Performance Monitoring and Diagnostic System for Three-Phase Induction Motor

R,Shankar,
Professor/EEE, Kongunadu College of Engineering and Technology,Tiruchirappalli-621 215.

R.Gopalakrishnan
Assistant Professor/EEE, Kongunadu College of Engineering and Technology,Tiruchirappalli-621 215.
Corresponding author: shankar098@gmail.com

Abstract:

Today, technology is advancing quickly with the Internet of Things (IoT), which helps things stay connected. We can keep an eye on and track important details about how well a special kind of motor works. The Induction motor can do things like change voltage, current, power, and speed. All this information shows up on a screen. If something goes wrong, like too much voltage or heat, a safety feature will stop the Induction motor until things are back to normal. Then, the Induction motor will start again on its own. The reliability and safety of this induction motor feature are being tested to ensure optimal performance, even under extreme conditions.

Keywords: Internet of Things(IoT), Induction Motor, Over Voltage, Under voltage, and Over Temperature.

I. INTRODUCTION

In the past, machines used different types of devices to keep them safe, like temperature sensors and switches. These devices were expensive and not very efficient. But now, with new digital systems, machines can be monitored and protected better, and at a lower cost [3].

The induction motor is a very important part of many industries, but it can break down over time due to different factors. It is important to be able to detect any problems with the motor to prevent it from causing big losses and being unsafe. Some common issues with induction motors include overheating, getting too much or too little electricity, and having problems with the different phases of electricity. If an induction motor gets too much electricity, it can start to get too hot[7].

Three-phase induction motors are popular because they are simple and reliable. They are used in many industries like railroads, mining, and cars. These motors are great for household items and machines because they work well and last a long time. Three-phase induction motors are widely used in various industries due to their reliability and efficiency. However, they can be prone to overheating, overvoltage, and under voltage conditions, which can lead to significant losses and even damage to the motor[11]. To address these issues, a performance monitoring and diagnostic system has been developed to ensure the safe and efficient operation of these motors.

