RESEARCH ARTICLE OPEN ACCESS

Speed Control Single Phase Induction Motor Using Android Phone

Mr. B. N. Patil , Mr. Sandesh Sonar , Mr. Pavankumar Karadiguddi , Mr. Shivanand Banti

[1]Professor, Electrical & Electronics Dept. , [2] Student, Electrical & Electronics Dept.
Angadi Institute of Technology & Management,
Belagavi, Karnataka.

Abstract:

As many of the industries use induction motors. So, controlling of induction motor plays a very vital role. So, our project concentrates on controlling the speed of induction motor using Android phone remotely by the help of the Bluetooth technology. We use Android application which uses Bluetooth to connect to the Bluetooth modem of control circuit which is connected to the motor. Bluetooth modem is interfaced with microcontroller. The Bluetooth slave modem receives the command from the mobile phone. The Bluetooth modem sends the signal to the Microcontroller. The Microcontroller decodes the signal and sends to the relays. Then, respective relay operates to change the speed of Induction motor from 0% to 100%.

We are not only controlling the speed of the Induction motor, using feedback network we can also detect the over temperature, high voltage, low voltage, MCB tripping on account of any faults. And we are also adding an extra application which is very important in industries. That is, monitoring of phase lines. Because these types of uncertainties like over temperature, high voltage, low voltage etc are likely to happen in Industries. So, this project will be very helpful in industries, house hold, shopping malls etc.

1. INTRODUCTION

The purpose of this project is to control the speed and direction of AC Motor using Microcontroller and Bluetooth with android phone. This uses a Resistance control technique to control the speed of AC motor from 0% to 100%.

Android is a software stack for mobile devices that includes an operating system, middleware and key applications. Android boasts a healthy array of connectivity options, including Wi-Fi, Bluetooth, and wireless data over a cellular connection (for example, GPRS, EDGE (Enhanced Data rates for GSM Evolution) and 3G). Android provides access to a wide range of useful libraries and tools that can be used to build rich applications. In addition, Android includes a full set of tools that have been built from the ground up alongside the platform providing developers with high productivity and deep insight into their applications.

1.1 Objectives

1. To control the speed of the single phase AC motor using wireless Bluetooth technology
2. To control the speed of the single phase AC motor using limited power supply.
3. To facilitate the flexible control of the speed of single phase AC induction motor used in industries.
4. Along with speed control, it also gives feedback for temperature rise.
5. To detect the over voltage and low voltage and indicates in mobile phone as well as in the kit display.
6. If any fault happens and MCB trips it will indicate in the kit display as well as in mobile phone via Android applications.

Along with speed control, it also monitors line for 3 phase supply. That is, which phase is on and which one is off and indicates in the mobile and kit display.

1.2 Project Overview

An embedded system is a combination of software and hardware to perform a dedicated task. Some of the main devices used in embedded products are Microprocessors and Microcontrollers.

Microprocessors are commonly referred to as general purpose processors as they simply accept the inputs, process it and give the output. In contrast, a microcontroller not only accepts the data as inputs

but also manipulates it, interfaces the data with various devices, controls the data and thus finally gives the result.

The project "**Single phase AC induction motor speed controlling based on Android mobile phone**" using PIC16F73 microcontroller is an exclusive project which is used to control the Single Phase induction motor using resistance control method by relays.

2 EMBEDDED SYSTEMS

An embedded system is a computer system designed to perform one or a few dedicated functions often with real-time computing constraints. It is embedded as part of a complete device often including hardware and mechanical parts. By contrast, a general-purpose computer, such as a personal computer (PC), is designed to be flexible and to meet a wide range of end-user needs. Embedded systems control many devices in common use today.

Embedded systems are controlled by one or more main processing cores that are typically either microcontrollers or digital signal processors (DSP). The key characteristic, however, is being dedicated to handle a particular task, which may require very powerful processors. For example, air traffic control systems may usefully be viewed as embedded, even though they involve mainframe computers and dedicated regional and national networks between airports and radar sites. (Each radar probably includes one or more embedded systems of its own.)

