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| PROJECT TITLE: | MONITORING AND PROTECTION SYSTEM OF THREE-PHASE INDUCTION MOTOR. |

# DECLARATION

I, Darlington Panje, declare that the monitoring and protection system for three-phase induction motors in this project is my original work under the supervision of Eng. M. Takawira. All sources are duly, acknowledged and referenced, and contributions from collaborators are appropriately, credited. This project is solely for educational and research purposes and may not be used or distributed commercially without prior consent.

03/10/24

(Signature of student)                                    (Date)

03/10/24

(Signature of Supervisor)                                 (Date)

## DISCLAIMER

This project's monitoring and protection system for three-phase induction motors is intended, solely for educational and research purposes. While every effort has been, made to ensure accuracy and reliability, the author assumes no liability for errors, omissions, or damages resulting from its use.

By using this system, users acknowledge and accept they do so at their own risk. The author disclaims any responsibility for direct, indirect, incidental, or consequential damages arising from its use. Professional advice should, be sought for industrial or commercial applications.

# ABSTRACT

This project presents the design and implementation of a monitoring and protection system for three-phase induction motors, focusing specifically on safeguarding against single-phasing, Undervoltage, and overvoltage faults. Utilizing the PIC16F877A microcontroller, the system continuously monitors the electrical parameters of the motor, providing real-time data on voltage levels. The system is designed, to detect single phasing, where one phase of the motor loses power, as well as conditions of undervoltage and overvoltage, which can significantly affect motor performance and longevity. Upon detecting any of these faults, the system immediately triggers an alarm, cuts off power to prevent damage, and sends a notification message to the maintenance team for prompt intervention.

## ACKNOWLEDGMENTS

# Contents

# CHAPTER ONE INTRODUCTION

## 1.1    INTRODUCTION

This section will discuss the background information about induction motors. More so will be discussing the faults normally affecting induction motors, when they are in operation.  In conclusion will talk about how an embedded system can monitor an induction motor and protect it from electrical faults.

## 1.2    BACKGROUND

Induction motors are defined as electromechanical devices for converting electrical energy into mechanical energy to impart motion to different machines and mechanisms for various kinds of process control. Induction motors are made up of two major parts the stator, which is the stationary part with windings that can be induced when electric power is supplied, and the rotor, which is the part that produces mechanical energy when it rotates. Three-phase induction motors are industry's workhorses and are widely used as electromechanical energy conversion devices. Although induction machines are relatively reliable and robust due to their simple design and well-developed manufacturing technologies, failures do occur and may severely disrupt industrial processes and even lead to disastrous accidents. To prevent this failure from happening, many techniques were been developed for early condition monitoring. The computer-based protection methods are costlier and the electrical parameters cannot visualised by the Programmable Logic Controller (PLC) based method. In most industries, induction motors are protected using thermal overload relays. Thermal overload relays the cutoff power to the motor with a bit of delay and sometimes it fails. Hence, to protect an Induction motor easily, microcontroller-based fault detection and protection of the induction motor is to be developed. This project tends to develop for protection of a phase induction motor from single phasing, over-voltage, and under-voltage.

### 1.3 PROBLEM STATEMENT

Induction motors are widely used in industrial, commercial, and residential systems, because of their ruggedness, simplicity, and relatively low cost to buy and replace the burnt induction motors may become expensive and may delay the production processes in the factory. Therefore, to mitigate these costs, I decided to design an intelligent electronic system that monitors the state of induction motors and protects them from electrical faults.

### 1.4 AIM

The aim is to develop a monitoring and protection system for induction motors to guard against single-phasing, under-voltage, and over-voltage faults. The system will cut off the power supply during abnormal conditions, notify the user or operator via an LCD and alarm, and send a text message to the maintenance team.

### 1.5 OBJECTIVES

- Design an electronic system to monitor and protect three-phase induction motors from electrical faults.
- Develop a display system for motor status, phase voltage levels, and voltage conditions.
- Implement a notification system that sends alerts to the maintenance team and sounds an alarm when power is cut off.
- Create a cost-effective solution to enhance the efficiency and reliability of three-phase induction motors.

### 1.6 JUSTIFICATION

This system provides a reliable and effective control solution for three-phase induction motors, significantly reducing the risk of motor failure. By implementing this design, manufacturing industries, and domestic users can save money by avoiding the costs associated with purchasing new induction motors and minimizing production downtime due to motor burnouts.

# CHAPTER TWO LITERATURE REVIEW

## 2.1 INTRODUCTION

The literature review chapter serves as a foundational exploration of existing research and knowledge relevant to monitoring and protection systems for three-phase induction motors. This chapter aims to provide a comprehensive understanding of the theoretical underpinnings, technological advancements, and practical applications in the field. Three-phase induction motors are widely used in industrial and commercial applications due to their efficiency and robustness. However, ensuring their reliable operation and protection against various electrical and mechanical faults is crucial for minimizing downtime and maintenance costs. [1]

## 2.2 BACKGROUND OF THE STUDY

### 2.2.1 ABNORMAL CONDITIONS

Single phasing is the condition that results when one phase of a three-phase motor is suddenly open-circuited during operation. Single phasing also known as phase failure can be a huge problem, especially in a manufacturing plant where having a downtime of any machine can result in a huge production loss. Three-phase induction motors are also affected by under voltage is the situation that occurs when the average voltage of a three-phase power system drops below the intended level. [2] Low voltage can lead to overheating, short life, reduced starting ability, and reduced pull-up and pull-out torque of the motor. Higher voltage is a condition when the average voltage is higher than the normal intended level. Higher voltage will push a higher-than-expected current through the motor coils. This leads to more heat, which might either damage the insulation and short-circuit the motor or melt the motor coils. [3]

## 2.3 FUNCTIONAL BLOCK DIAGRAM

```
                          ┌─────────────────┐
                          │   LCD Display   │
                          └─────────────────┘
                                   ▲
                                   │
┌──────────────────┐      ┌─────────────────┐      ┌─────────────────┐
│  Phase sensing   │─────▶│                 │─────▶│   Relay Unit    │
│      unit        │      │                 │      └─────────────────┘
└──────────────────┘      │                 │               │
                          │                 │               ▼
┌──────────────────┐      │ MICROCONTROLLER │      ┌─────────────────┐
│ Voltage sensing  │─────▶│                 │      │ Induction Motor │
│      unit        │      │                 │      └─────────────────┘
└──────────────────┘      │                 │      ┌─────────────────┐
                          │                 │─────▶│     Buzzer      │
┌──────────────────┐      │                 │      └─────────────────┘
│    Regulated     │─────▶│                 │      ┌─────────────────┐
│  Power supply    │      │                 │─────▶│   GSM Module    │
└──────────────────┘      └─────────────────┘      └─────────────────┘
```
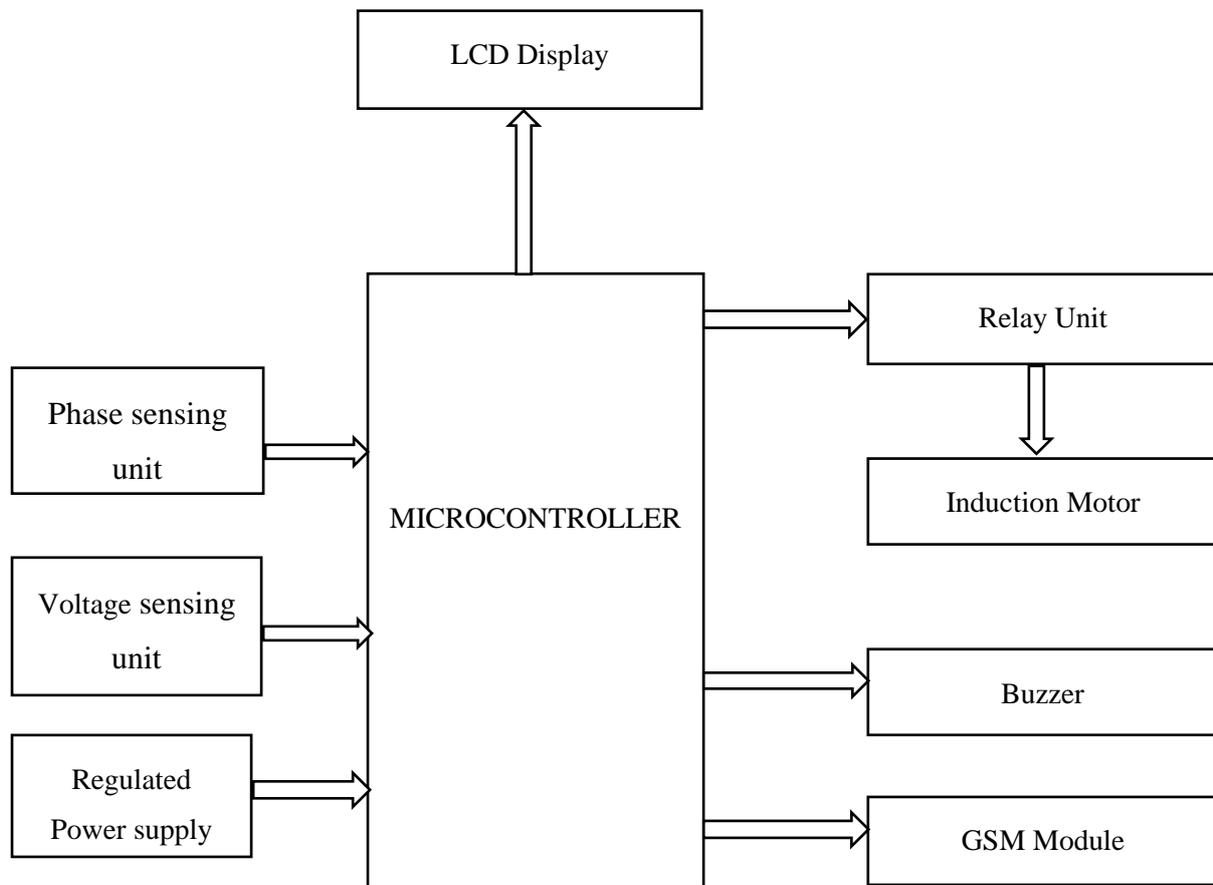
Figure 2.3

This figure shows the functional block diagram for the monitoring and protection system of the three three-phase action motor. The above diagram shows the blocks that make up the system as a unit.

## 2.4 VOLTAGE SENSING UNIT

This is the circuit used by utilities to monitor the voltage in transmission lines. They are also used by utility customers to monitor voltage conditions in single and three-phase motors to detect blown-out conditions, phase loss, etc., or to protect the electronic circuits in soft starters and similar equipment from possibly damaging low voltages. Voltage sensors are also used for power factor evaluations. Potential transformer develops the voltage sensor circuit and some discrete electronic components. For monitoring and protection, the microcontroller is used. The circuit with a microcontroller of the voltage measuring system can work as a voltage phase sensing unit. The microcontroller can check the availability of phase voltage from all phases and if one of the phases is, missing then the system takes protection action. The system with a microcontroller can help with single-phasing protection. [4]



Figure 2.4 Voltage sensor

Figure 2.4 is an electronic voltage sensor to measure voltage.

## 2.5 MICROCONTROLLER

### 2.5.1 PIC16F877A MICROCONTROLLER

The PIC16F887A is one of the latest products from *Microchip*. It features all the components that modern microcontrollers normally have. For its low price, a wide range of applications, high quality, and easy availability, it is an ideal solution for applications such as the control of different processes in the industry, machine control devices, measurement of different values, etc. [5]

### 2.5.2 ADVANTAGES OF PIC16F877A

The PIC architectures have these advantages:

- Small instruction set to learn

- RISC architecture

- Built-in oscillator with selectable speeds

- Easy entry level, in circuit programming plus circuit debugging  units available from

- Inexpensive microcontrollers

- Wide range of interfaces including I2C, SPI, USB, USART, A/D, programmable Comparators, PWM, LIN, CAN, PSP, and Ethernet

### 2.5.3 FEATURES OF PIC16F877A

- **RISC architecture**

  o Only 35 instructions to learn

  o All single-cycle instructions except branches

- **Operating frequency 0-20 MHz**

- **Precision external oscillator**

- o   Factory calibrated

- o   Software selectable frequency range of 8MHz to 31KHz

- **Power supply voltage 2.0-5.5V**

  - o   Consumption: 220uA (2.0V, 4MHz), 11uA (2.0 V, 32 KHz) 50nA (standby mode)

- **Power-Saving Sleep Mode**

- **Brown-out Reset (BOR) with software control option**

- **35 input/output pins**

  - o   High current source/sink for direct LED drive

  - o   software and individually programmable *pull-up* resistor

  - o   Interrupt-on-Change pin

- **8K ROM memory in FLASH technology**

  - o   Chip can be reprogrammed up to 100.000 times

- **In-Circuit Serial Programming Option**

  - o   Chip can be programmed even embedded in the target device

- **256 bytes EEPROM memory**
  - o   Data can be written more than 1.000.000 times
  - **368 bytes of RAM**

- **A/D converter:**

  - o   14-channels

  - o   10-bit resolution

- **3 independent timers/counters**

- **Watch-dog timer**

- **Analogue comparator module with**

  - Two analogue comparators

  - Fixed voltage reference (0.6V)

  - Programmable on-chip voltage reference

- **PWM output steering control**

- **Enhanced USART module**

  - Supports RS-485, RS-232 and LIN2.0

  - Auto-Baud Detect

- **Master Synchronous Serial Port (MSSP)**

  - supports SPI and I2C mode

## 2.5.4 BLOCK DIAGRAM



| Device | Program Flash | Data Memory | Data EEPROM |
|---|---|---|---|
| PIC16F874A | 4K words | 192 Bytes | 128 Bytes |
| PIC16F877A | 8K words | 368 Bytes | 256 Bytes |

