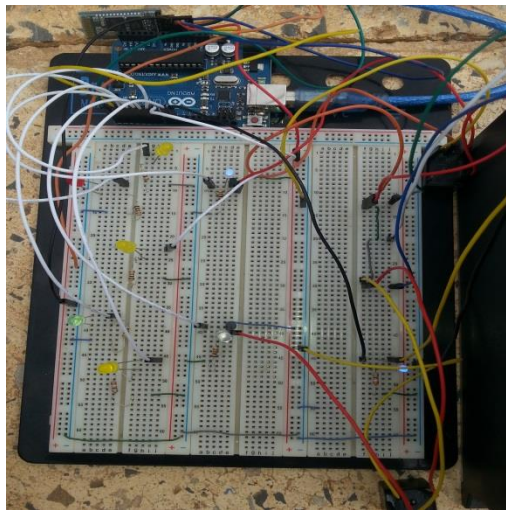


Figure 4.1: control circuit

- ✓ **Power Circuit:** supplied by 3-Phase 380 Volt, 50 Hz. It involves controlled motor which supplied from high voltage side in inverter. It also select suitable values of voltage and frequency which is required to run the motor according to signals received from microcontroller. Power circuit is shown in Figure (4.2)



Figure 4.2 power circuit

## 4.1 Operation:

Several requirements must be taken into consideration in order to achieve proper operating condition which system is programmed by. Firstly, we must press (START) button to prepare system for operating. Then, rotation direction must be determined by pressing either (FORWARD) or (REVERSE) button, and we can change direction set if needed. Then we have to select the speed by pressing (SPEED1), (SPEED2) or (SPEED3). After that motor will run depending on the selected speed by the direction specified in the previous step, we can also change between speeds directly, but if we want to change direction of rotation while motor is running; the motor will stop running for 10 seconds determined according to the time needed by the motor to stop running if it runs by the maximum speed (speed 3), in order to protect its shaft. When we want to turn off the system at any step can press (STOP).

In general when we press any button on the phone - in the keypad designed in the Bluetooth application "Bluetooth spp pro"- a signal will be sent a to Arduino via Bluetooth Module (HC-05). Then Arduino will send the signal to control panel of the inverter according to the programmed instructions. As a result the inverter changes its output (voltage and hertz) according to the signal received to run the motor.

### ➤ Procedures of connecting and controlling by Bluetooth

To connect the device with Bluetooth to wireless control there are some steps must take:

- ✓ On the mobile phone side, user chooses the program “SPP Bluetooth Pro.” as shown in Figure (4.3).

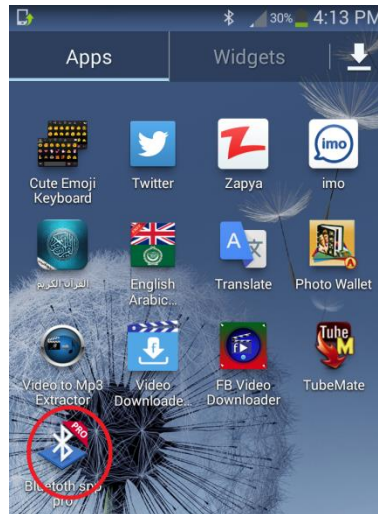


Figure 4.3: Choosing SPP Bluetooth Pro from mobile's menu

- ✓ The program starts searching for Bluetooth devices nearby. As shown in Figure (4.4).

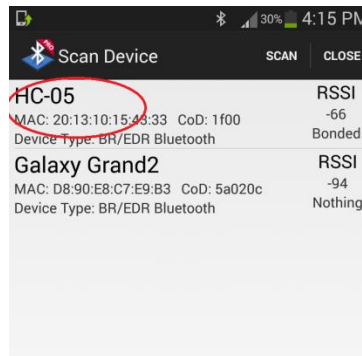


Figure 4.4: Choosing HC-05 from the menu to get connected

- ✓ The device shows (as previously set) by name "HC-05". As shown in Figure (4.4)
- ✓ User enters a password (1234) to secure the connection and complete pairing operation. After the completion of pairing, Bluetooth LED stops flashing and remains on to indicate that the Bluetooth module successfully

connected. Then the Mobile phone will be paired device and authorized to communicate at any time.