II. EXISTING SYSTEM BLOCKDIAGRAM

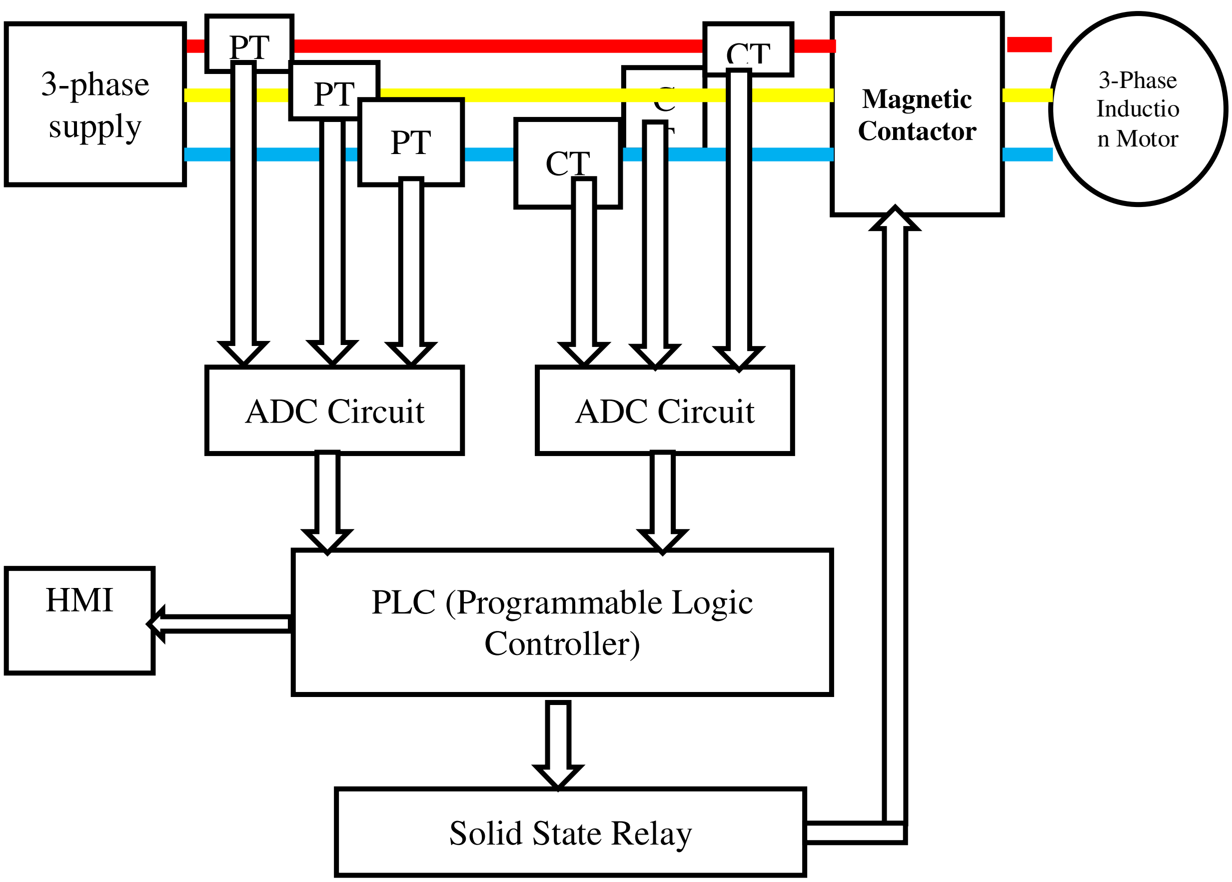

Figure.1.Block Diagram of Existing PLC Based Monitor and Control

The power from the source is first converted to a lower voltage using transformers, then rectified and sent to the PLC for monitoring. The PLC controls a relay that switches the motor ON and OFF through a magnetic contactor. When everything is working normally, the motor runs smoothly. But if the voltage goes too high, the system shuts off the motor to prevent any damage. In simple terms, the system keeps an eye on the voltage coming in and if it's too high, it stops the motor from running to keep it safe. The hardware used in this system includes different electrical components like an induction motor, transformers, relays, and a PLC as shown in figure 1. To protect the motor from getting damaged by high voltage, we use sensors connected to the controller. The sensors monitor the voltage coming from the power source and if it goes above a safe level, the motor is automatically turned off.[1]

Under normal conditions, the motor operates safely. However, if an issue arises, the LM35 sensor will transmit a signal to the PLC. If the signal exceeds a certain threshold, the motor will be shut down to ensure safety. When the power goes too low or there is too much electricity in a machine, it can cause problems because it is not working properly.

III. PROPOSED SYSTEM BLOCKDIAGRAM

In the figure 2 block diagram the proposed system used to monitor the induction motor health conditions like voltage, current, Power, Power factor, frequency, and Speed. At the time of 3-phase supply will flow from interconnected circuits and then followed by the induction motor. The components such as PZEM sensor, voltage regulator and motor will gain the three phase power. Other components like Arduino Mega, NodeMCU, temperature sensor, buzzer and LCD display are connected as DC power supply as per requirements.

It requires a 12V DC supply for Arduino from the AC socket. After the connections done, the Arduino instantly monitor the every action of the every component by the help of a coding part fed into it. The LCD screen will display the data input into the Arduino. It will instantly monitor the motor temperature, voltage, current, frequency, power, and power factor of each phases power supply. Here the programming language as Embedded C in Arduino IDE, helps to be written and fed into the Arduino Mega will control the every connected component.