Fig 2.5.4 Block Diagram [6]

The above figure shows the orientation of pic16f877a microcontroller ports, communication networks, and memory allocations.
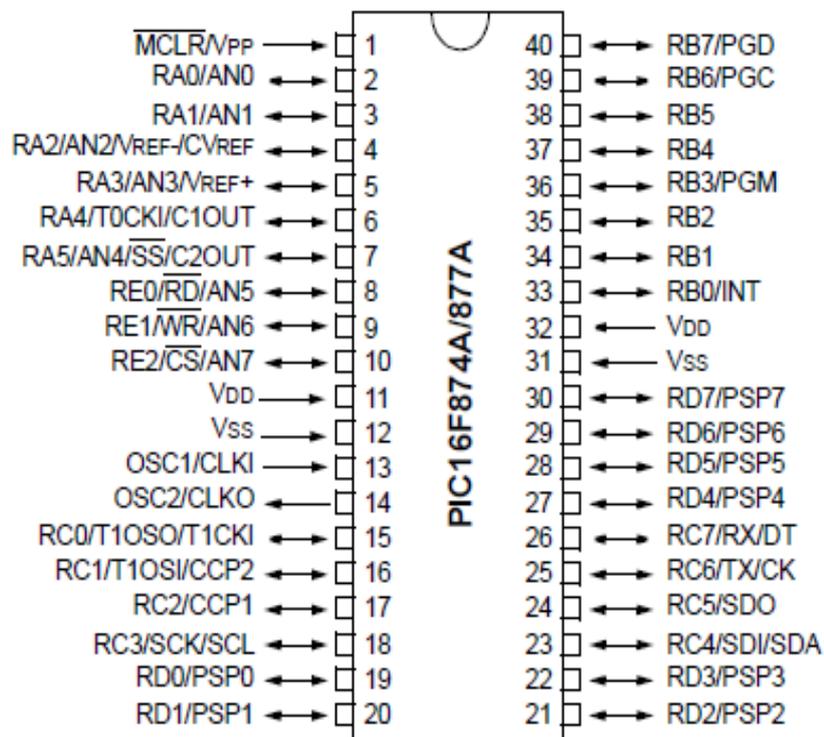
**2.5.5 PIN DESCRIPTION**



Fig 2.5.5 Pin Diagram

The above figure shows the orientation of pins for the pic16f877a microcontroller chip. The pin diagram shows all 40 pins of the microcontroller and their functionality purposes. [7]

**2.5.6 PIC16F877A PINS FUNCTIONS**

As seen in Fig.2.5.5, most of the pins are multi-functional. For example, designator RA3/AN3/Vref+ for the fifth pin specifies the following functions:

- RA3 Port A third digital input/output

- AN3 Third analog input

- Vref+ Positive voltage reference

| PIN NAME | NUMBER | FUNCTION | DESCRIPTION |
|---|---|---|---|
| MCLR/VPP | 1 | MCLAREN<br><br>VPP | Master Clear (Reset) input. This pin is active low<br><br>Programming voltage input. |
| RA0/AN0 | 2 | RA0<br><br>AN0 | Digital I/O.<br><br>Analog input 0 |
| RA1/AN1 | 3 | RA1<br><br>AN1 | Digital I/O.<br><br>Analog input 1. |
| RA2/AN2/VREF-/CVREF | 4 | RA2<br><br>AN2<br><br>VREF<br><br>CVREF | Digital I/O.<br><br>Analog input 2.<br><br>A/D reference voltage (Low) input.<br><br>Comparator VREF output. |
| RA3/AN3/VREF+ | 5 | RA3<br><br>AN3<br><br>VREF+ | Digital I/O.<br><br>Analog input 3.<br><br>A/D reference voltage (High) input. |
| RA4/T0CKI/C1OUT | 6 | RA4<br><br>T0CKI<br><br>C1OUT | Digital I/O – Open-drain when configured as output.<br><br>Timer0 external clock input.<br><br>Comparator 1 output. |
| RA5/AN4/SS/C2OUT | 7 | RA5<br><br>AN4<br><br>SS<br><br>C2OUT | Digital I/O.<br><br>Analog input 4.<br><br>SPI slave select input.<br><br>Comparator 2 output. |
| RE0/RD/AN5 | 8 | RE0 | Digital I/O. |

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| | | RD | Read control for Parallel Slave Port. |
|---|---|---|---|
| RE1/WR/AN6 | 9 | AN5 | Analog input 5. |
| | | RE1 | Digital I/O. |
| | | WR | Write control for Parallel Slave Port. |
| | | AN6 | Analog input 6. |
| RE2/CS/AN7 | 10 | RE2 | Digital I/O. |
| | | CS | Chip select control for Parallel Slave Port. |
| | | AN7 | Analog input 7. |
| VDD | 11 | | Positive supply |
| VSS | 12 | | Ground |
| OSC1/CLKI | 13 | OSC1 | Oscillator crystal input |
| | | CLKI | External clock source input. Always associated with pin function OSC1 |
| OSC2/CLKO | 14 | OSC2 | Oscillator crystal output. |
| | | CLKO | In RC mode, the OSC2 pin outputs CLKO, which has 1/4 the frequency of OSC1 |
| RC0/T1OSO/T1CKI | 15 | RC0 | Digital I/O. |
| | | T1OSO | Timer1 oscillator output. |
| | | T1CKI | Timer1 external clock input |
| RC1/T1OSI/CCP2 | 16 | RC1 | Digital I/O. |
| | | T1OSI | Timer1 oscillator input. |
| | | CCP2 | Capture2 input, Compare2 output, PWM2 output. |

| | | | |
|---|---|---|---|
| RC2/CCP1 | 17 | RC2 | Digital I/O. |
| | | CCP1 | Capture1 input, Compare1 output, PWM1 output. |
| RC3/SCK/SCL | 18 | RC3 | Digital I/O. |
| | | SCK | Synchronous serial clock input/output for SPI mode. |
| | | SCL | Synchronous serial clock input/output for I2C mode. |
| RD0/PSP0 | 19 | RD0 | Digital I/O. |
| | | PSP0 | Parallel Slave Port data. |
| RD1/PSP1 | 20 | RD1 | Digital I/O. |
| | | PSP1 | Parallel Slave Port data. |
| RD2/PSP2 | 21 | RD2 | Digital I/O. |
| | | PSP2 | Parallel Slave Port data. |
| RD3/PSP3 | 22 | RD3 | Digital I/O. |
| | | PSP3 | Parallel Slave Port data. |
| RC4/SDI/SDA | 23 | RC4 | Digital I/O. |
| | | SDI | SPI data in. |
| | | SDA | I2C data I/O |
| RC5/SDO | 24 | RC5 | Digital I/O. |
| | | SDO | SPI data out. |
| RC6/TX/CK | 25 | RC6 | Digital I/O. |
| | | TX | USART asynchronous transmit. |
| | | CK | USART1 synchronous clock |
| RC7/RX/DT | 26 | RC7 | Digital I/O. |
| | | RX | USART asynchronous receive. |

| | | DT | USART synchronous data. |
|---|---|---|---|
| RD4/PSP4 | 27 | RD4 | Digital I/O. |
| | | PSP4 | Parallel Slave Port data. |
| RD5/PSP5 | 28 | RD5 | Digital I/O. |
| | | PSP5 | Parallel Slave Port data. |
| RD6/PSP6 | 29 | RD6 | Digital I/O. |
| | | PSP6 | Parallel Slave Port data. |
| RD7/PSP7 | 30 | RD7 | Digital I/O. |
| | | PSP7 | Parallel Slave Port data. |
| VSS | 31 | | Ground |
| VDD | 32 | | Positive supply |
| RB0/INT | 33 | RB0 | Digital I/O. |
| | | INT | External interrupt. |
| RB1 | 34 | | Digital I/O. |
| RB2 | 35 | | Digital I/O. |
| RB3/PGM | 36 | RB3 | Digital I/O. |
| | | PGM | Low-voltage ICSP programming enables pin. |
| RB4 | 37 | | Digital I/O. |
| RB5 | 38 | | Digital I/O. |
| RB6/PGC | 39 | RB6 | Digital I/O. |
| | | PGC | In-circuit debugger and ICSP programming clock. |
| RB7/PGD | 40 | RB7 | Digital I/O. |
| | | PGD | In-circuit debugger and ICSP programming data. |

Table 2.5.6. Pin description

The above table shows the pins of the pic16f877a microcontroller, the names of the pins, and their specific functions. The above table has a description of how pins work.

## 2.5.7 APPLICATIONS

PIC16F877A perfectly fits many uses, from automotive industries and controlling home appliances to industrial instruments, remote sensors, electrical door locks, and safety devices. It is also ideal for smart cards as well as for battery-supplied devices because of its low consumption. EEPROM memory makes it easier to apply microcontrollers to devices where permanent storage of various parameters is needed (codes for transmitters, motor speed, receiver frequencies, etc.) In System Programmability of this chip (along with using only two pins in data transfer) makes possible the flexibility of a product, after assembling and testing are completed. This capability creates assembly-line production, stores calibration data available only after final testing, or improves programs on finished products. [8]

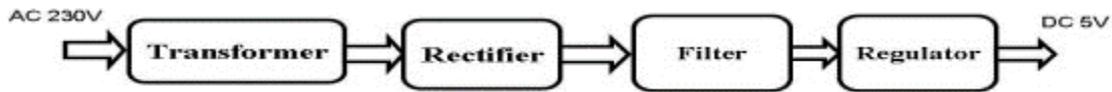## 2.6 REGULATED POWER SUPPLY

### 2.6.1 INTRODUCTION

A regulated power supply is an electronic device or circuit that provides a stable and constant output voltage (or current) regardless of variations in input voltage, load current, or ambient conditions. It ensures that electronic devices receive the correct and consistent power they need to operate reliably. [9]

A power supply may include a power distribution system as well as primary or secondary sources of energy such as

- Conversion of one form of electrical power to another desired form and voltage, typically involving converting AC line voltage to a well-regulated lower-voltage DC for electronic devices. Low voltage, low-power DC power supply units are commonly integrated with the devices they supply, such as computers and household electronics.
- Batteries.

- Chemical fuel cells and other forms of energy storage systems.
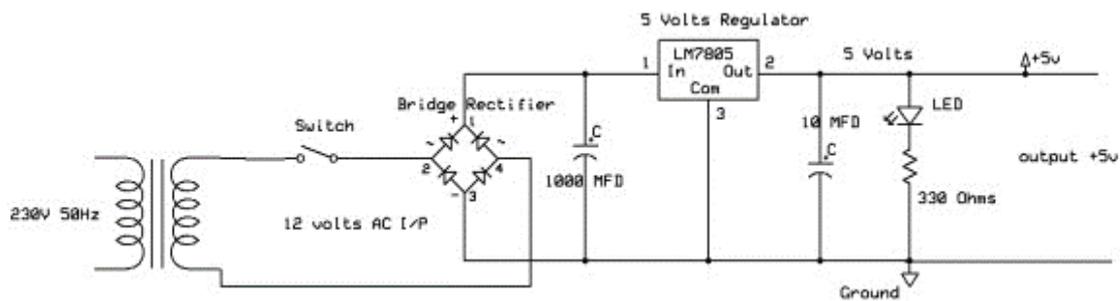- Solar power.
- Generators

## 2.6.2 BLOCK DIAGRAM



[10]

Fig 2.6.2 Regulated power supply

Shows the circuit diagram blocks for a 5V DC power supply.

## 2.6.3 POWER SUPPLY COMPONENTS



[11]

Fig 2.6.3 Regulated power supply

Figure 2.6.3 shows the regulated 5V DC power supply circuit.

- .**Transformer**:

  o **Function**: Steps down the input AC voltage to a lower AC voltage suitable for rectification.

  o **Types**: This can be step-down (to reduce voltage) or step-up (to increase voltage), depending on the application.

- **Rectifier**:

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- o  **Function**: Converts AC voltage from the transformer into pulsating DC voltage.

- o  **Types**: Bridge rectifiers (using diodes) are common for converting AC to DC.

- **Filter Capacitor**:

  - o  **Function**: Smooth the rectified DC voltage by filtering out the AC ripple component.

  - o  **Types**: Electrolytic capacitors are used due to their high capacitance and ability to handle ripple currents.

- **Voltage Regulator**:

  - o  **Function**: Maintains a constant output voltage despite variations in input voltage or load current.

  - o  **Types**: Linear regulators (like LM7805) or switching regulators (like buck converters) are used based on efficiency and application requirements.

**Types of Regulated Power Supplies**

1. **Linear Regulated Power Supply**:

   - o  **Operation**: Uses a linear regulator to maintain a constant output voltage.

2. **Switching Regulated Power Supply**:

   - o  **Operation**: Utilizes a switching regulator (such as a buck converter) to efficiently regulate output voltage.

**Design Considerations**

- **Output Voltage and Current**: Select a power supply with adequate output voltage and current capacity to meet the requirements of the load.

- **Regulation and Ripple**: Ensure the power supply maintains tight voltage regulation and minimal ripple for sensitive electronics.