Since the embedded system is dedicated to specific tasks, design engineers can optimize it to reduce the size and cost of the product and increase the reliability and performance. Some embedded systems are mass-produced, benefiting from economies of scale.

Labeled parts include microprocessor (4), RAM (6), flash memory (7).Embedded systems programming is not like normal PC programming. Fig 2.1: A modern example of embedded system**.** In many ways, programming for an embedded system is like programming PC 15 years ago. The hardware for the system is usually chosen to make the device as cheap as possible. Spending an extra dollar a unit in order to make things easier to program can cost millions. Hiring a programmer for an extra month is cheap in comparison. This means the programmer must make do with slow processors and low memory, while at the same time battling a need for efficiency not seen in most PC applications. Below is a list of issues specific to the embedded field.

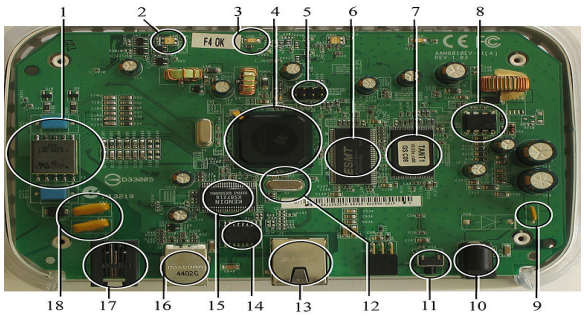


Fig 2.1: A modern example of embedded system

In many ways, programming for an embedded system is like programming PC 15 years ago. The hardware for the system is usually chosen to make the device as cheap as possible. Spending an extra dollar a unit in order to make things easier to program can cost millions. Hiring a programmer for an extra month is cheap in comparison. This means the programmer must make do with slow processors and low memory, while at the same time battling a need for efficiency not seen in most PC applications. Below is a list of issues specific to the embedded field.

3 .HARDWARE DESCRIPTION

Speed control of single phase AC induction motor based on Resistance control.

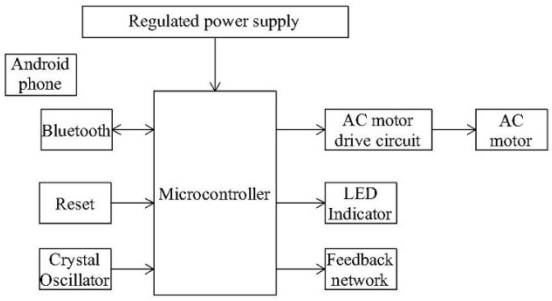


Fig 3.1 Main block diagram

3.1 The main blocks of this project are:

1. Micro controller (16F73)
2. Reset button
3. Crystal oscillator
4. Regulated power supply (RPS)
5. LED indicator
6. Bluetooth module
7. Relay
8. AC motor drive circuit
9. AC motor
10. Feedback network

3.1.1 Micro controller:

Fig 3.2 Microcontroller PIC16F73

Introduction

The PIC16F73 CMOS FLASH-based 8-bit microcontroller is upward compatible with the PIC16C73B/74B/76/77,
PIC16F873/874/876/877devices. It features 200 ns instruction execution, self programming, an ICD, 2 Comparators, 8 channels of 8-bit Analog-to-Digital (A/D) converter, 2 capture/compare/PWM functions, a synchronous serial port that can be configured as either 3-wire SPI or 2-wire I2C bus, a USART, and a Parallel Slave Port.

Pin description

PIC16F73 has a total of 28 pins. It is most frequently found in a DIP28 type of case but can also be found in SMD case which is smaller from a DIP. DIP is an abbreviation for Dual in Package. SMD is an abbreviation for Surface Mount Devices suggesting that holes for pins to go through when mounting aren't necessary in soldering this type of a component.