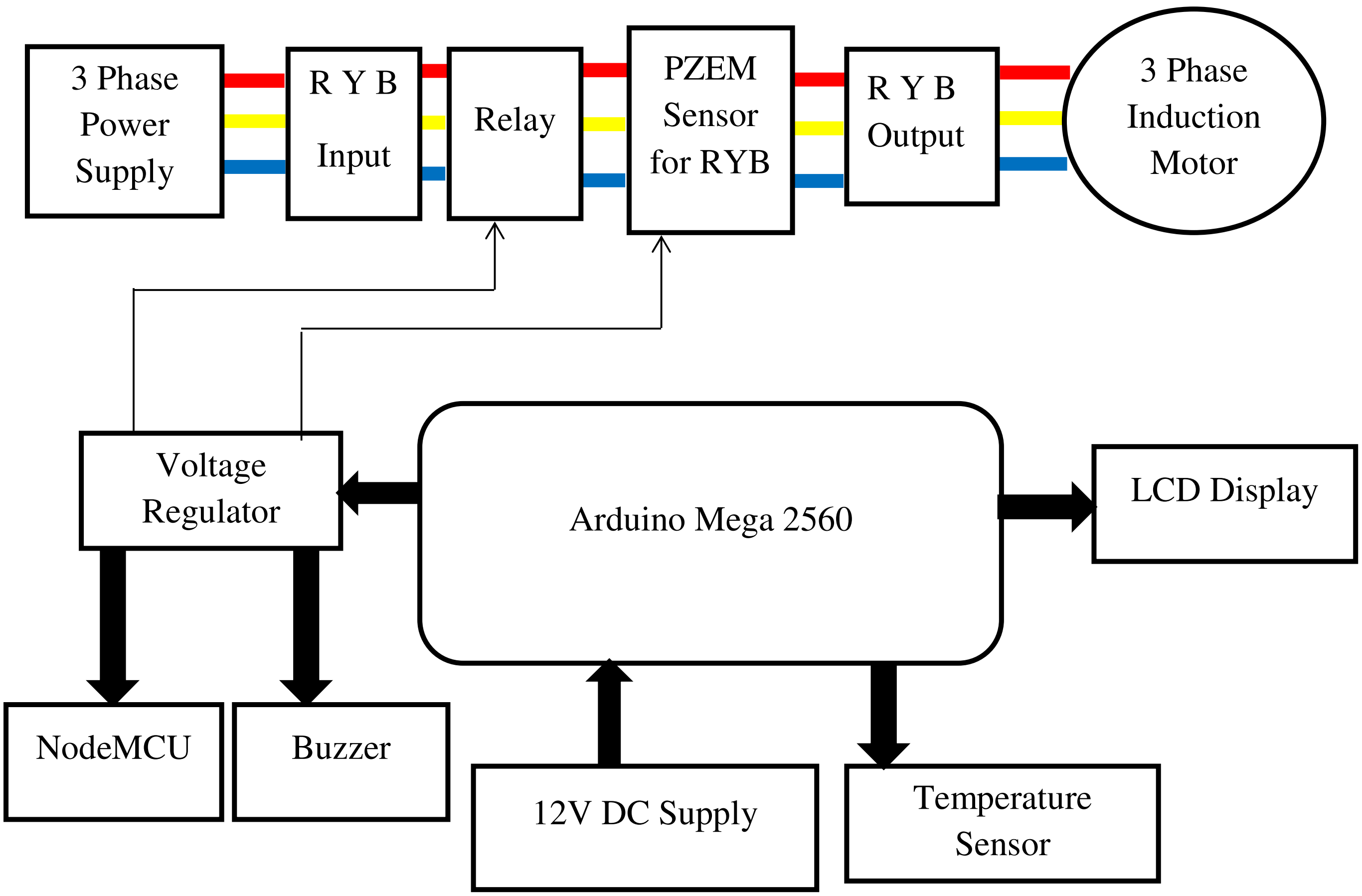

Figure.2. Block Diagram of Proposed system

After the PZEM sensor the relay connected with motor. If there is any abnormal conditions such as Over Voltage, Under Voltage and Over Temperature, the Arduino will notify the relay and automatically the motor power supply get cut off. When the temperature increased, the temperature sensor as DHT11 will send the temperature data to the developed application called MQTT with a buzzer sound.

With the help of NodeMCU, every action on the motor power supply will instantly transmit data to this application. This process ensures the motor is easily protected, enhancing its long-term efficiency.

IV.SYSTEM COMPONENTS DISCRIPTION

1. POWER SUPPLY

The AC voltage, typically 230V, is connected to a circuit. The AC supply is then transferred to the relay circuit through a wired connection. The DC voltage is supplied from the AC socket, regulated by the Arduino Mega controller, and distributed to all other required circuits. Components such as the regulator, NodeMCU, LCD display, and buzzer receive the DC supply.

Voltage regulators are very common in electronic circuits as they provide a constant output voltage for a varied input voltage. In our case, the 7805 IC is an iconic regulator IC that finds application in most projects.

The LM7805 is a voltage regulator that outputs +5 volts. Like most other regulators on the market, it is a three-pin IC: an input pin for accepting incoming DC voltage, a ground pin for establishing ground for the regulator, and an output pin that supplies the positive 5 volts.

2. PZEM SENSOR (PART ZONE EXPANSION MODULE)

The PZEM-004T in figure 3 is a highly comprehensive sensor module that measures current, voltage, power, power factor, frequency, and even energy consumption. The individual sensors for current, voltage, frequency, and power factor, and often used. Additionally, AC voltage sensors available in the market were sometimes unstable for reasons that were unclear.