**2.7 DISCRETE COMPONENTS**

**2.7.1 RESISTOR**

The resistor is a passive electrical component that limits the flow of electric current in an electronic circuit. Resistors can also used to provide a specific voltage for an active device as transistors. In a DC circuit, current through a resistor is inversely proportional to its resistance and directly proportional to the voltage across it.  More, so in AC circuits, this applies as long as the resistor does not contain inductance or capacitance. [12]

$$V = IR$$

- **Fixed resistor**

A fixed resistor has a specific value, which does not vary either by design or in response to the environment around it. [13]



Figure 2.7.1 shows fixed resistors

- **Variable resistor**

  Variable resistor.is a resistor whose value of electrical resistance changes on demand and is used for voltage divider circuits perfectly.[14]



Figure 2.7.2 shows the variable resistor

### 2.7.2 CAPACITOR

A capacitor is an electronic component that stores electrical charge and creates a potential difference across its plates similar to a rechargeable battery. It consists of parallel metal plates separated by an insulating material or dielectric. Capacitor types include non-polarized for AC circuits and polarized for DC circuits. They can also be fixed or variable. Variable capacitors are utilized in tuning circuits for radio and television.
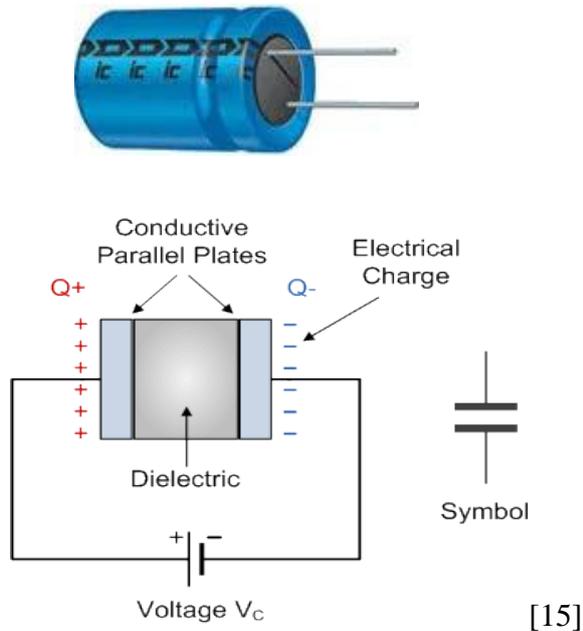
[15]

Figure 2.7.3 capacitor

Shows capacitor component, capacitor circuit, and symbol

### 2.7.4 DIODE

A diode is an electrical component used to facilitate the flow of electrical currents in one direction. Diodes are used in rectifier circuits to convert AC to DC. Diodes are also used to protect circuits and electronics from reversing currents and to regulate voltage in a circuit.
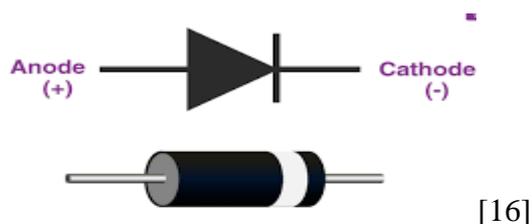
[16]

Figure 2.7.4 Diode, shows the rectifier diode

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**2.7.5 LED**

A light-emitting diode (LED) is a semiconductor light source. LEDs are used as indicator lamps in many devices for lighting. The light-emitting semiconductor material is what determines the LED's colour. LEDs present many advantages over incandescent light sources including lower energy consumption, longer lifetime, improved robustness, smaller size, faster switching, and greater durability and reliability. However, they are relatively expensive and require more precise current and heat management than traditional light sources. Current LED products for general lighting are more expensive to buy than fluorescent lamp sources of comparable output.[17]
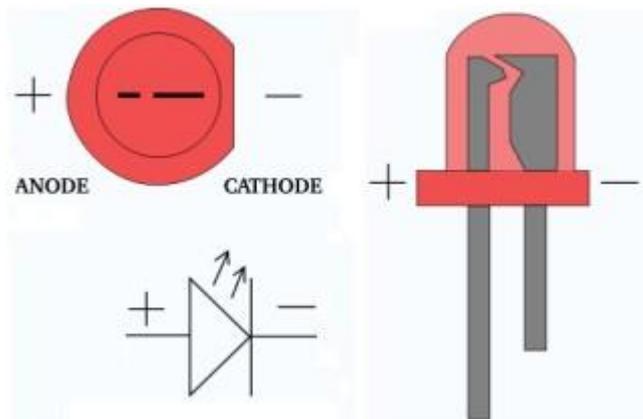


Figure 2.7.5 Electrical symbol and polarities for a led

Figure 2.7.5 shows the symbol and the terminal identification for an LED.

**2.8 LCD DISPLAY**

LCD BACKGROUND:

One of the most common devices attached to a microcontroller is an LCD. Some of the most common LCDs connected to the many microcontrollers are 16x2 and 20x2 displays. This means 16 characters per line by 2 lines and 20 characters per line by 2 lines, respectively.
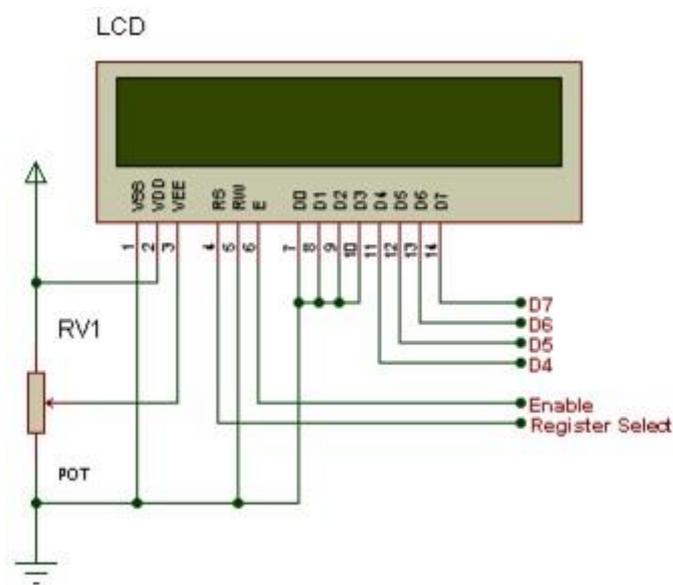
**2.8.1 16X2 LCD**

**Basic 16x 2 Characters LCD**



Figure 2.8.1 LCD pin diagram

**Pin description:**

| Pin Number | Name | Description |
|------------|------|-------------|
| Pin 1 | VSS | Power supply (GND) |
| Pin 2 | VCC | Power supply (+5V) |
| Pin 3 | VEE | Contrast adjust |

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| | | |
|---|---|---|
| Pin 4 | RS | 0 = Instruction input<br><br>1 = Data input |
| Pin 5 | R/W | 0 = Write to LCD module<br><br> 1 = Read from LCD module |
| Pin 6 | EN | Enable signal |
| Pin 7 | D0 | Data bus line 0 (LSB) |
| Pin 8 | D1 | Data bus line 1 |
| Pin 9 | D2 | Data bus line 2 |
| Pin10 | D3 | Data bus line 3 |
| Pin 11 | D4 | Data bus line 4 |
| Pin 12 | D5 | Data bus line 5 |
| Pin 13 | D6 | Data bus line 6 |
| Pin 14 | D7 | Data bus line 7 (MSB) |

Table 1: Description of LCD pins [18]

The above table shows the crystal LCD pin names and their specific work in communication. More so, the table shows the pin numbering.

## 2.8.2 LCD COMMUNICATION

The LCD requires three control lines as well as either four or eight I/O lines for the data bus. The user may select whether the LCD is to operate with a 4-bit data bus or an 8-bit data bus. If a 4-bit data bus is used the LCD will require seven data lines (3 control lines plus the 4 lines for the data bus). If an 8-bit data bus is used the LCD will require 11 data lines (3 control lines plus the 8 lines for the data bus).

The three control lines are EN, RS, and RW.

The EN line is "Enable." This control line is used to tell the LCD that we are sending it data. To send data to the LCD, our program should make sure this line is low (0) and then set the other two control lines and/or put data on the data bus. When the other lines are completely ready, bring EN high (1) wait for the minimum amount of time required by the LCD datasheet (this varies from LCD to LCD), and end by bringing it low (0) again.

The RS line is the "Register Select" line. When RS is low (0), the data is to be treated as a command or special instruction (such as a clear screen, position cursor, etc.). When RS is high (1), the data being sent is text data which should be displayed on the screen. For example, to display the letter "T" on the screen we would set RS high.

The RW line is the "Read/Write" control line. When RW is low (0), the information on the data bus is written to the LCD. When RW is high (1), the program is effectively querying (or reading) the LCD. Only one instruction ("Get LCD status") is a read command. All others are write commands--so RW will usually be low.

Finally, the data bus consists of 4 or 8 lines (depending on the mode of operation selected by the user). In the case of an 8-bit data bus, the lines are DB0, DB1, DB2, DB3, DB4, DB5, DB6, and DB7.

## LCD APPLICATIONS

• Electronic test equipment

• Industrial machinery Interface

• Security systems

- PLC Interface

- Student projects

- Home automation

- HMI operator interface.

## 2.9 RELAY UNIT

Relays are switches that use small electrical power to control large electrical power. All relays work on the principle of electromagnetism (they are electromagnetic switches) except a few like some overload relays and solid-state relays (SSR). Inside these relays (that work on electromagnetism), there is a coil that is energized when its operating voltage (usually small voltage of say AC 220V or DC voltages of 24V or 12V) is supplied to it. When the coil is energized it attracts all metallic contacts that are close to it, thus changing the previous state of the contacts; those that were normally closed (NC) become normally open (NO), and those that were NO become NC. [19]

**Kinds of relays commonly found in industries include**:

a. Pin relays

b. Card/reed relay

c. Solid state relay

d. Overload relay

### 2.9.1 SSOLID STATE RELAY (SSR)

These are purely electronic relays. They are made of semiconductors like thyristors, triacs, diodes, and transistors. They don't have any movable parts (mechanical parts), as they are purely electronic. They have the advantage of a fast response. They are energized only by DC voltage (12V or 24V). they usually have four contact points; 2 for input to the relay (for example a 24v relay will have an input wire supplying 24v and 0V) and the other 2 contacts will be for NO and NC contact points. Thus whenever the required DC voltage is supplied to

the relay coil, the contacts close NO contacts change to NC and when the supply is removed, the relay opens again( the contacts return to their default NO position)



Figure 2.9.2 solid-state relay

## 2.9.2 OVERLOAD RELAY

This kind of relay protects the circuit against overload.it is usually employed in electrical motors to protect them against overload. They have bimetallic strips that bend when they are heated to a certain temperature thereby causing some switches to open or close at the right temperature, and with the aid of a spring can be restored to their previous position. Overload relays usually have a current range that they can operate on, and are adjusted with a screwdriver to any particular set point within the range (such that beyond this set the relay will trip thus protecting the motor. There are different types of overload relays, however the most common ones that are widely used in the industry are, and this type of overload cannot work on its own. It usually works with a contactor. For connection purposes, it has two sections where connection is made, (main contacts and the auxiliary contacts). It equally has 3 pins, these pins are tucked directly into the contactor. Such that electrical power flows from the contactor through it (i.e. the pins) and then to its main contacts (where the electrical motor is connected).

### HOW OVERLOAD WORKS:

The purpose of overload is to protect electrical motor windings' current from rising beyond a certain value. All overload relays usually have a current range, which is the range of current that they can protect. The full load current of the load that the overload relay protects is what determines the right choice of overload relay and the right set point to keep it.
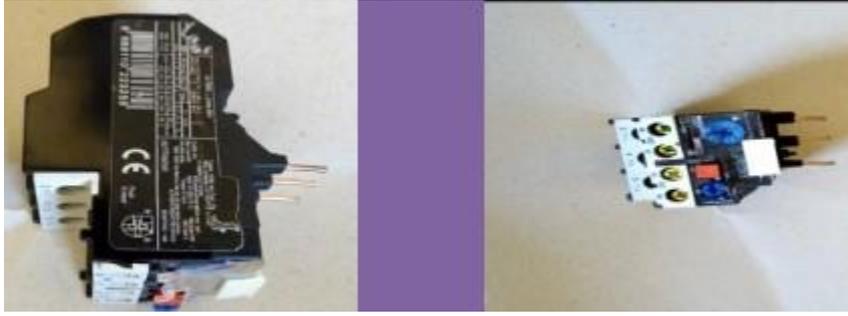
Figure 2.9.3 Overload relay

## 2.10 BUZZER

The electronic component generates sound through the transmission of electrical signals. Its primary function is to provide an audible alert or notification and typically operates within a voltage range of 5V to 12V.



Figure 2.10 Buzzer

In the figure above is the electronic buzzer.

This is an alarm that is triggered when an unusual or dangerous condition occurs or is about to occur in a circuit. AC or DC Voltage can power them. There are many ways to communicate between the user and a product. One of the best ways is audio communication using a buzzer IC. So during the design process, understanding some of the Applications

The applications of the buzzer include the following.

- Communication Devices

- Electronics used in Automobiles

- Alarm Circuits

- Portable Devices

- Security Systems

- Timers

## 2.11 GSM MODULE

A GSM (Global System for Mobile Communications) module is a specialized device that enables communication over GSM networks. It integrates GSM functionality into electronic devices, allowing them to send and receive data, make voice calls, and send SMS (Short Message Service) texts. GSM modules are widely used in IOT (Internet of Things), M2M (Machine-to-Machine) communication, and various other applications where cellular connectivity is required. [20]

**Key Features of GSM Modules**

- **Communication Capabilities**:

  o **Data Transmission**: Enables devices to transmit data over GSM networks, facilitating remote monitoring, control, and data exchange.

  o **Voice Calls**: Supports voice communication, allowing devices to make and receive calls like a regular mobile phone.

  o **SMS Messaging**: Allows devices to send and receive text messages, which is useful for notifications and alerts.

- **Integration and Compatibility**:

  o **Interface**: Typically interfaces with microcontrollers or other devices via UART (Universal Asynchronous Receiver-Transmitter) or SPI (Serial Peripheral Interface) communication protocols.