- ✓ After choosing “connect” to connect phone with the module; APP keyboard mode keys had been adjusted with data which must be sent to the Arduino to make suitable option. As shown in Figure (4.5) the selection of mode keyboard.

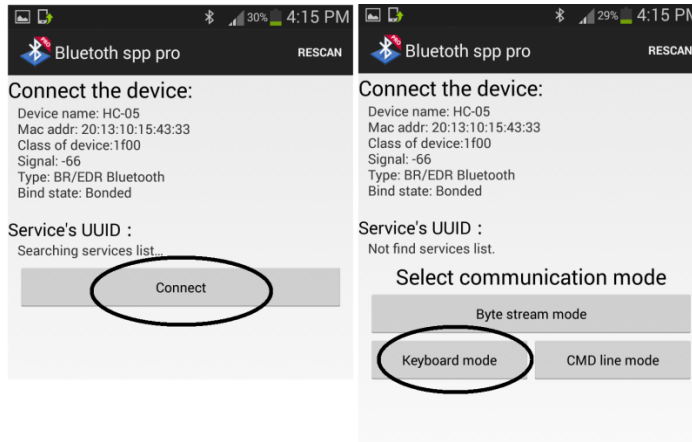


Figure 4.5: choosing “connect” when ready and selecting keyboard mode

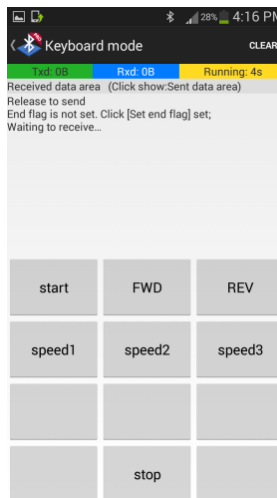


Figure 4.6: Control screen on the mobile phone

- ✓ In APP's keyboard mode (Figure 4.6), a keyboard appears with all the options, when you click any option on the screen the device make distinctive whistle for orders received via Bluetooth.

- **Start:** When we press (START) button pin 3 in Arduino will be high to light the start indicator (green led) in breadboard. After that the system is in standby mode.
- **Case1:** When we press (FORWARD) button the pin 4 in Arduino will be high to active FWD in control panel of inverter also light the forward indicator(yellow led) in breadboard and the inverter indicator (FWD) in its screen as shown in Figure (4.7). After that motor is ready to receive speed by the operator.



Figure 4.7: FWD indicator in screen inverter

When we press (SPEED1) button the pin 6 in arduino will be high to light the speed1 indicator (yellow led) and pin 9 (analog/out) out 2.25V to CI analog input also low light motor indicator (white led) in breadboard. And the inverter double the value of CI then out frequency (16.62 Hz) and voltage (81 v), Then show these values on an inverter's screen as shown in Figure (4.8), and these values enter the motor and make it run by speed (495.9 r.p.m) as shown in Figure (4.9).



Figure 4.8: Values of frequency and voltage of speed-1



Figure 4.9: Value of speed-1

When we press (SPEED2) button the pin 7 in arduino will be high to light the speed 2 indicator (yellow led) and pin 9 (analog/out) out 3V to CI analog input also medium light motor indicator (white led) in breadboard. And the inverter double the value of CI then out frequency (26.87 Hz) and voltage (134 V), then show these values on an inverter's screen as shown in Figure (4.10) ,and these values enter the motor and make it run by speed (797.3 r.p.m) as shown in Figure (4.11).



Figure 4.10: Values of voltage and frequency for speed-2



Figure 4.11: Value of speed-2

When we press (SPEED3) button the pin 8 in arduino will be high to light the speed3 indicator (yellow led) and pin 9 (analog/out) out 5V to CI analog input also high light motor indicator (white led) in breadboard. And the inverter is double the value CI then out frequency (50 Hz) and voltage (250 V), and show

these values on a screen inverter as shown in Figure (4.12) and these values enter the motor and make it run by speed (1495 r.p.m) as shown in Figure (4.13).