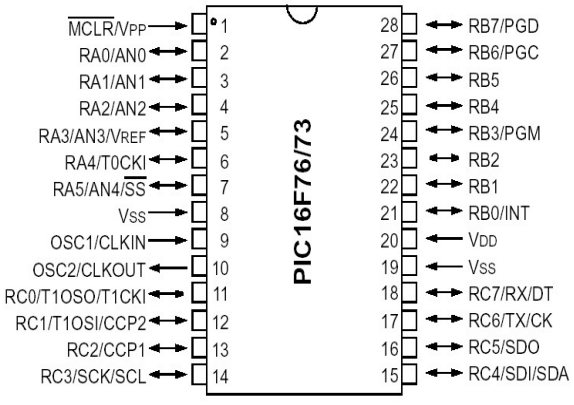


Fig 3.3 Pin diagram of PIC16F73

By utilizing all of this pin so many application can be done such as:
1. LCD – connect to Port B pin.
2. LED – connect to any pin declared as output.
3. Relay and Motor - connect to any pin declared as output.
4. External EEPROM – connect to I2C interface pin – RC3 and RC4 (SCL and SDA)
5. LDR, Potentiometer and sensor – connect to analogue input pin such as RA0.
6. GSM modem dial up modem – connect to RC6 and RC7 – the serial communication interface using RS232 protocol.

For more detail function for each specific pin please refer to the device datasheet from Microchip.

Ports

Term "port" refers to a group of pins on a microcontroller which can be accessed simultaneously, or on which we can set the desired combination of zeros and ones, or read from them an existing status. Physically, port is a register inside a microcontroller which is connected by wires to the pins of a microcontroller. Ports represent physical connection of Central Processing Unit with an outside world. Microcontroller uses them in order to monitor or control other components or devices. Due to functionality, some pins have twofold roles like PA4/TOCKI for instance, which is in the same time the fourth bit of port A and an external input for free-run counter. Selection of one of these two pin functions is done in one of the configuration registers. An illustration of this is the fifth bit T0CS in OPTION register. By selecting one of the functions the other one is disabled.

All port pins can be designated as input or output, according to the needs of a device that's being developed. In order to define a pin as input or output pin, the right combination of zeros and ones must be written in TRIS register. If the appropriate bit of TRIS register contains logical "1", then that pin is an input pin, and if the opposite is true, it's an output pin. Every port has its proper TRIS register. Thus, port A has TRISA, and port B has TRISB. Pin direction can be changed during the course of work which is particularly fitting for one-line communication where data flow constantly changes direction. PORTA and PORTB state registers are located in bank 0, while TRISA and TRISB pin direction registers are located in bank 1.

Memory organization

PIC16F73 has two separate memory blocks, one for data and the other for program. EEPROM memory with GPR and SFR registers in RAM memory make up the data block, while FLASH memory makes up the program block.

Program memory

Program memory has been carried out in FLASH technology which makes it possible to program a microcontroller many times before it's installed into a device and even after its installment if eventual changes in program or process parameters should occur. The size of program memory is 1024 locations with 14 bits width where locations zero and four are reserved for reset and interrupt vector.

Data memory

Data memory consists of EEPROM and RAM memories. EEPROM memory consists of 256 eight bit locations whose contents are not lost during loosing of power supply. EEPROM is not directly addressable, but is accessed indirectly through EEADR and EEDATA registers. As EEPROM memory usually serves for storing important parameters (for example, of a given temperature in temperature regulators), there is a strict procedure for writing in EEPROM which must be followed in order to avoid accidental writing. RAM memory for data occupies space on a memory map from location 0x0C to 0x4F which comes to 68 locations. Locations of RAM memory are also called GPR registers which is an abbreviation for *General Purpose Registers*. GPR registers can be accessed regardless of which bank is selected at the moment.

3.1.2 Reset button:

In our project, reset button is used to reset all the relays and feedback indicators. Reset button will be present in the Android application. So, that we can control the reset button by using mobile phone.