However, the PZEM-004T sensor has resolved all these issues. This module includes all the necessary components for a complete energy or power meter, and even incorporates frequency and power factor sensors, making it a highly versatile and reliable solution.

The specifications of the PZEM-004T AC communication module indicate that it is primarily used for measuring AC voltage, current, active power, frequency, power factor, and active energy. The module does not have a display function; instead, data is read through the TTL interface.

- PZEM-004T-10A: Measuring range up to 10A (built-in shunt).
- PZEM-004T-100A: Measuring range up to 100A (external transformer).

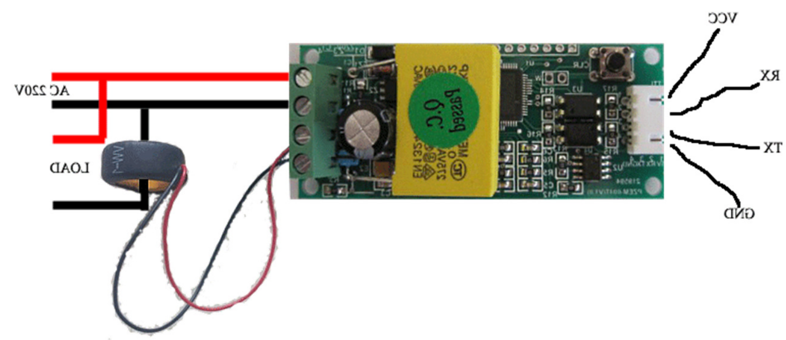

Figure.3. PZEM sensor

Table.1. Ranges of PZEM sensor

Voltage	80-260 V
Frequency	45-65 Hz
Measuring Range	0-10 A/0-100A

3. ARDUINO MEGA CONTROLLER

The Arduino Mega is based on the ATmega2560 microcontroller is shown in figure 4. The ATmega2560 is an 8-bit microcontroller. To get started with the Arduino Mega, a simple USB cable to connect it to a computer and an AC-to-DC adapter or battery for power. The Arduino Mega is programmed using the Arduino IDE (Integrated Development Environment), which can run on various platforms. The functioning of the Arduino Mega is similar to other Arduino boards, and no extra components are required for its basic operation.

The ATmega2560 microcontroller is compatible with most of the shields designed for the Arduino UNO. This compatibility makes the Arduino Mega a versatile choice for a wide range of applications.

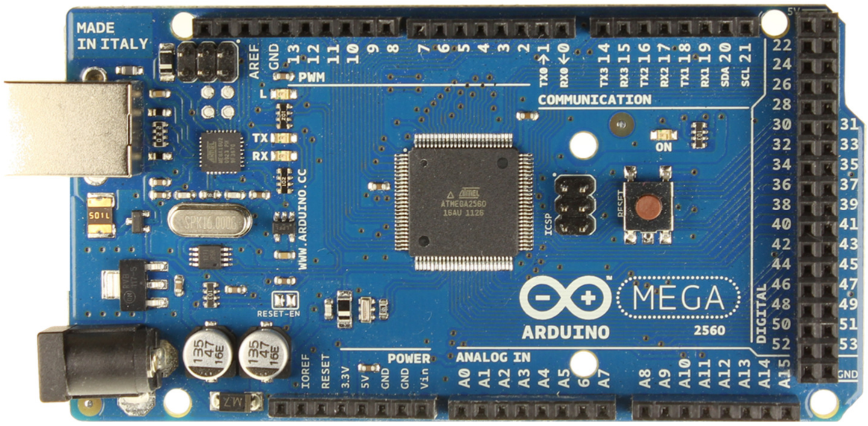

Figure.4.Arduino Mega 2560

The advantage of using the Arduino Mega board over other boards is its larger memory space and higher processing power. These features allow it to handle multiple sensors simultaneously and manage more complex projects.

The preinstalled flash memory includes a bootloader that occupies 8 KB of the 256 KB total memory. The Arduino Mega also has 8 KB of SRAM (Static Random Access Memory) and 4 KB of EEPROM (Electrically Erasable Programmable Read-Only Memory), providing ample space for dynamic and non-volatile data storage, respectively.

4. LIQUID CRYSTAL DISPLAY

The JHD162A LCD display module is a monochrome LCD module, which is the best and most affordable module for starter projects and experiments. As a 16x2 display, it has 32 character blocks, each with a dot matrix of 5x8 to display characters. It has 16 pins for interfacing as shown in figure 5.