Figure 4.12: Values of voltage and frequency of speed-3



Figure 4.13: Value of speed-3

- **Case 2:** When we press (REVERSE) button the pin 4 in Arduino will be high to active (REV) in control panel of inverter also light the forward indicator (yellow led) in breadboard and the inverter indicator (REV) in its screen as shown in Figure (4.14). After that motor is ready to receive speed by the operator.



Figure 4.14: REV indicator in screen inverter

When we press (SPEED1) button the pin 6 in arduino will be high to light the speed1 indicator (yellow led) and pin 9 (analog/out) out 2.25V to CI analog input also low light motor indicator (white led) in breadboard. And the inverter double the value of CI then out frequency (16.62 Hz) and voltage (81 V) then show these values on an inverter's screen, and these values enter the motor and make it run by speed (495.5 r.p.m).

When we press (SPEED2) button the pin 7 in arduino will be high to light the speed 2 indicator (yellow led) and pin 9 (analog/out) out 3V to CI analog input also medium light motor indicator (white led) in breadboard. And the inverter double the value of CI then out frequency (26.87 Hz) and voltage (134 V) then show these values on an inverter's screen, and these values enter the motor and make it run by speed (797.3 r.p.m).

When we press (SPEED3) button the pin 8 in arduino will be high to light the speed 3 indicator (yellow led) and pin 9 (analog/out) out 5V to CI analog input also high light motor indicator (white led) in breadboard. And the inverter is double the value CI then out frequency (50 Hz) and voltage (250 V) and show these values on a screen inverter and these values enter the motor and make it run by speed (1495 r.p.m).

- **Stop:** When we press (STOP) button at any time the pin 2 in arduino will be high to light stop indicator (red led). After that the system is stop and the motor stop running.

#### **4.2 Simulation:**

Control circuit simulated by using Proteus 7 Professional programming language.

- Proteus

Proteus was designed to be practical (easy to use, efficient, complete), readable and consistent. Proteus contains everything needed to develop; test and virtually prototype embedded system designs based around the Microchip Technologies of microcontrollers. This design allows engineers to evolve their projects more quickly, empowering them with the flexibility to make hardware changes at will and reducing the time of design.