3.1.3 Crystal oscillator:

Crystal oscillator is used to generate required frequency for the Microcontroller.

3.1.4 Regulated power supply:

Introduction:

Power supply is a supply of electrical power. A device or system that supplies electrical or other types of energy to an output load or group of loads is called a power supply unit or PSU. The term is most commonly applied to electrical energy supplies, less often to mechanical ones, and rarely to others.

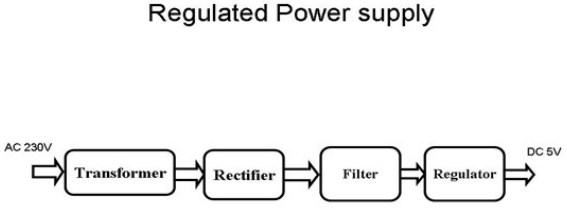


Fig 3.4 Regulated Power Supply

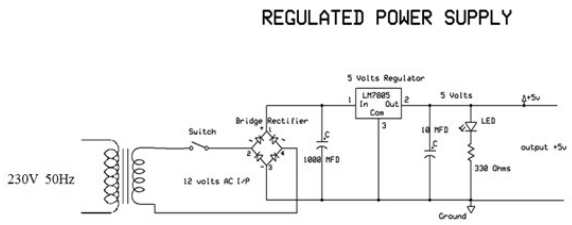


Fig 3.5 Circuit diagram of Regulated Power Supply with Led connection

The components mainly used in above figure are

- 230V AC MAINS
- TRANSFORMER
- BRIDGE RECTIFIER(DIODES)
- CAPACITOR
- VOLTAGE REGULATOR(IC 7805)
- RESISTOR
- LED(LIGHT EMITTING DIODE)

The detailed explanation of each and every component mentioned above is as follows:

Transformation:

The process of transforming energy from one device to another is called transformation. For transforming energy we use transformers.

Transformers:

A transformer is a device that transfers electrical energy from one circuit to another through inductively coupled conductors without changing its frequency. A varying current in the first or primary winding creates a varying magnetic flux in the transformer's core, and thus a varying magnetic field through the secondary winding. This varying magnetic field induces a varying electromotive force (EMF) or "voltage" in the secondary winding. This effect is called mutual induction.

Rectification:

The process of converting an alternating current to a pulsating direct current is called as rectification. For rectification purpose we use rectifiers.

Rectifiers:

A rectifier is an electrical device that converts alternating current (AC) to direct current (DC), a process known as rectification. Rectifiers have many uses including as components of power supplies and as detectors of radio signals. Rectifiers may be made of solid-state diodes, vacuum tube diodes, mercury arc valves, and other components.

A device that it can perform the opposite function (converting DC to AC) is known as an

inverter. A capacitor will pass alternating current but (apart from an initial surge) it will not pass DC.

Regulation:

The process of converting a varying voltage to a constant regulated voltage is called as regulation. For the process of regulation we use voltage regulators.

Voltage Regulator:

A voltage regulator (also called a 'regulator') with only three terminals appears to be a simple device, but it is in fact a very complex integrated circuit. It converts a varying input voltage into a constant 'regulated' output voltage. Voltage Regulators are available in a variety of outputs like 5V, 6V, 9V, 12V and 15V. The LM78XX series of voltage regulators are designed for positive input. For applications requiring negative input, the LM79XX series is used. Using a pair of 'voltage-divider' resistors can increase the output voltage of a regulator circuit.

It is not possible to obtain a voltage lower than the stated rating. You cannot use a 12V regulator to make a 5V power supply. Voltage regulators are very robust. These can withstand over-current draw due to short circuits and also over-heating. In both cases, the regulator will cut off before any damage occurs. The only way to destroy a regulator is to apply reverse voltage to its input. Reverse polarity destroys the regulator almost instantly. Fig: 3.5 shows voltage regulator.