Figure.5.LCD Display

This module can be interfaced with various microcontrollers using different data modes (8-bit or 4-bit). Programming the JHD162A LCD allows for a range of special features and tricks, which can give a new look to your application and expand its functionality.

5. TEMPERATURE SENSOR (DHT11)

The DHT11 is a commonly used temperature and humidity sensor that comes with a dedicated NTC thermistor to measure temperature and an 8-bit microcontroller to output the values of temperature and humidity as serial data.

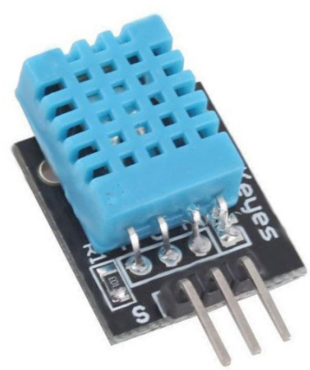

Figure.6.DHT11 Sensor

In the above figure 6 DHT11 measures relative humidity. Relative humidity is the amount of water vapor in the air compared to the saturation point of water vapor in the air. At the saturation point, water vapor starts to condense and accumulate on surfaces, forming dew.

The saturation point changes with air temperature. Cold air can hold less water vapor before it becomes saturated, and hot air can hold more water vapor before it becomes saturated. Relative humidity is expressed as a percentage. At 100% RH, condensation occurs, and at 0% RH, the air is completely dry.

6. RELAYS

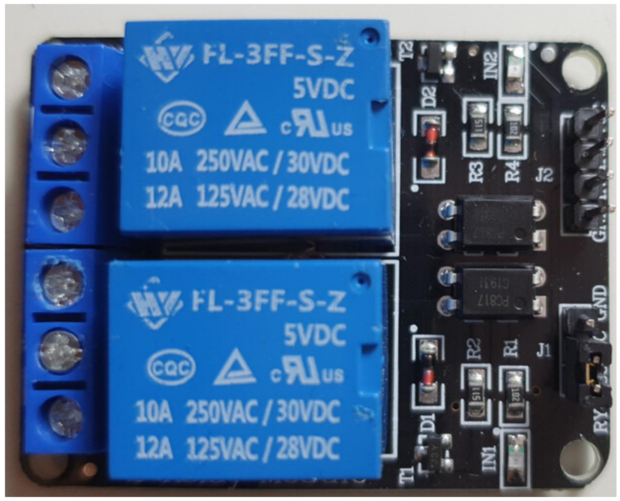

Figure.7 Relay FL-3FF-S-Z module

The FL-3FF-S-Z relay, produced by the manufacturer "FLOURISHING," is an electronic component that performs the same function as a “PC Board Relay” as shown in figure 7. These relays are typically used in industrial applications to control high power circuits, but they are also used in cars, homes, and other electrical applications.

Relays are composed of an electromagnet that moves a tiny metallic plank, known as the COM (common) terminal, between two different positions: the NC (normally closed) terminal and the NO (normally open) terminal. The position of the COM terminal is controlled by activating or deactivating the electromagnet through a low power signal applied to the electromagnet control terminals.

7. BUZZER

Figure.8.TMB 12A05 Buzzer

The buzzer is a sounding device that can convert electrical signals into sound. It is usually powered by DC voltage and is widely used in alarms, computers, printers, and other electronic products as a sound device. Buzzers are mainly divided into piezoelectric buzzers and electromagnetic buzzers, represented by the letter "H" or "HA" in circuits. Depending on their design and use, buzzers can emit various sounds such as music, sirens, buzzers, alarms, and electric bells.

TMB 12A05 Buzzer shown in figure 8 is a small 12mm round speaker that operates around the audible 2kHz range. It is not a true piezoelectric speaker but behaves similarly. Instead of a piezoelectric crystal that vibrates with an electric current, this tiny speaker uses an electromagnet to drive a thin metal sheet.

8. THREE PHASE INDUCTION MOTOR

In the below figure 9 is a 3-phase induction motor with half HP power. A 3-phase induction motor is an electromechanical energy conversion device that converts 3-phase input electrical power into output mechanical power. A 3-phase induction motor consists of a stator and a rotor. The stator carries a 3-phase stator winding, while the rotor carries a short-circuited winding called the rotor winding. The stator winding is supplied from a 3-phase supply. The rotor winding derives its voltage and power from the stator winding through electromagnetic induction.