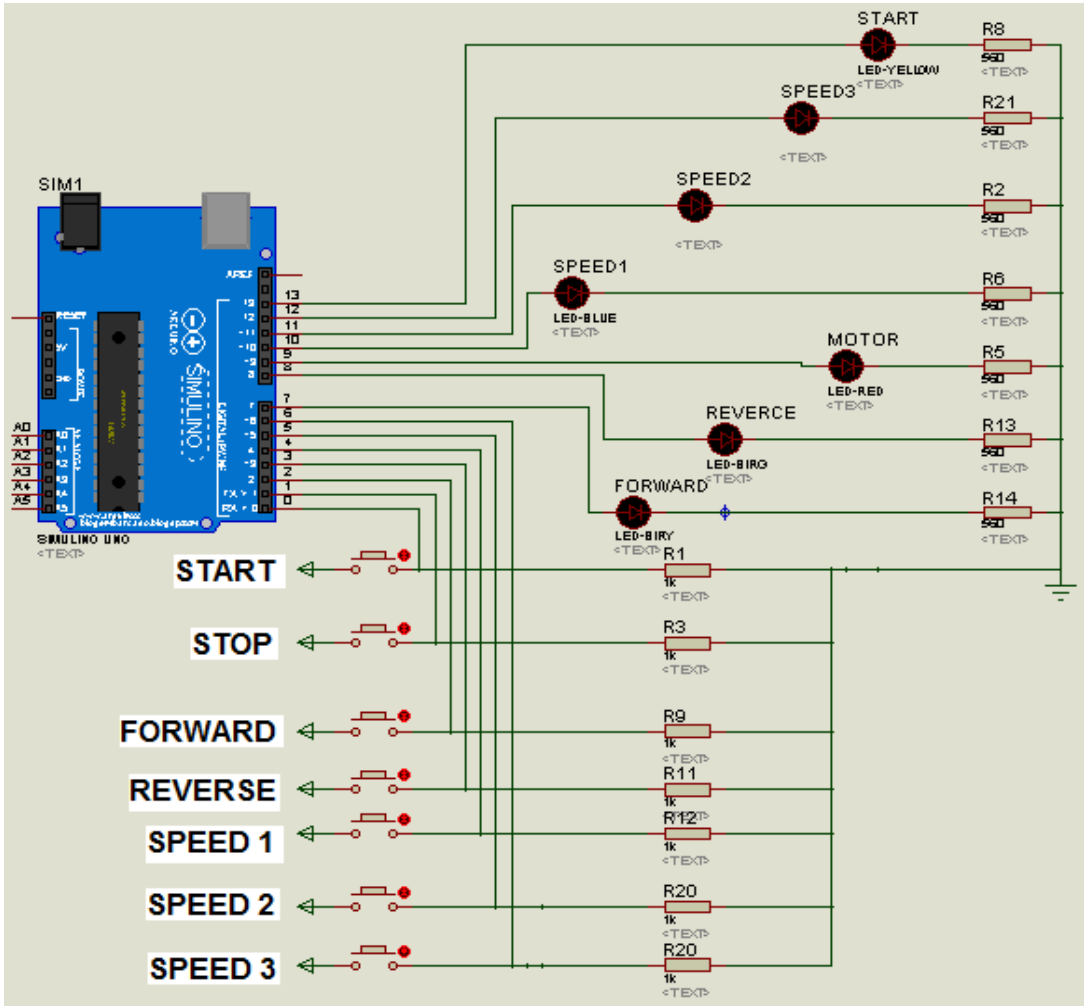


Figure 4.15: control circuit simulation

# CHAPTER FIVE

## CONCLUSION AND RECOMMENDATIONS

### 5.1 Conclusion

In the previous chapter the functions and operation were demonstrated for this project according to objectives and aims that have been mentioned in the beginning, giving solutions for problems which this project was made to solve. The control of induction motor has been optimized by using Bluetooth technology as one of wireless connection technologies, which is widely available in mobile phones and computers. This experience gave it greater flexibility and ease of use. The operator becomes safer and has more comfort remote controlling the motor from a distance.

### 5.2 Recommendations

To achieve high performance of this system or to raise its efficiency many recommendations can be followed:

- ❖ Bluetooth technology has small range (15m) so Zig-Bee technology can be used which has wide range (reach to 1 km). In addition; there are many technologies can be used to improve wireless connectivity; like GSM technology then system can be controlled from anywhere.
- ❖ If more fast needed we can use Wi-Fi technology instead of Bluetooth technology because Wi-Fi is faster in sending and receiving data.
- ❖ This system can be improved into close loop system (feedback system) providing it by sensors to add auto control facility to the system.
- ❖ For industrial application; PLC (Programmable Logic Controller) is more suitable than arduino especially in heavy industries.

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# APPENDIX

## Programme code

```
#include<SoftwareSerial.h>

SoftwareSerial bluetooth(0,1);

char BluetoothData;

int const Stop=2;

int const Start=3;

int const fwd=4;

int const rev=5;

int const sp1=6;

int const sp2=7;

int const sp3=8;

int const motor=9;

void setup()

{

  Serial.begin(9600);

  bluetooth.begin(9600);

  pinMode(fwd,OUTPUT);

  pinMode(rev,OUTPUT);

  pinMode(Stop,OUTPUT);

  pinMode(Start,OUTPUT);

  pinMode(sp1,OUTPUT);

  pinMode(sp2,OUTPUT);
```

```

pinMode(sp3,OUTPUT);
pinMode(motor,OUTPUT);
}
void loop()
{
BluetoothData=bluetooth.read();
int latchstop=digitalRead(Stop);
int latchstart=digitalRead(Start);
int latchfwd=digitalRead(fwd);
int latchrev=digitalRead(rev);
int latchsp1=digitalRead(sp1);
int latchsp2=digitalRead(sp2);
int latchsp3=digitalRead(sp3);
if (BluetoothData=='0')
{
digitalWrite(Stop,HIGH);
digitalWrite(Start,LOW);
digitalWrite(sp1,LOW);
digitalWrite(sp2,LOW);
digitalWrite(sp3,LOW);
digitalWrite(fwd,LOW);
digitalWrite(rev,LOW);
analogWrite(motor,0);