- o **SIM Card**: Requires a SIM (Subscriber Identity Module) card for network authentication and access.

- **Power Requirements**:

- o **Low Power Consumption**: Designed to operate efficiently to conserve battery life, crucial for applications in remote or battery-powered devices.

- **Form Factors**:

- o **Variety**: Available in different form factors, from compact modules suitable for embedded applications to larger modules with additional functionalities.

### 2.11.1 SIM800L GSM Module Overview

The SIM800L is a popular GSM/GPRS module known for its compact size and robust performance. It is widely used in IoT and M2M applications due to its versatility and ease of integration. Key features of the SIM800L include:

- **Frequency Bands**: Supports multiple GSM frequencies (Quad-Band 850/900/1800/1900 MHz) for global compatibility.

- **Interfaces**: Interfaces with external devices via UART, making it compatible with various microcontrollers and systems.

- **Power Supply**: Operates on a wide range of voltages (3.4V to 4.4V DC) and includes power-saving features.

- **Additional Features**: Includes support for GPRS (General Packet Radio Service) for data transmission, and integrated TCP/IP protocol stack for internet connectivity in certain models.

### Applications of GSM Modules [22]

- **IoT and M2M**: Enables remote monitoring and control of devices and systems over cellular networks.

- **Security Systems**: Used in alarm systems and surveillance equipment for alert notifications.

- **Telemetry**: Collects and transmits data from remote sensors and meters.

- **Automotive**: Provides communication capabilities in vehicle tracking and fleet management systems.

- **Consumer Electronics**: Integrated into devices for mobile communication and connectivity.

**Considerations**

- **Network Coverage**: Relies on GSM network coverage, so deployment in remote areas should consider network availability.

- **Antenna**: Proper antenna placement and quality affect signal strength and module performance.

- **Regulatory Compliance**: Ensuring compliance with local regulations regarding SIM cards and GSM communication.

## 2.12 CONCLUSION

The literature review conducted in this chapter has provided a comprehensive overview of the current state-of-the-art monitoring and protection systems for three-phase induction motors. In conclusion, this literature review has laid the foundation for understanding the theoretical framework and technological landscape of monitoring and protection systems for three-phase induction motors. The insights gained will inform the design and implementation stages of the proposed project, ensuring it aligns with current best practices and addresses emerging challenges in the field.

# CHAPTER THREE DESIGN

## 3.1 INTRODUCTION

In this chapter, the detailed design of the monitoring and protection system for three-phase induction motors will be presented. The design process involves the development of the system in sections integrated to form a functional embedded system. The system unit is an embedded system, requiring both hardware mathematical calculations and modeling. The integration of hardware and software components is essential to achieve the desired functionality. The chapter will also cover the stages of development, including the software development for the system's microcontroller unit (MCU) and concurrent hardware development.
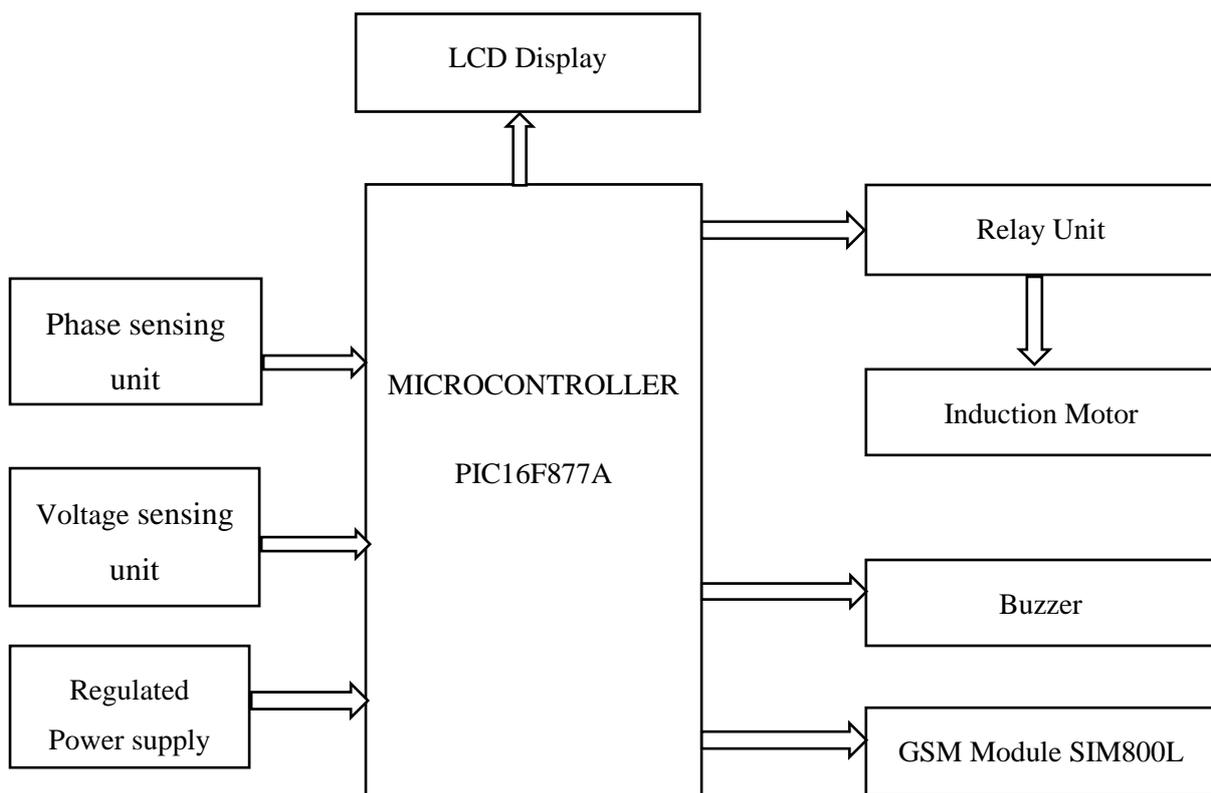
## 3.2 MONITORING AND PROTECTION SYSTEM BLOCK DIAGRAM



Figure 3.2 three phase induction motor monitoring and protection system

Figure 3.2 shows the modules integrated to develop one functional system.

## 3.3 VOLTAGE SENSING UNIT DESIGN

To design a voltage-measuring unit there are several parameters considered:

- Voltage transformation
- Voltage conversion
- Microcontroller voltage resolution

### 3.3.1 UNITS DESIGN

1. **Transformer design and selection**

   A step-down transformer is designed to step down high voltage C so that it is reduced to a level read with a microcontroller.

   1. Taking:

   Primary Voltage (Vp )= 220V AC

   Secondary Voltage (Vs) =12V AC

   2. Calculate Turns Ratio

   The turns $are$ determined by the ratio of the primary voltage to the secondary voltage.

   $$Turns\ Ratio = \frac{Np}{Ns} = \frac{Vp}{Vs} = \frac{220}{12} = 18.33$$

2. **Rectification and smoothing of circuit design**

   1. **Bridge rectifier**

   Once 12VAC is obtained then rectification is needed to convert AC voltage to DC voltage because pic16f877A reads DC voltage. Full wave rectifier is designed with four rectifier diodes, 1N4007 rectifier diodes are selected because of their low forward biased voltage drop of approximately 0.7V.

   2. **Smoothing capacitor**

   The rectified voltage has some ripples that are going to be removed by the smoothing capacitor connected parallel to the rectifier output. The capacitor is to remove some ripples in the rectified DC to have a smooth DC voltage. The capacitor will be continuously charging and discharging in the circuit.

$$C = \frac{Iload}{f \times \partial v}$$

Assume Iload =0.5A, f=50Hz, $\partial v = 1V$

$$C = \frac{0.5}{50 \times 1} = 100uF$$

3. **voltage divider design**

Scale down the high voltage to a safe level for ADC input of a pic16f877A which must be of the voltage level of DC less than 5.5V. The divider is made up of two fixed resistors in series.

## 3.4 MICROCONTROLLER

PIC16F877A microcontroller is selected to read the voltage via its ADC pins and the voltage is from the voltage divider output.

The pic16f877a microcontroller has to have a code to configure its ADC to read the scaled voltage and convert it to actual reading.

```
while (1) {
    // Read ADC values
    adc_value_phase1 = ADC_Read(0); // Read from AN0
    adc_value_phase2 = ADC_Read(1); // Read from AN1
    adc_value_phase3 = ADC_Read(2); // Read from AN2

    // Convert ADC values to voltages
    voltage_phase1 = adc_value_phase1 * (5.0 / 1023.0) * scaling_factor; // Scale as
    voltage_phase2 = adc_value_phase2 * (5.0 / 1023.0) * scaling_factor;
    voltage_phase3 = adc_value_phase3 * (5.0 / 1023.0) * scaling_factor;

    // Display voltages on LCD
```
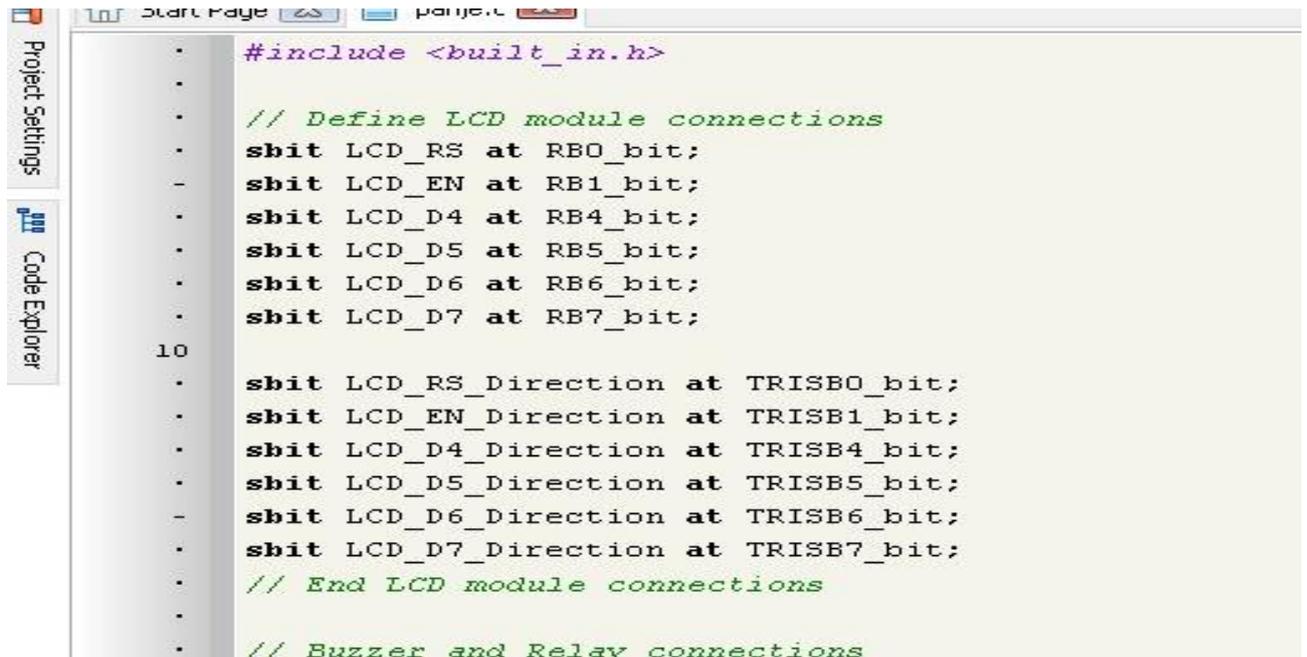
Figure 3.4 code snap

The above figure shows the code designed to perform voltage readings on ADC pins of the pic16f877a microcontroller and converted into the exact voltage values. The code is written on MikroC for Pic ide.