Figure.9.Three-phase induction motor

Table2: Specifications of an Induction Motor

RATED PARAMETERS	RANGES
Voltage	415V
Current	1.09A
Power	0.37kW
HP	0.5
Speed	1400RPM
Frequency	50Hz
Connection	Star
Efficiency	72.70%
Weight	8Kg
Temperature	50^0C
Power Factor	0.65

V.EXPERIMENTAL SETUP

The system consists of a three-phase induction motor, PZEM sensor, NodeMCU, Arduino Mega, LCD display, temperature sensor, voltage regulator, and buzzer as shown in figure 10. When the power supply is activated, the three-phase power flows through interconnected circuits to the induction motor. Components such as the PZEM sensor, voltage regulator, and motor receive three-phase power. Other components, including the Arduino Mega, NodeMCU, temperature sensor, buzzer, and LCD display, are powered by a DC supply as required.

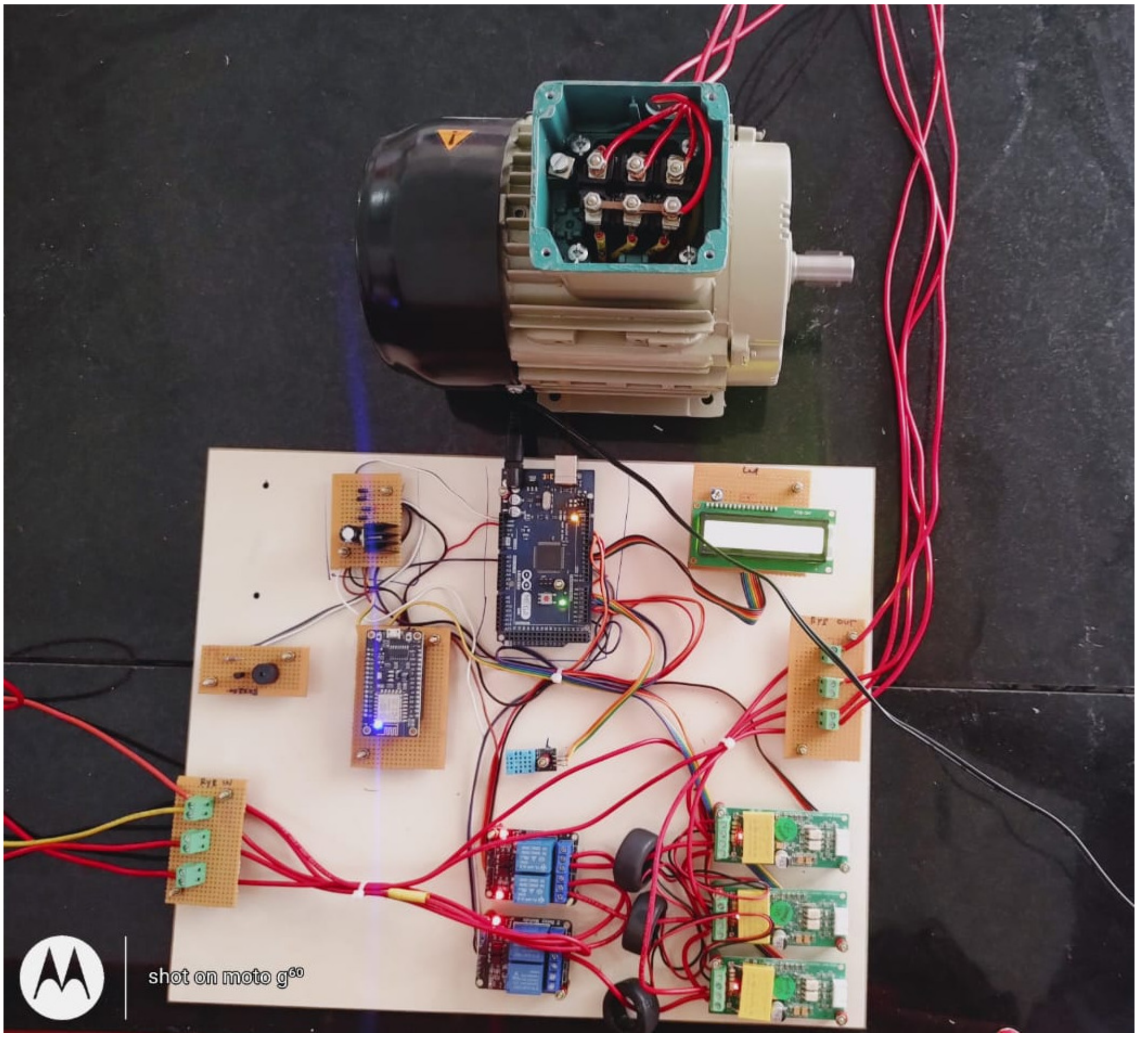

Figure.10. Experimental setup

VI.RESULT AND DISCUSSION

It can able to control the Motor from the three conditions called Over Voltage, Over Temperature, Under Voltage.