```

```

}

if
((BluetoothData=='1')&&(latchsp1==LOW)&&(latchsp2==LOW)&&(latchsp3
==LOW)&&(latchfwd==LOW)&&(latchrev==LOW))

{

digitalWrite(Stop,LOW);

digitalWrite(Start,HIGH);

digitalWrite(sp1,LOW);

digitalWrite(sp2,LOW);

digitalWrite(sp3,LOW);

digitalWrite(fwd,LOW);

digitalWrite(rev,LOW);

analogWrite(motor,0);

}

if
((BluetoothData=='2')&&(latchstop==LOW)&&(latchstart==HIGH)&&(latchsp
1==LOW)&&(latchsp2==LOW)&&(latchsp3==LOW))

{

    digitalWrite(fwd,HIGH);

    digitalWrite(rev,LOW);

}

else if
((BluetoothData=='2')&&(latchstop==LOW)&&(latchstart==HIGH)&&(latchf
wd==LOW)&&((latchsp1==HIGH)||(latchsp2==HIGH)||(latchsp3==HIGH)))

{

    digitalWrite(sp1,LOW);

```

```

digitalWrite(sp2,LOW);
digitalWrite(sp3,LOW);
analogWrite(motor,0);
digitalWrite(fwd,LOW);
digitalWrite(rev,LOW);
delay(10000);
digitalWrite(fwd,HIGH);
digitalWrite(rev,LOW);
}
if
((BluetoothData=='3')&&(latchstop==LOW)&&(latchstart==HIGH)&&(latchsp
1==LOW)&&(latchsp2==LOW)&&(latchsp3==LOW))
{
digitalWrite(fwd,LOW);
digitalWrite(rev,HIGH);
}
else if
((BluetoothData=='3')&&(latchstop==LOW)&&(latchstart==HIGH)&&(latchre
v==LOW)&&((latchsp1==HIGH)||(latchsp2==HIGH)||(latchsp3==HIGH)))
{
digitalWrite(sp1,LOW);
digitalWrite(sp2,LOW);
digitalWrite(sp3,LOW);
analogWrite(motor,0);
digitalWrite(rev,LOW);
}

```

```

digitalWrite(fwd,LOW);

delay(10000);

digitalWrite(rev,HIGH);

digitalWrite(fwd,LOW);

}

if
((BluetoothData=='4')&&(latchstop==LOW)&&(latchstart==HIGH)&&((latchf
wd==HIGH)||latchrev==HIGH))

{

digitalWrite(sp1,HIGH);

digitalWrite(sp2,LOW);

digitalWrite(sp3,LOW);

analogWrite(motor,115);

}

if
((BluetoothData=='5')&&(latchstop==LOW)&&(latchstart==HIGH)&&((latchf
wd==HIGH)||latchrev==HIGH))

{

digitalWrite(sp1,LOW);

digitalWrite(sp2,HIGH);

digitalWrite(sp3,LOW);

analogWrite(motor,153);

}

if
((BluetoothData=='6')&&(latchstop==LOW)&&(latchstart==HIGH)&&((latchf
wd==HIGH)||latchrev==HIGH))

```

```
{  
    digitalWrite(sp1,LOW);  
    digitalWrite(sp2,LOW);  
    digitalWrite(sp3,HIGH);  
    analogWrite(motor,255);  
}  
}
```