## 3.5 LCD DISPLAY CONNECTION

The system has to display voltage measured for the user to visualize the voltage levels read by the microcontroller. The LCD is to be configured by the code that will be loaded into the microcontroller. The LCD connections are done on the output pins of the microcontroller and this project port B was selected.
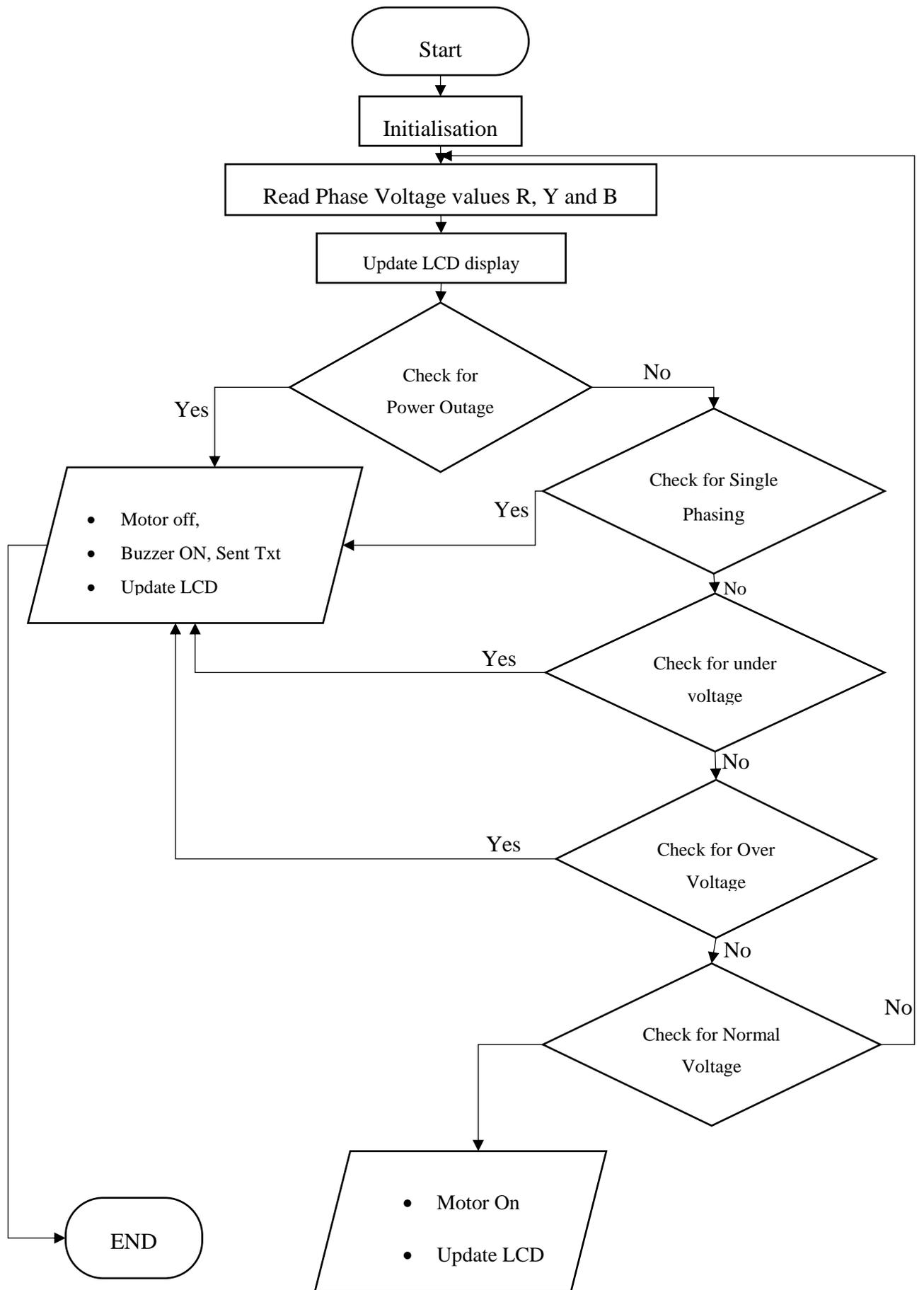


Figure 3.5 LCD code

The figure shows the LCD connection interfacing code with the microcontroller.

## 3.6 PROPOSED SYSTEM FLOW CHART

The flow chart shows how the system operates monitoring and protecting the three-phase induction motor. The process of monitoring and protection is done with the help of software programmed in the microcontroller. The microcontroller will read the voltage values for the phases, first check if all values are equal to 0V motor will be off, the message is sent, and the buzzer turned on. The system will then check for single phasing, under voltage, and over-voltage if any of the faults are there it cuts off the supply to the motor.  If the voltage checked is normal the system will turn on the motor.

```mermaid
flowchart TD
    Start([Start]) --> Init[Initialisation]
    Init --> Read[Read Phase Voltage values R, Y and B]
    Read --> LCD[Update LCD display]
    LCD --> PowerOutage{Check for Power Outage}
    PowerOutage -->|Yes| MotorOff
    PowerOutage -->|No| SinglePhasing{Check for Single Phasing}
    SinglePhasing -->|Yes| MotorOff
    SinglePhasing -->|No| UnderVoltage{Check for under voltage}
    UnderVoltage -->|Yes| MotorOff
    UnderVoltage -->|No| OverVoltage{Check for Over Voltage}
    OverVoltage -->|Yes| MotorOff
    OverVoltage -->|No| NormalVoltage{Check for Normal Voltage}
    NormalVoltage -->|No| UnderVoltage
    NormalVoltage -->|Yes| MotorOn
    MotorOff[Motor off, Buzzer ON Sent Txt, Update LCD] --> END([END])
```

Start

Initialisation

Read Phase Voltage values R, Y and B

Update LCD display

Check for Power Outage — Yes / No

Check for Single Phasing — Yes / No

Check for under voltage — Yes / No

Check for Over Voltage — Yes / No

Check for Normal Voltage — No

- Motor off,
- Buzzer ON, Sent Txt
- Update LCD

END

- Motor On
- Update LCD

## 3.7 EMBEDDED SYSTEM CODE DEVELOPMENT

The code for the monitoring and protection system was developed on mikroC for pic ide. The code then builds into the hardware microcontroller using a picture programmer for prototype development. Before the prototype development, the system was designed and simulated on proteus. The code for pic16f877A will be the central part of the system to do all the controls. For hardware the turning on and off protection, measures are done with the help of relays. The monitoring and protection system is an embedded system because hardware and software work together for the best system functionality.
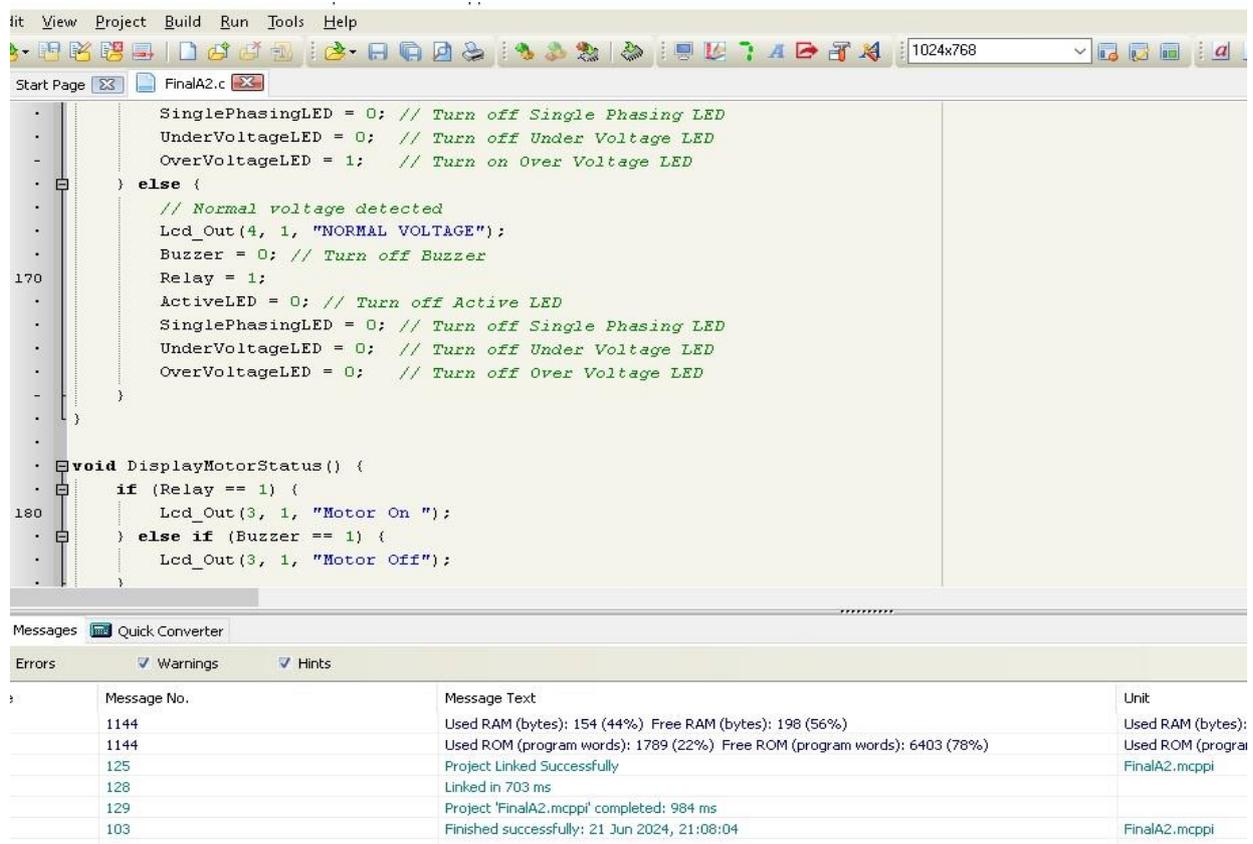


Figure 3.7 system code

Figure 3.7 shows the snap of a part of the successfully developed project code. The code is successfully built on mikroC ide.

## 3.8 CONCLUSION

In conclusion, the hardware and software were developed and the system as a unit is now ready for simulation modeling. Integrations of the system will result in the system, that is best for protecting three-phase induction motors. The above designs are very useful for the practical development of a real functional system.

# CHAPTER FOUR SIMULATION MODELLING

## 4.1 INTRODUCTION

This chapter focuses on the Proteus simulations conducted to validate and evaluate the proposed monitoring and protection system for three-phase induction motors. This chapter presents a detailed exploration of the simulated scenarios, providing insights into the system's performance under various operating conditions.

## 4.2 VOLTAGE SENSING CIRCUIT

The circuit has the functionality of dropping down high AC voltage to low AC voltage. Step two is to convert from AC voltage to DC and pulsating DC is obtained. To get smooth voltage a smoothing capacitor in the circuit then filters ripples. To get the stable voltage required by the ADC inputs pins of pic16f877a a voltage divider handles this function. The final stage of this circuit is for the microcontroller to process read values.
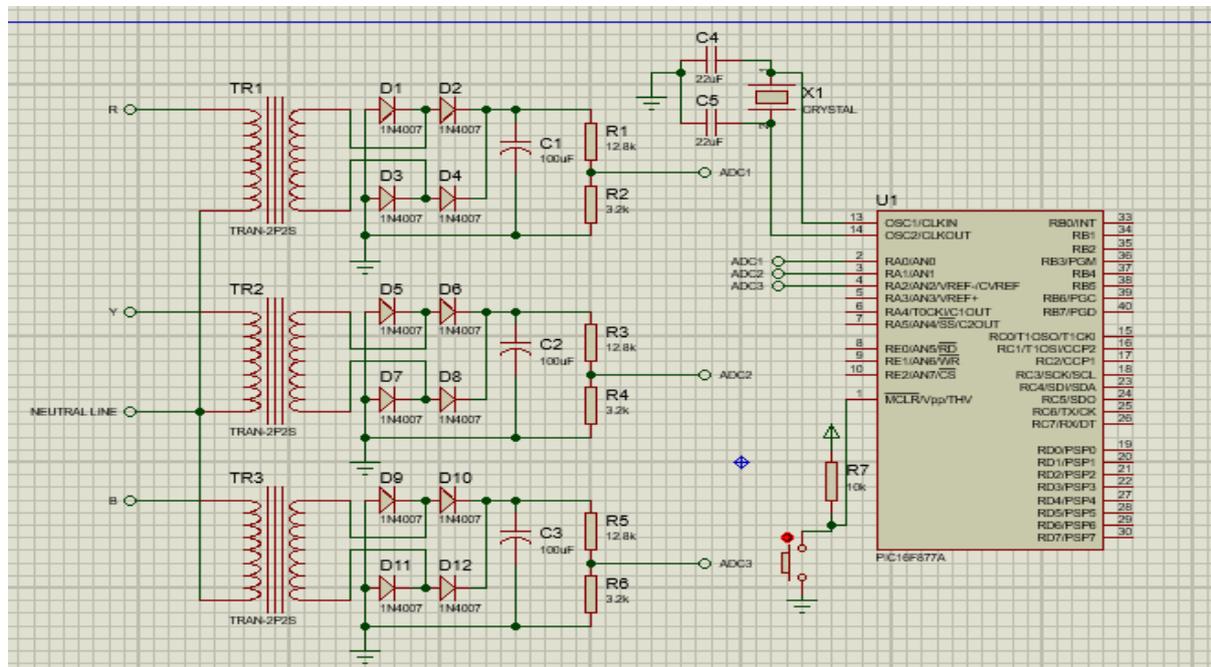


Figure 4.2 Voltage sensing circuit

Figure 4.2 shows the circuit that performs measuring, conversion, and processing of phase voltage in the monitoring and protection system.