1**. Overvoltage Condition**

The normal voltages of the induction motor are set as 230V in each phase, while the abnormal voltage is set as 250V. Under normal conditions, the three-phase variable power supply is positioned at 230V, and the position of the relay and magnetic contactor is on, as per the logic defined in the Arduino IDE programming. In normal conditions, the three-phase supply is connected to the motor, and the motor keeps running properly at its rated speed at this voltage level. However, an abnormal condition is introduced when the voltage level is increased from its normal value and is set to 250V. As the knob of the three-phase power supply is positioned at 250V, the Arduino IDE programming considers this voltage as an abnormal condition and trips the relay.

2. **Over temperature Condition**

Under normal conditions, the induction motor will be running safely. However, during an abnormal condition, the DHT11 temperature sensor generates a higher range of voltages (in mV) that are connected to the analog input pin of the Arduino Mega. As the voltage level goes higher than the defined range (the safe temperature threshold), the output of the Arduino Mega goes high, and thus the relay is activated, which disconnects the motor from supply.

3. **Under Voltage Condition**

During an under voltage condition occurs the voltage drops below the standard or normal operating voltage level, which causes an overflow of current in the induction motor and electrical stress on the winding insulation. Since the normal voltage of the induction motor is 230V, whenever this voltage level drops very low, i.e., 180V, then this voltage level is considered as an under voltage or over current condition.

In this proposed work, each sensors are tested individually and implemented. While the motors are operating, the sensed values are continuously displayed as temperature, voltage and power factor. The motor is tested for abnormal condition. The sensor information displayed in serial monitor, LCD display are given below figure 11.

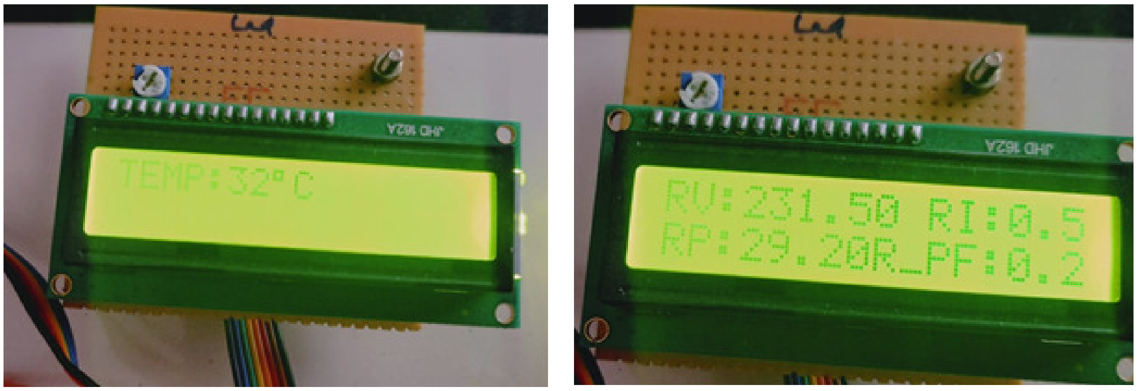

Figure.11.Temperature, Voltage and Power factor display on LCD

VII.CONCLUSION

This paper presents a cost-effective, real-time monitoring and protection scheme for industrial three-phase induction motors against overcurrent, overvoltage, and over temperature conditions using the ATmega2560 microcontroller. The induction motor is effectively monitored using various sensors, and its health is assessed by analysing the continuous parameter data obtained.

REFERENCES

[1] M. E. H. Rayner, S. J. Dodds, R. M. Asher, and M. Sinnathurai, "Condition monitoring of induction motors using online digital current monitoring," in Proc. IEEE Int. Conf. Electr. Mach. Drives, 1997, pp. MA1/4.1–MA1/4.6.