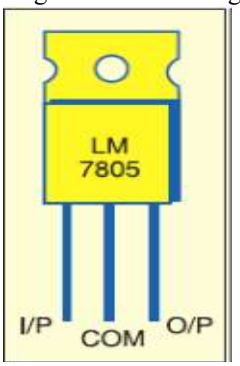


Fig 3.6 Voltage Regulator

Resistors:

A resistor is a two-terminal electronic component that produces a voltage across its terminals that is proportional to the electric current passing through it in accordance with Ohm's law.

Ohm's law:

The behavior of an ideal resistor is dictated by the relationship specified in Ohm's law:

$$V = IR \text{……} (1)$$

Ohm's law states that the voltage (V) across a resistor is proportional to the current (I) through it where the constant of proportionality is the resistance (R).

Power dissipation:

The power dissipated by a resistor (or the equivalent resistance of a resistor network) is calculated using the following:

$$P = I^2R = IV = V^2/R \text{……..} (2)$$

3.1.4 LED indicator:

A light-emitting diode (LED) is a semiconductor light source. LED's are used as indicator lamps in many devices, and are increasingly used for lighting. Introduced as a practical electronic component in 1962, early LED's emitted low-intensity red light, but modern versions are available across the visible, ultraviolet and infrared wavelengths, with very high brightness.

3.1.5 Bluetooth module:

The 'Bluetooth' is the short-range radio link technology designed to "connect" an array of devices including mobile phones, PCs and PDAs. In our project we are using HC – 06 Bluetooth module. In our project Bluetooth module is used in the motor drive circuit to connect with Android mobile phone by the help of Android application.

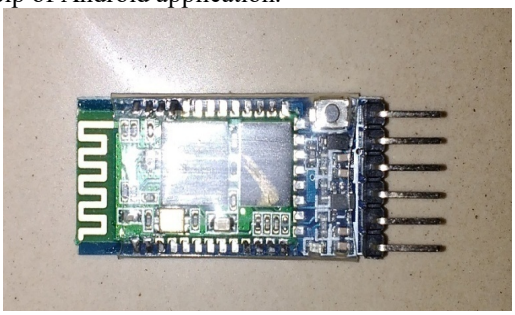


Fig 3.5 Bluetooth module used (JY-MCU-HC-06)

Bluetooth module specifications:

HC – 06 with serial port module.

Bluetooth number: JY-MCU-HC-06, surface mount with integrated antenna.

Operating Voltage: 5 volt, reduced to 3.3 volts, @ 8 mA.

Default baud rate: 9600 bps.

3.1.6 Motor drive circuit:

Motor drive circuit is used to control the speed of motor by resistance control method with the help of relays which are connected to the respective resistances. The relays are interfaced with the Microcontroller with the help of relay driver chip. The two important components of motor drive circuit are,

- Relay
- Relay driver chip

The description and specifications of these components are given below.

- **Relays:**

Relays are the primary protection as well as switching devices in most of the control processes or equipment regardless of whether they are electronic or electromechanical. All the relays respond to one or more electrical quantities like voltage or current such that they open or close the contacts or circuits. A relay is a switching device as it works to isolate or change the state of an electric circuit from one state to another. These are found in all sorts of devices. Relays allow one circuit to switch over to a second circuit that can be completely separated from the first. There is no electrical connection inside the relay between the two circuits – the link is magnetic and mechanical only.

- **Relay driver chip (ULN2003A):**

The ULx200xA devices are high-voltage, high-current Darlington transistor arrays. Each consists of seven NPN Darlington pairs that feature high-voltage outputs with common-cathode clamp diodes for switching inductive loads.

3.1.7 AC motor:

An induction or asynchronous motor is an AC electric motor in which the electric current in rotor needed to produce torque is obtained by electromagnetic induction from the magnetic field of the stator winding. An induction motor can therefore be made without electrical connections to the rotor as found in universal, DC and synchronous motors. An induction motor's rotor can be either wound type or squirrel–cage type.