## 4.3 LCD DISPLAY MODELLING

The system is integrated with a 20x4 LCD for the output of the system. The display shows the values of read voltage values, phase voltage conditions, and motor status. LCD data from pic16f877a microcontroller and on this project was configured on PORTB. Line 1 and line 2 of the 20x4 LCD were assigned in the code to display voltage values. Line 3 is assigned for motor status and line 4 displays the condition of phase voltage read by the system.
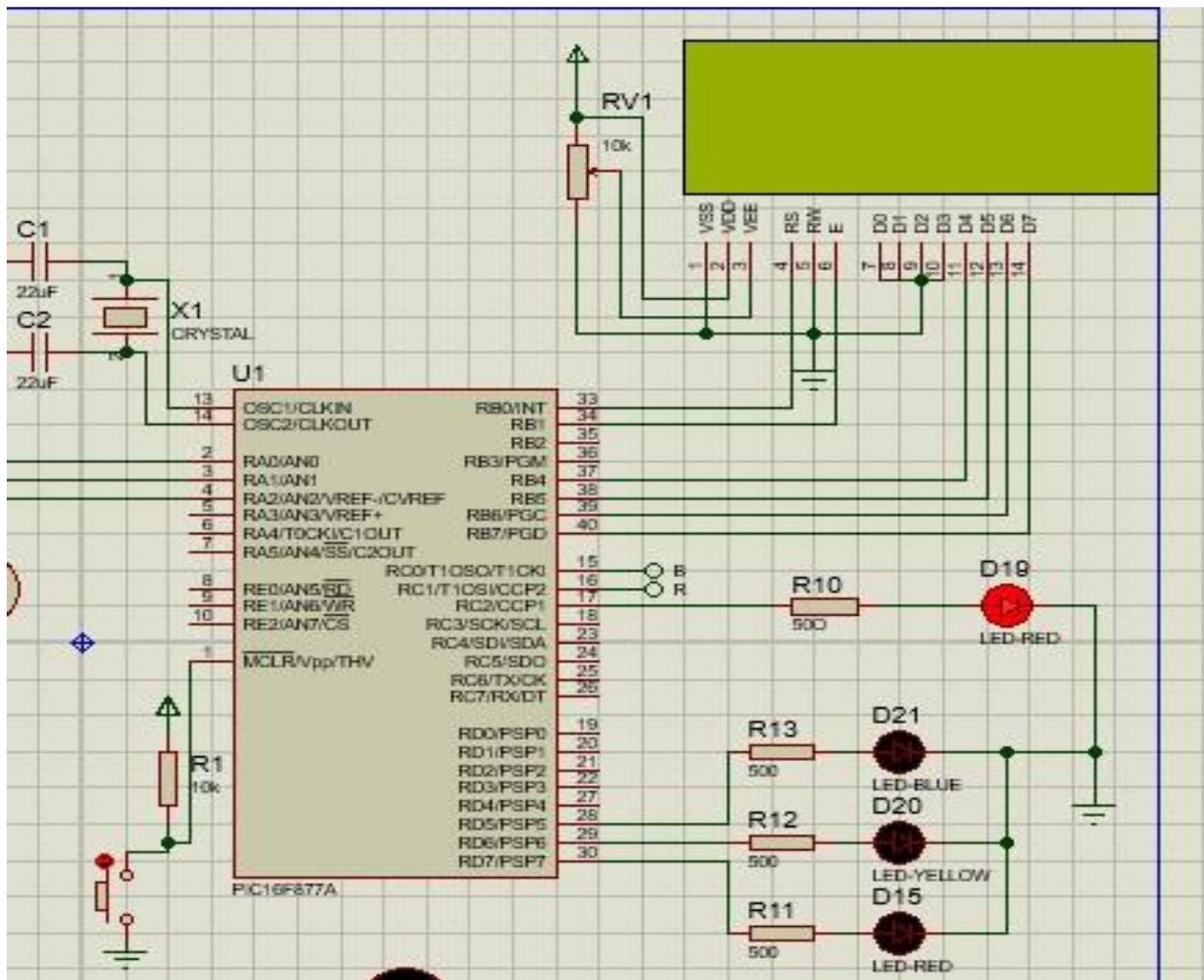


Figure 4.3 LCD

Figure 4.3 shows the connection of the LCD to the microcontroller for system simulation and testing on proteus. The LCD was interfaced using 4-bit parallel interfacing and for data, transfer D4 to D7 was used.

## 4.4 SYSTEM MODELLING

The whole system of monitoring and protection system designed in the previous chapter is created now as a unit on proteus for simulation testing. All different sections are integrated to build one functional system and for testing. Software developed on mikroC for pic is integrated into the hardware designed on proteus. For functionality of the system, the hex file is added to the pic16f877a microcontroller. A hex file is a set of functions executed by a microcontroller when powered on.
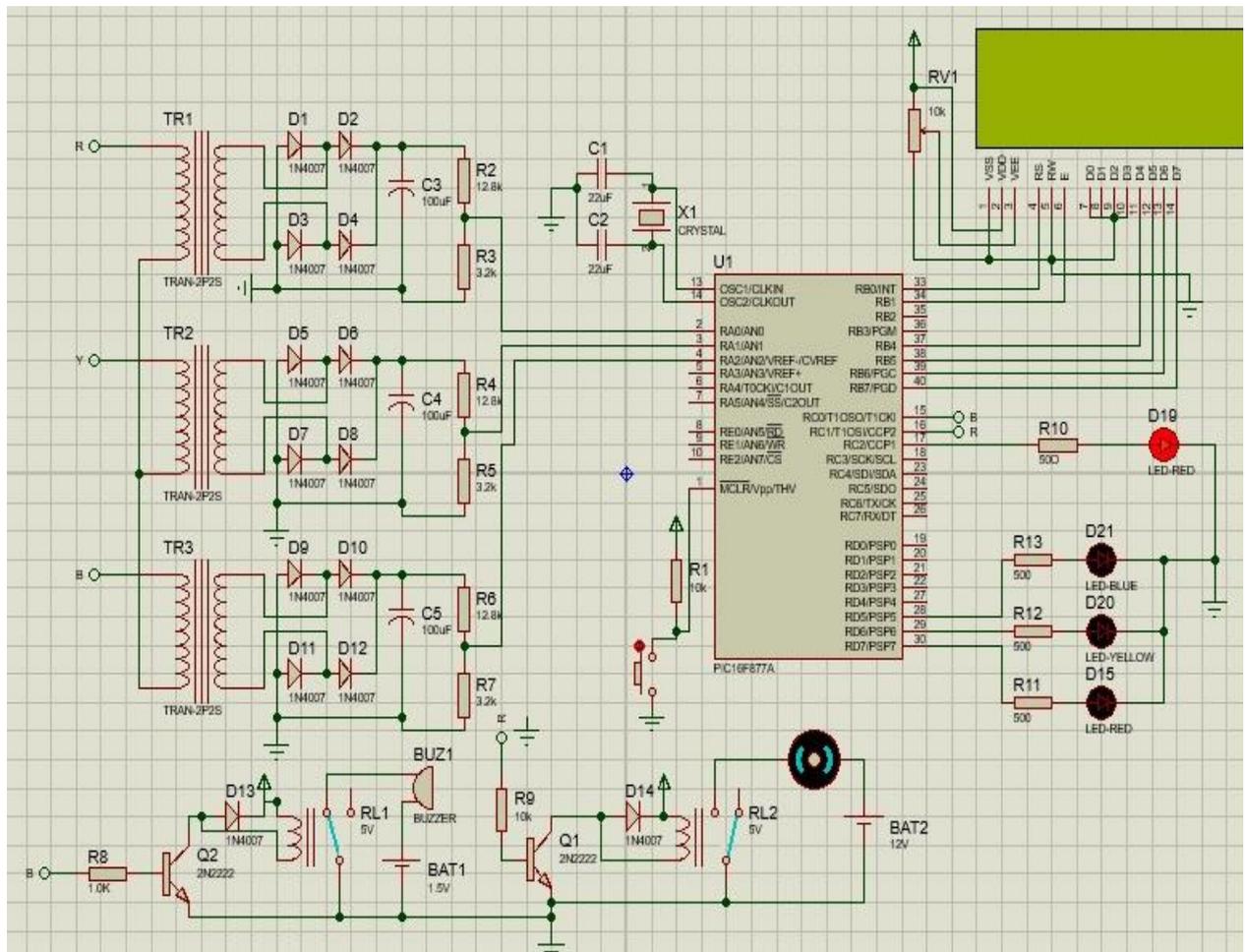


Figure 4.4 monitoring and protection system

Figure 4.4 shows the whole system with the buzzer and the motor relay

## 4.5 SYSTEM SIMULATION

The entire system was simulated in Proteus to evaluate its monitoring and protection capabilities. The simulation was conducted in sections to observe how the system responds to different voltage conditions, including power outage, single phasing, under-voltage, over-voltage, and normal voltage.

- o Power Outage, this condition is simulated when all phases drop to 0V.
- o Single Phasing, this occurs when one of the three-phase supplies is missing.
- o Under-voltage, this condition arises when the phase voltage falls below the system's normal operational voltage.
- o Over-voltage, this occurs when the phase voltage exceeds the operational voltage level.
- o Normal Voltage, this represents the system's operational voltage.

For the project, the code was written with thresholds based on system testing. According to the design, the motor relay will activate only under normal voltage conditions. Additionally, indicating LEDs in Proteus show the presence of voltage in the phases, while a red LED flashes to signal any abnormal conditions.

### 4.5.1 POWER OUTAGE CONDITION

All phase voltages are equal to 0V, meaning there is a power cut-off in the system. On this condition buzzer is triggered ON and the motor is off and a text message will be sent to the maintenance team to notify them about the abnormal condition detected. The message sent using the sim800l gsm module was written, "Power Outage detected". On Proteus, only the LCD shows the condition detected by the system.
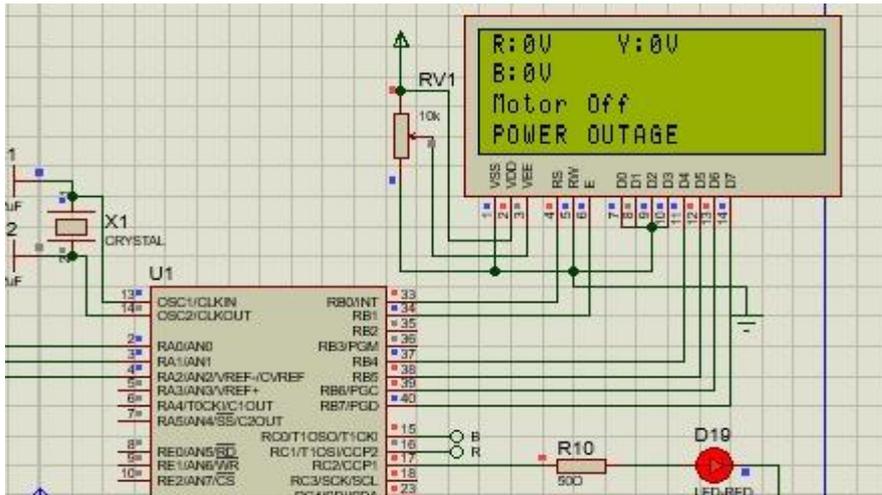
Figure 4.5.1 power outage shows the power outage condition where all the phase voltage is equal to 0V.

## 4.5.2 UNDER VOLTAGE CONDITION

It is the condition where the voltage read is below the threshold voltage for the system to operate normally. A threshold value is set in the code, which is the maximum value that determines the range of low voltage. If one of the phases is below the threshold then the microcontroller will send a protection signal to the output components.
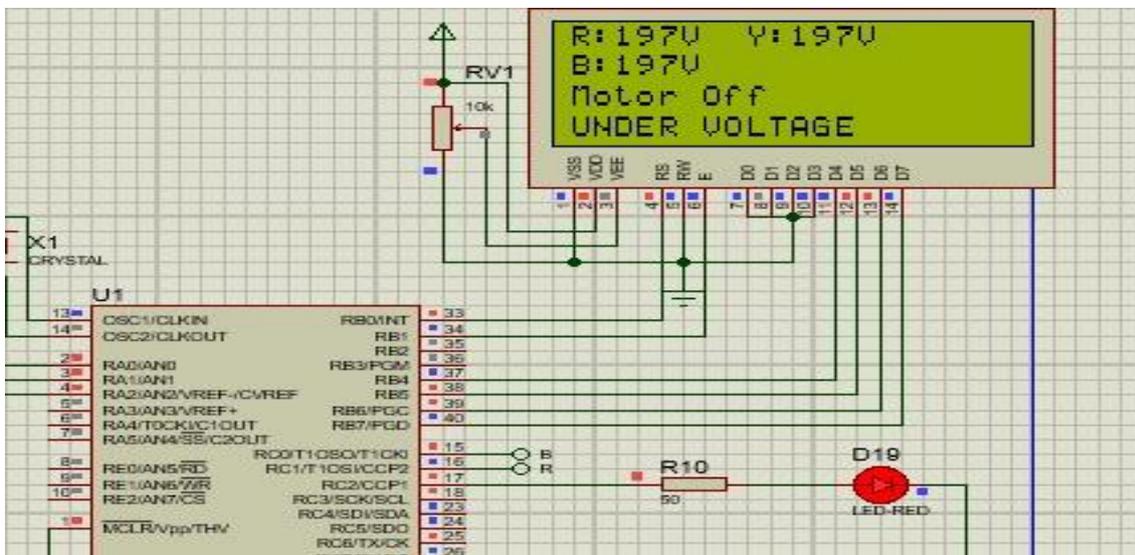


Figure 4.5.2 under voltage condition

The figure above shows the condition when the voltage is below the threshold. The alert red LED is ON and the buzzer is turned ON to notify the operator about the abnormal condition. For this project when any of the phases is below under voltage threshold.

### 4.5.3 SINGLE PHASING CONDITION

Single phasing is the condition when one of the phase voltages is missing in the three-phase power supply. In this system, the code cuts off the supply to the motor and triggers the buzzer ON.
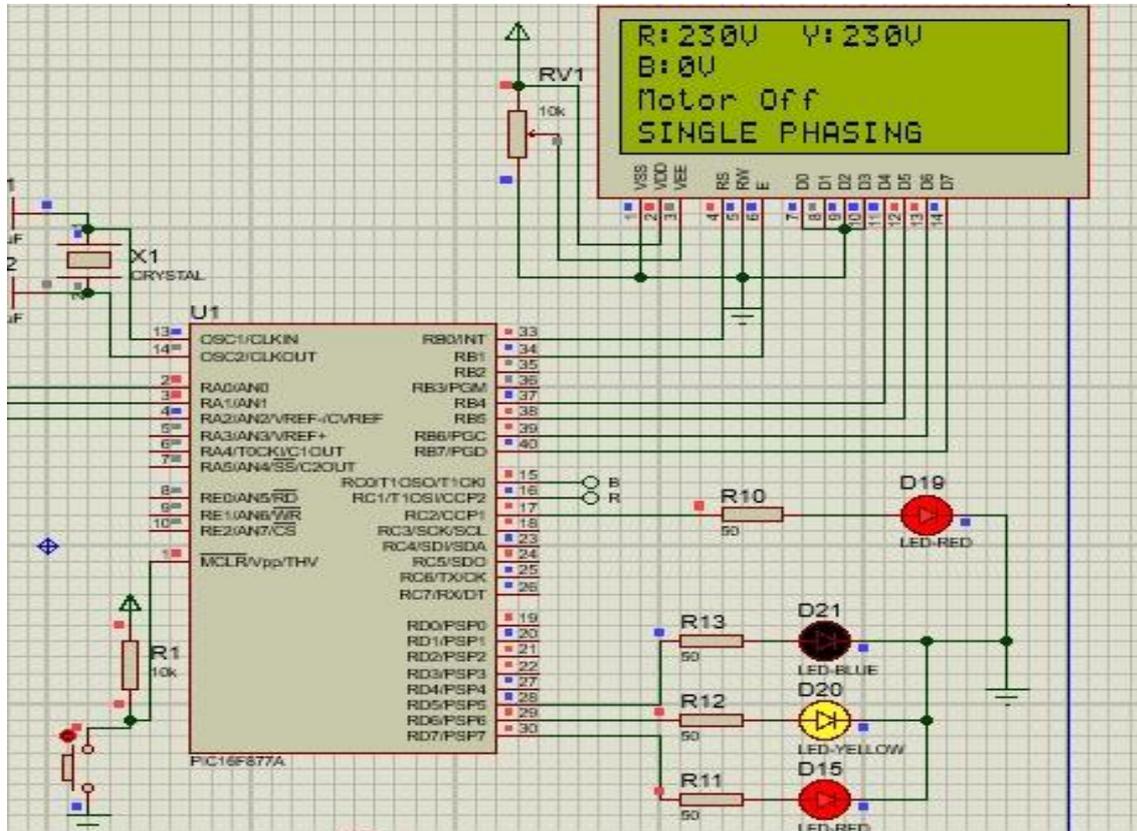


Figure 4.5.3 Single phasing condition

The above figure shows the simulation on proteus where one of the phases is missing. The indicator LED is off showing the phase is at 0V level and the warning LED is ON showing abnormal conditions.

### 4.5.4 OVER-VOLTAGE CONDITION

The read voltage value is greater than the normal voltage level. When over-voltage occurs the system will take protection action of a power cut off and activate the buzzer. The system will create a protection measure for the induction whenever one of the phases is above the over-voltage threshold. This action of cut-off will protect the motor from phase voltage imbalance as well. The system takes protection measures and updates the LCD.
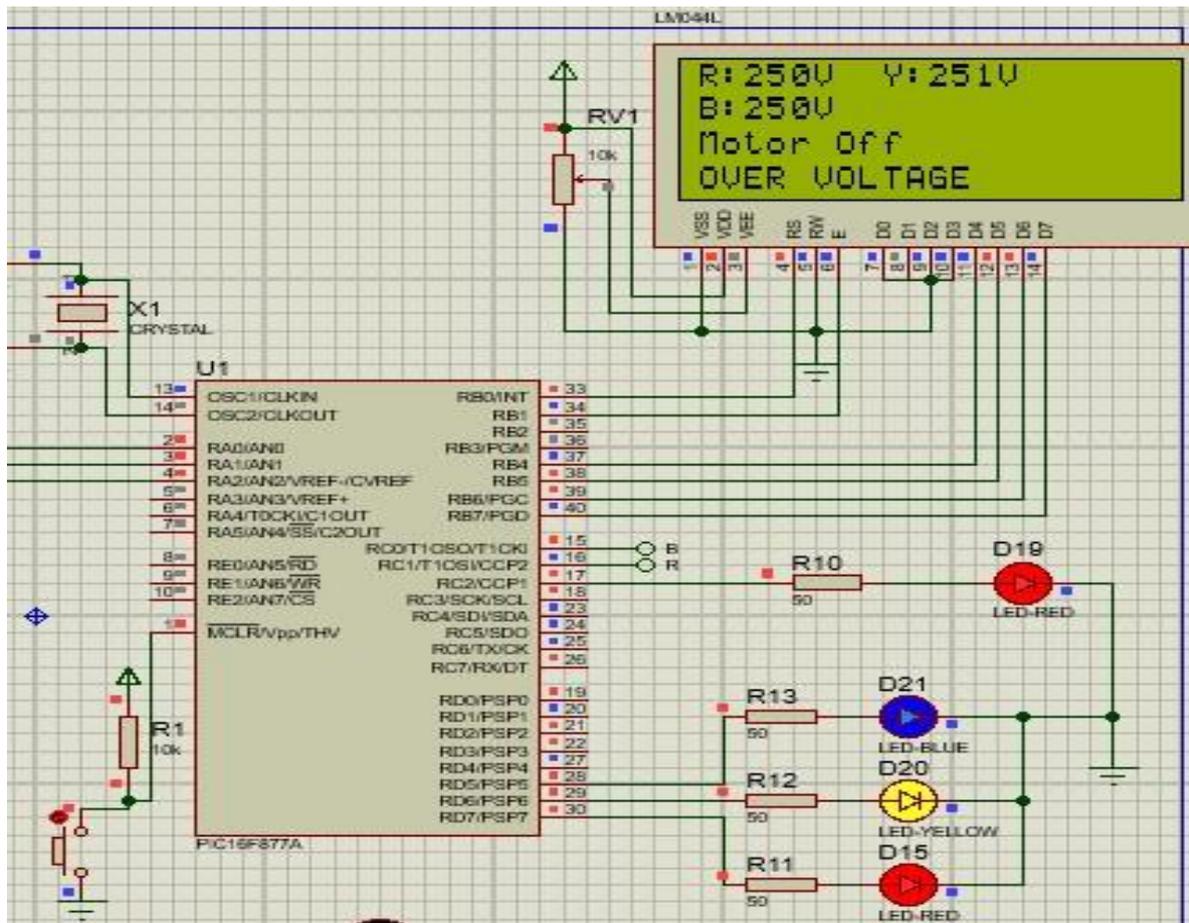
43

Figure 4.5.4 over voltage condition.

Figure 4.5.4 shows the proteus simulation when the phase voltages are above the threshold. All the phase indicator lights are on showing that there is voltage in all phases. The red warning LED is ON showing that the abnormal condition detected by the system.

### 4.5.5 NORMAL VOLTAGE CONDITION

This will the voltage levels required by the motor to run perfectly. The normal condition phase voltage has a range, minimum threshold, and maximum threshold. Below the minimum threshold, it has an under-voltage condition, and above the maximum threshold, it is overvoltage.  This project will activate the motor relay and turn off the buzzer and warning LED.
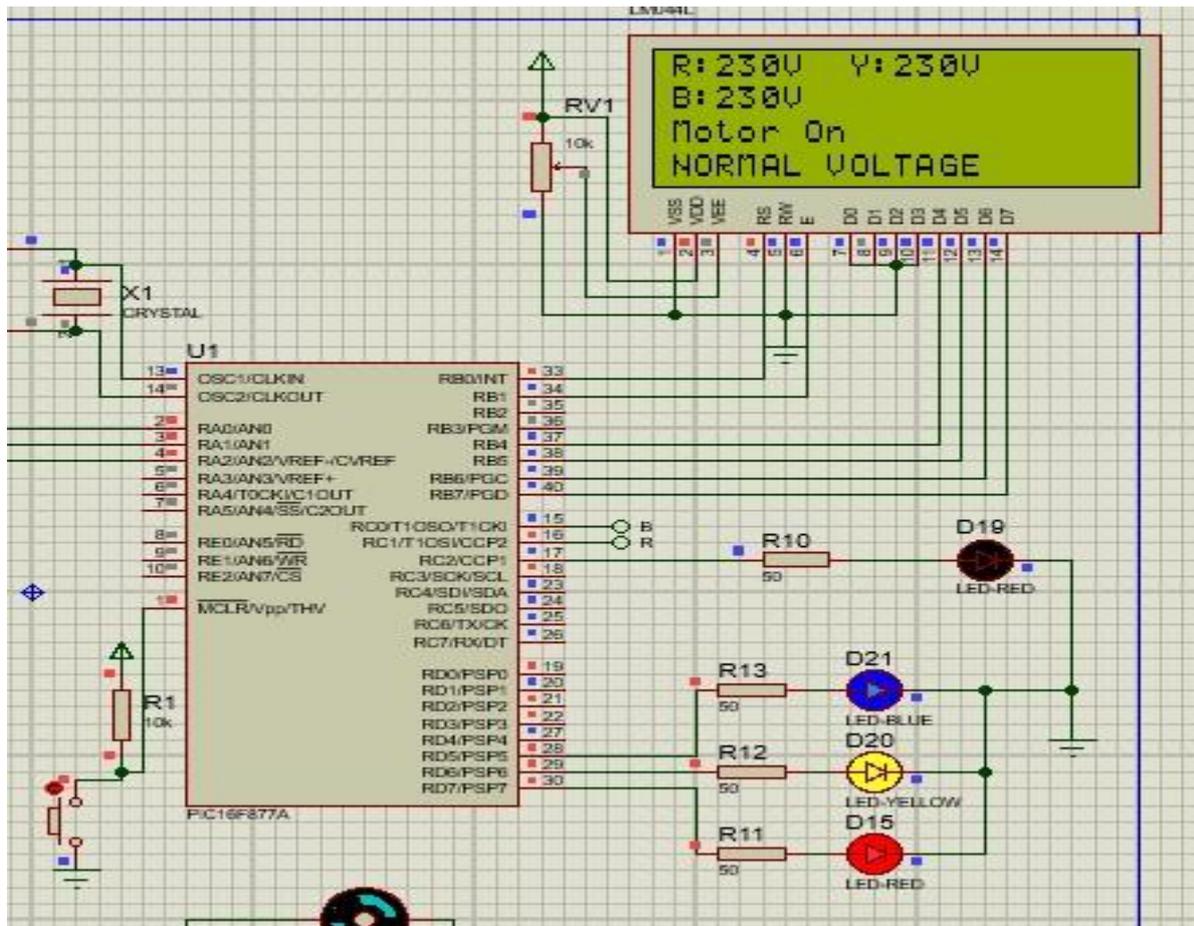
Figure 4.5.5 normal voltage condition

Figure 4.5.5, shows the normal voltage condition, the motor is ON, and the warning LED is off showing that the system is running perfectly.

## 4.6 CONCLUSION

In this chapter, the Proteus simulations of the project provided valuable insights into the functionality and performance of the monitoring and protection system for three-phase induction motors. The simulations allowed for a thorough assessment of the system's behavior under various operational conditions, validating its design and functionality. Overall, the Proteus simulations have been instrumental in validating the theoretical concepts and practical implementation of the monitoring and protection system. The insights gained will guide further development stages, ensuring that the system meets safety standards and operational requirements in real-world applications.

# CHAPTER FIVE PRACTICAL IMPLEMENTATION AND TESTING

## 5.1 INTRODUCTION

This chapter covers on implementation of the prototype of the dual output power supply designed and simulated in previous chapters. The prototype was developed through the integration of different functions together and testing, starting from the voltage sensing circuit and doing the system implementation and testing incrementally until the required monitoring and protection system is developed. The hardware is tested for all the abnormal conditions as well as the normal conditions. The practical testing is done the way it is in the proteus simulations.
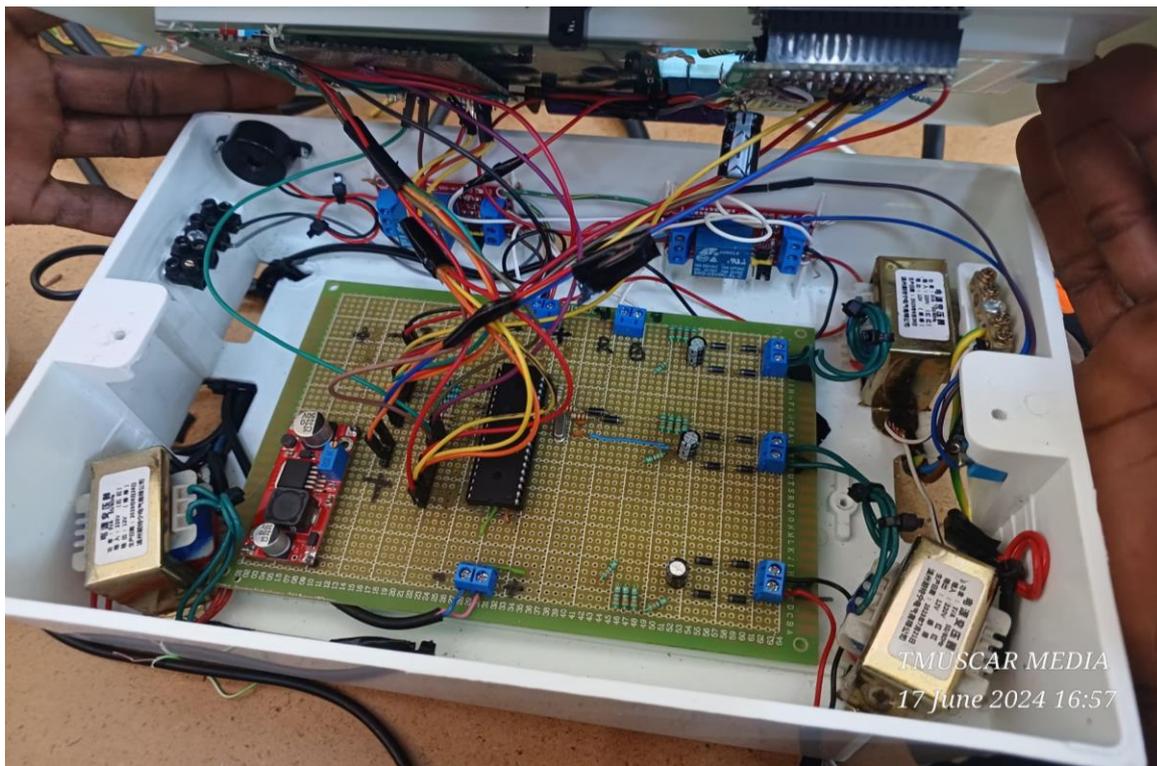
## 5.2 PROTOTYPE CIRCUIT



Figure 5.2 Prototype circuit

The figure above shows the system circuit inside the system with all the components inside the casing.