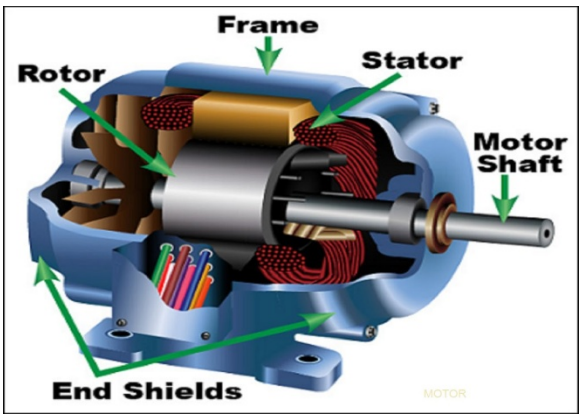


Fig 3.5 Induction motor

Specifications of the motor we used in our project:

Speed: 2800 RPM Operating frequency: 50Hz

Supply Voltage: 230V AC Power: ¼ HP

3.1.8 Feedback network:

Along with speed control, we can also detect the common problems which are likely to be happened in the industries with the help of feedback network. In our project we are using feedback network to detect problems like over temperature, high voltage, low voltage, tripping of MCB due to any faults in the supply.

We are also monitoring phase lines which will be very helpful in industries. That is, to monitor which phase is on and which phase is off.

3.2 Methodology:

The speed of the AC motor is measured using wireless speed measurement technique. Speed control is done using Resistance control method. User can increase and decrease the speed of the AC motor through android Smartphone. The controlling device of the whole system is speed control. The Microcontroller is programmed using Embedded C language.

This project uses regulated 5V, 500mA power supply, PIC microcontroller 7805, a three terminal voltage regulator is used for voltage regulation. Bridge type full wave rectifier is used to rectify the AC output of 230/12v step down transformer.

The application will be installed in the phone which uses Bluetooth device of the android phone. Various types of control switches are present in the application. On the other side the control circuitry of motor also contains a Bluetooth modem which is used connect with the phone. The Bluetooth modem is connected with microcontroller which is used to decode the command sent by mobile. Microcontroller is then connected with relay drive, to which various relays are connected. The relays are connected with Resistance speed control. That is, we use armature resistance to control the speed of motor. The regulated power supply is given to the control circuit.

4. SOFTWARE DESCRIPTION

This project is implemented using following software's:

- Express PCB – for designing circuit
- PIC compiler - for compilation part

4.1 Express PCB:

Breadboards are great for prototyping equipment as it allows great flexibility to modify a design when needed; however the final product of a project, ideally should have a neat PCB, few cables, and survive a shake test. Not only is a proper PCB neater but it is also more durable as there are no cables which can yank loose.

Express PCB is a software tool to design PCBs specifically for manufacture by the company Express PCB (no other PCB maker accepts Express PCB files). It is very easy to use, but it does have several limitations.

1. It can be likened to more of a toy then a professional CAD program.
2. It has a poor part library (which we can work around).
3. It cannot import or export files in different formats.
4. It cannot be used to make prepare boards for DIY production.

Express PCB has been used to design many PCBs (some layered and with surface-mount parts. Print out PCB patterns and use the toner transfer method with an Etch Resistant Pen to make boards. However, Express PCB does not have a nice print layout. Here is the procedure to design in Express PCB and clean up the patterns so they print nicely.

4.2 PIC Compiler:

PIC compiler is software used where the machine language code is written and compiled. After compilation, the machine source code is converted into hex code which is to be dumped into the microcontroller for further processing. PIC compiler also supports C language code.