## 5.3 PROTOTYPE CONDITIONS TESTING

The implemented prototype testing for functionality was performed to check how the hardware is working practically.

### 5.3.1 POWER OUTRAGE CONDITION



Figure 5.3.1 power outage

In figure 5.3.1, the LCD shows that all phase voltages are equal to 0Vand and the motor is off. This means at this stage there is no supply power in any of the phases.

### 5.3.2 SINGLE PHASING CONDITION



Figure 5.3.2 Single phasing condition

The above figure shows the condition where one of the phases is missing. Figure 5.3.2 shows the display on LCD and the bulb represents the coil of the contactor which is energized to close the power circuit of the phase induction motor.

### 5.3.3 UNDER VOLTAGE CONDITION



Figure 5.3.3 under voltage condition

Figure 5.3.3, shows the condition of voltage below the normal and the bulb is off showing no power to the motor, and on display, it shows that the motor is OFF.

### 5.3.4 OVER-VOLTAGE CONDITION



Figure 5.3.4 Overvoltage

Figure 5.3.4 shows that there is a high voltage above the threshold the motor is off and the display is showing it. The figure above shows that the system will detect a condition even its one of the phases is in an abnormal state.

### 5.3.5 NORMAL VOLTAGE CONDITION



Figure 5.3.5 normal voltage

Figure 5.3.5 shows that the voltage level is normal, it is on LCD, and the indicators are ON. The bulb that represents the motor is glowing, showing that the motor is running.

## 5.4 SYSTEM PROTECTION NOTIFICATION

The monitoring and protection system has to notify the operator or user through an audible alarm when an abnormal condition occurs. The system cut off the power supply to the motor and updated the LCD for condition visualization. The designed system has also a warning red LED which flashes only when abnormal condition is detected. The system also notified the maintenance team via a text message. The designed with a green LED that blinks when the gsm successfully sends the message.

Figure 5.4.1 Abnormal notification

Figure 5.4.1, shows that the warning LED is ON and the green LED indicates that the message has been successfully sent. The LCD shows the condition detected by the system.
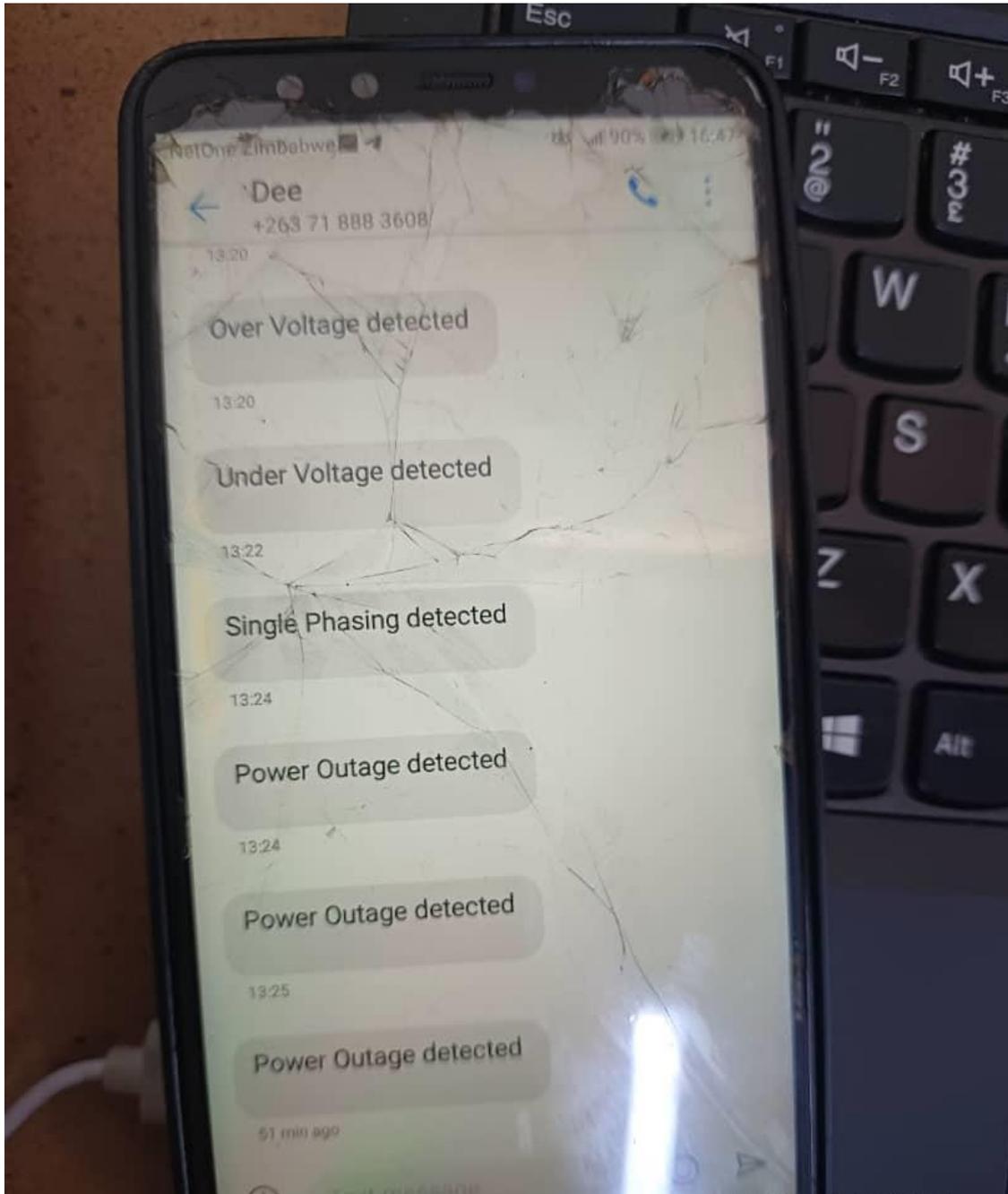
Figure 5.4.2 Message notification

The above figure shows the messages received immediately when the system detects abnormal conditions. It shows that the maintenance team receives the message that states the specific condition detected.

## 5.5 FINAL FUNCTIONAL UNIT

The final functional unit was implemented. The final monitoring and protection system was put in a casing.



Figure 5.5 final system

Shows the final monitoring and protection system in a PVC casing box.

## 5.6 CONCLUSION

The practical implementation of the monitoring and protection system for three-phase induction motors, as outlined in this chapter, demonstrates the efficacy and reliability of utilizing a microcontroller-based approach. Throughout the implementation process, key protective features such as single-phasing detection, under-voltage, and over-voltage protection were successfully integrated and tested. The system's ability to trigger alarms, cut off the power supply, and notify maintenance personnel through SMS notifications ensures prompt response to potential faults, thereby enhancing the operational safety and longevity of the motors.

# CHAPTER SIX RECOMMENDATIONS AND CONCLUSION

## 6.1 INTRODUCTION

This chapter describes the strengths and weaknesses of the project of a monitoring and protection system of a three-phase induction motor. More so, this chapter gives recommendations to use for future design projects.

## 6.2 STRENGTH OF THE PROJECT

The strengths of a monitoring and protection system for a three-phase induction motor using a PIC16F877A microcontroller include:

1. Enhanced Motor Protection
   o The system has comprehensive fault detection, it can detect and respond to various faults, overvoltage, undervoltage, and phase failure, ensuring the motor operates within safe parameters.
2. Improved Reliability and Longevity
   o Preventive Maintenance, continuous monitoring helps in early detection of potential issues, allowing for preventive maintenance and reducing unexpected downtimes.
   o Optimized Operation, by maintaining motor operation within safe limits, the system extends the motor's operational life.
3. Cost-Effectiveness
   o Affordable Components, the PIC16F877A microcontroller, and associated sensors are cost-effective, making the overall system economical.
   o Damage Prevention, reducing the likelihood of severe motor damage saves on repair and replacement costs.
4. Ease of Integration and Use
   o Simple Design, the system's design is straightforward, making it easy to implement and integrate into existing motor setups.

5. Real-Time Monitoring

   o Continuous Data Display, real-time display of voltage provides immediate insights into motor performance.

   o Immediate Alerts, the system can provide visual and audible alerts in case of faults, ensuring prompt attention.

6. Versatility

   o Wide Application Range, suitable for various types and sizes of three-phase induction motors used in different industrial and commercial applications.

   o Adaptable, the system can be adapted for other types of motors or equipment with similar monitoring and protection needs.

## 6.3 WEAKNESSES OF THE PROJECT

Despite its strengths, a monitoring and protection system for a three-phase induction motor using a PIC16F877A microcontroller may have several weaknesses:

1. Limited Processing Power and Memory

   o Microcontroller Constraints, the PIC16F877A has limited processing power and memory, which may restrict the complexity and number of features that can be implemented.

   o Data handling and limited memory capacity can affect the ability to log extensive historical data or handle high-resolution sensor data.

2. Accuracy and Precision Limitations

   o Sensor Calibration, the accuracy of the system heavily depends on the calibration and quality of the sensors used. Inaccurate sensor readings can lead to improper protection actions.

   o ADC Resolution, the 10-bit ADC on the PIC16F877A may not provide the precision needed for some applications, leading to less accurate monitoring.

3. User Interface Limitations

   o Basic Display, The LCD interface, while functional, may not provide the most user-friendly experience compared to more advanced graphical user interfaces.

o  Limited User Interaction, simple interfaces might limit the level of interaction and customization available to users, reducing the flexibility of the system.

4.  Limited Communication Capabilities

o  Data Transmission, basic communication interfaces (like UART) may not be sufficient for advanced data transmission needs, limiting remote monitoring and control capabilities.

o  Integration Challenges, integrating the system with modern IoT platforms or networks may require additional hardware and software, complicating the design.

## 6.2 RECOMMENDATIONS

Here are some recommendations to improve the monitoring and protection system for a three-phase induction motor using a PIC16F877A microcontroller:

1. Enhance Processing Power and Memory

o  Upgrade the Microcontroller; consider using a more advanced microcontroller with greater processing power, memory, and additional features. For instance, the PIC18F series or ARM Cortex-M series could provide better performance.

o  Optimize Code Streamline, the code to ensure efficient use of memory and processing resources. Utilize interrupt-driven programming to manage sensor data and control logic effectively.

2. Improve Accuracy and Precision

o  High-Quality Sensors, invest in high-quality, industrial-grade sensors for more accurate and reliable readings. Ensure regular calibration of sensors to maintain accuracy.

o  Increase ADC Resolution, if the current ADC resolution is insufficient; consider using an external ADC with higher resolution or switching to a microcontroller with a better-integrated ADC.

3. Enhance User Interface

- Advanced Display, upgrade to a graphical LCD or OLED display to provide a more user-friendly interface. This can display more detailed information and enhance user interaction.
- Touchscreen Interface, consider integrating a touchscreen interface for easier navigation and control.

4. Expand Communication Capabilities

- Advanced Communication Interfaces, incorporate advanced communication interfaces such as I2C, SPI, CAN, or Ethernet to enhance data transmission capabilities.
- IoT Integration, integrated with IoT platforms for remote monitoring and control. Use modules like ESP8266 or ESP32 for Wi-Fi connectivity and MQTT for communication.

5. Improve Protection Mechanisms

- Faster Response Times, optimize the firmware to ensure faster detection and response to faults. Utilize dedicated hardware for critical protection features.
- Redundancy, add redundancy in critical components and sensors to enhance reliability and fault tolerance.

6. Simplify Maintenance and Troubleshooting

- Diagnostic Features include diagnostic features in the firmware to help identify issues quickly. Provide clear error codes and messages on the display.
- Documentation and Training provide comprehensive documentation and training materials to users and technicians for easier maintenance and troubleshooting.

## 6.5 CONCLUSION

The development of a monitoring and protection system for a three-phase induction motor using a PIC16F877A microcontroller demonstrates significant advancements in motor safety, reliability, and efficiency. By incorporating features such as real-time current, voltage, and temperature monitoring, as well as implementing robust protection mechanisms, this project ensures the motor operates within safe parameters and prevents damage from various electrical and thermal faults.

- Key Outcomes

  1. Enhanced Motor Protection, the system effectively detects and responds to overvoltage, undervoltage, and phase failure conditions, ensuring the motor's safety and longevity.

  2. Improved Reliability, continuous monitoring and immediate response to faults help prevent severe motor damage, reducing downtime and maintenance costs.

  3. Cost-Effectiveness, the use of the PIC16F877A microcontroller and cost-effective sensors makes the system economically viable while still providing robust protection.

  4. User-Friendly Interface, the LCD offers an accessible and straightforward way for users to monitor motor parameters and respond to alerts.

  5. Customization and Scalability, the system's design allows for customization of protection thresholds and the potential for future enhancements, making it adaptable to various motor types and operational requirements.

- Future Work:

  Future developments can focus on:
  - Upgrading the microcontroller for more complex and feature-rich functionalities.
  - Implementing advanced user interfaces, such as graphical displays and touchscreens.
  - Integrating IoT capabilities for remote monitoring and control.
  - Enhancing data logging with external or cloud storage options.
  - Expanding the system's scalability and modularity for broader applications

In conclusion, this project demonstrates the feasibility and effectiveness of using a microcontroller-based system to monitor and protect three-phase induction motors. With further refinements and enhancements, such systems can become an integral part of industrial and commercial motor management, ensuring optimal performance, safety, and efficiency.

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