It's important that you know C language for microcontroller which is commonly known as Embedded C. As we are going to use PIC Compiler, hence we also call it PIC C. The PCB, PCM, and PCH are separate compilers. PCB is for 12-bit opcodes, PCM is for 14-bitopcodes, and PCH is for 16-bit opcode PIC microcontrollers. Due to many similarities, all three compilers are covered in this reference manual. Features and limitations that apply to only specific microcontrollers are indicated within. These compilers are specifically designed to meet the unique needs of the PIC microcontroller. This allows developers to quickly design applications software in a more readable, high-level language. When compared to a more traditional C compiler, PCB, PCM, and PCH have some limitations. As an example of the limitations, function recursion is not allowed.

This is due to the fact that the PIC has no stack to push variables onto, and also because of the way the compilers optimize the code. The compilers can efficiently implement normal C constructs, input/output operations, and bit twiddling operations. All normal C data types are supported along with pointers to constant arrays, fixed point decimal, and arrays of bits.

4.3 Android notes

Android is a software platform and operating system for mobile devices, based on the Linux kernel, and developed by Google and later the Open Handset Alliance. It allows developers to write managed code in the Java language, controlling the device via Google-developed Java libraries. The unveiling of the Android platform on 5 November 2007 was announced with the founding of the Open Handset Alliance, an association of 48 hardware, software and telecom companies devoted to advancing open standards for mobile devices. Google released most of the Android code under the Apache license, a free-software and open source license.

Free and Open Source

Android is an open source platform. Neither developers nor handset manufacturers pay royalties or license fees to develop for the platform. The underlying operating system of Android is licensed under GNU General Public License Version 2 (GPLv2), a strong "copy left" license where any third-party improvements must continue to fall under the open source licensing agreement terms. The Android framework is distributed under the Apache Software License (ASL/Apache2), which allows for the distribution of both open and closed source derivations of the source code. Commercial developers (handset manufacturers especially) can choose to enhance the platform without having to provide their improvements to the open source community. Instead, developers can profit from enhancements such as handset-specific improvements and redistribute their work under whatever licensing they want. Android application developers have the ability to distribute their applications under whatever licensing scheme they prefer. Developers can write open source freeware or traditional licensed applications for profit and everything in between.

Network Connectivity

It supports wireless communications using:

GSM mobile-phone technology
3G
Edge

802.11 Wi-Fi networks

4.4 Program Code:

The program code which is dumped in the microcontroller of our project is shown below.

```
#include <16F73.h>

#use     delay(CLOCK=20M)
```

```
#use rs232 (baud = 9600, xmit=PIN_B1,rcv=PIN_B0,stream=BT) //New RFID Reader baudrate

#include <BT136.c>

int i = 0;
char data[15];
char ch;

void main()
{
  int j = 0;
  output_high(pin_A0);
  output_high(pin_A1);
  delay_ms(800);
  output_low(pin_A0);
  output_low(pin_A1);
  delay_ms(800);
  output_high(pin_A0);
  output_high(pin_A1);
  delay_ms(800);
  output_low(pin_A0);
  output_low(pin_A1);
  delay_ms(800);

  while(1) //working with pull up of 10 at output pin of Hall Effect Sensor
  {

      ch = fgetc(BT);

        if(strstr(data,up1))
        {
          if(i < 12)
          {
            i++;
            output_c(up[i]);

            output_high(PIN_A0);
            delay_ms(250);
            output_low(PIN_A1);
            output_low(PIN_A0);
          }
          else
          {
            output_high(PIN_A0);
          }
        }

        if(strstr(data,down1))
        {
          if(i > 0)
          {
            i--;
            output_c(up[i]);
            output_high(PIN_A1);
            delay_ms(250);
            output_low(PIN_A1);
            output_low(PIN_A0);
            delay_ms(52);
          }
          else
          {
            output_high(PIN_A1);
          }
        }
      }
    }
  }
```

5. ADVANTAGES, DISADVANTAGES AND APPLICATIONS

5.1 Advantages:

1. Bluetooth Wireless communication using android mobile
2. Conservation of energy.
3. Efficient and low cost design.
4. Easily operable.
5. Fast response with the help of resistance control.
6. Low power consumption.

5.2 Disadvantages:

1. Interfacing resistance and relays to Micro Controller is highly sensitive.
2. Sensitive to high voltage devices.
3. Bluetooth wireless communication supports only for limited distance.

5.3 Applications:

This can be practically implemented in real time to control the electrical power usage in

- Industries,
- House hold,
- Shopping malls etc.

6 RESULT & CONCLUSION

6.1 Result

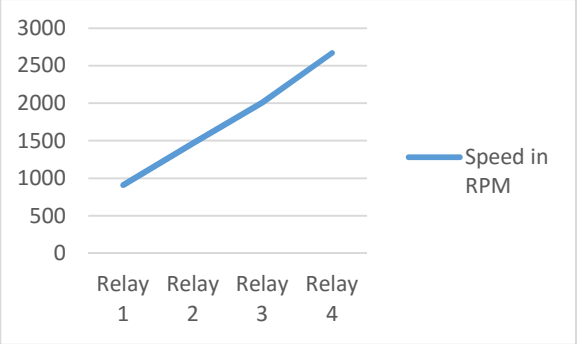
The project “Single phase induction motor speed controlling based on Android mobile phone” was designed such that to control the speed of the AC motor using Bluetooth control technique by making use of resistance control method to control the speed of the motor using android mobile with Bluetooth wireless communication. The speed can be controlled from 0% to 100% as four different speeds. Using feedback network we can also detect over temperature, high voltage, low voltage, MCB tripping

on account of any faults. We are also monitoring phases. Compared to other methods like frequency control, PWM method, TRIAC control and Thyristor firing angle control this method is less expensive and design is easy.

Table 1 Speed of motor for different relays

Relay number	Resistance (Ω)	Speed in RPM
1	134	911
2	249	1463
3	362	2011
4	481	2672

Graph 1 Graph of speed versus relay



6.2 Conclusion

Integrating features of all the hardware components used have been developed in it. Presence of every module has been reasoned out and placed carefully, thus contributing to the best working of the unit. Secondly, using highly advanced IC's with the help of growing ANDROID technology, the project has been successfully implemented.

6.3 Future Scope:

Our project "**Single phase Induction motor speed controlling based on Android mobile phone**" is mainly intended to control the motor speed using resistance control technique. This system has Bluetooth receiver module, Relays which are interfaced to the micro controller.

The controlling device of the whole system is a Microcontroller. Bluetooth module, Relays, AC motor are interfaced to the Microcontroller. The data received by the Bluetooth module from Android smart phone is fed as input to the Microcontroller. The Microcontroller decodes the signal received from Bluetooth module and sends the signal to the relays.

The relays work according to the command. In achieving the task the controller is loaded with a program written using Embedded 'C' language.

The main drawback of the system is the Bluetooth wireless technology supports only for limited distance. This can be eliminated using GSM or Wi-Fi technology which can increase the distance using SMS technology.

The project can also be extended by using DTMF technology we can increase or decrease the motor speed control.

References

1). "Thyristor controlled power for induction motor (ISSN 2319-9725)" from international journal of innovative research & studies by Devendrakumar Shukla &Sudhanshu Tripathi.

2). "Speed control of single phase induction motor using AC chopper by asymmetrical PWM method" from IJAREEIE by R. Suneeth and P. Usha.

3). "Speed control of induction motor using TRIAC" by Prachi M. Palpankar, Sanraj Harle, Tushar Karade, Suraj Lekurwale.

4). "Speed control of single phase AC induction motor using microcontroller" from IJERA by Chaitanya N. Jibhakate, Asst. Prof. Vijaya Huchhe.

5). "Development of single phase induction motor adjustable speed control using M68HC11E-9 microcontroller" from journal of applied sciences by Senan M. Bashi, I. Aris and S. H. Harmad.

6). "Speed control and Monitoring of AC motor by wireless communication using DTMF decoder technique" form international journal of engineering and science by Asst. Prof. Burali Y. N and Patil R. T.