[2] M. E. H. Rayner, A. C. Tan, S. J. Dodds, and M. J. Reyersbach, "Condition monitoring of induction motors using non-invasive sensors," in Proc. IEEE Int. Conf. Electr. Mach. Drives, 1999, pp. 464–466.

[3] S. Nandi, H. A. Toliyat, and X. Li, "Condition monitoring and fault diagnosis of electrical motors—A review," IEEE Trans. Energy Convers., vol. 20, no. 4, pp. 719- 729, Dec. 2005.

[4] A. Bellini, F. Filippetti, C. Tassoni, and G.-A.Capolino, "Advances in diagnostic techniques for induction machines," IEEE Trans. Ind. Electron., vol. 55, no. 12, pp. 4109–4126, Dec. 2008.

[5] W. T. Thomson and M. Fenger, "Current signature analysis to detect induction motor faults," IEEE Ind. Appl. Mag., vol. 7, no. 4, pp. 26–34, Jul./Aug. 2001.

[6] Dharmalingam M, Umarani B, Shankar R and Kumar K, “Analysis of Internet of Thing in Smart Manufacturing Industry”, Journal of Computational and Theoretical Nanoscience, Volume 17, Number 12, December 2020, pp. 5495-5502(8).

[7] M. Arkan, D. K. Perovic, and P. Unsworth, "Online stator current monitoring of induction machines," in Proc. IEEE Ind. Appl. Soc. Annu.Meeting, Oct. 1999, pp. 2609–2615.

[8] M. E. H. Rayner, S. J. Dodds, and R. M. Asher, "Diagnostic monitoring of induction motors," in Proc. IEEE Int. Conf. Electr. Mach. Drives, 1997, pp. MD1/4.1–MD1/4.6.

[9] S. Nandi and H. A. Toliyat, "Condition monitoring and fault diagnosis of electrical machines - A review," in Proc. IEEE Int. Conf. Electr. Mach. Drives, 1999, pp. 197–204.

[10] A. Siddique, G. S. Yadava, and B. Singh, "A review of stator fault monitoring techniques of induction motors," IEEE Trans. Energy Convers., vol. 20, no. 1, pp. 106–114, Mar. 2005.

[11] S. Nandi, H. A. Toliyat, and X. Li, "Condition monitoring and fault diagnosis of electrical motors—A review," IEEE Trans. Energy Convers., vol. 20, no. 4, pp. 719–729, Dec. 2005.

[12] E. Noyjeen and C. Tanita, "Monitoring parameters of three-phase induction motor using IoT," in Proc. 2021 Int. Electr. Eng. Congr. (iEECON), Pattaya, Thailand, 2021.

[13] A. Gedzurs and A. Sniders, "Induction motor stator winding thermal process research and modelling under locked rotor mode," in Proc. 13th Int. Sci. Conf. Eng. Rural Dev., Jelgava, Latvia, May 2021, pp. 265-270.

[14] E. C. Quispe, X. M. Lopez-Fernandez, A. M. S. Mendes, A. J. Marques Cardoso, and J. A. Palacios, "Experimental study of the effect of positive sequence voltage on the derating of induction motors under voltage unbalance," in Proc. IEEE Int. Electr. Mach. Drives Conf. (IEMDC), 2021, pp. 908-912.

[15]C. Woodford, "Induction motors," [Online]. Available: http://www.explain that stuff.com/induction-motors.html. [Accessed: 4-Nov-2020].

[16] In-Plant Services, "Understanding vibration analysis," [Online]. Available: http://inplantservices.com/pdf/understanding-vibrationanalysis.pdf. [Accessed: 3-Nov-2020].

[17] F. Champavier, "Condition monitoring of induction motors using vibration and electrical signature analysis," in Proc. EE Mods Conf., Nantes, France, Sep. 2019.

[18] CommTest Instruments, "How vibration is measured," Reliability web.com, Jun. 2016. [Online]. Available: http://reliabilityweb.com/index.php/articles/how_is_vibration_measured/. [Accessed: 15-Nov-2017].

[19] M. R. Reed, S. Pryer, and J. Pryer, "Detection and classification of induction motor faults using motor current signature analysis and multilayer perception," in Proc. IEEE 8th Int. Power Eng. Optim. Conf., Mar. 2014, pp. 35-40.

[20] S. J. Murchite and S. A. Patil, "ARM based protection system for induction motor against faults," Int. J. Mod. Trends Eng. Res., vol. 1, no. 6, pp. 201-208, Dec. 2014.

[21] M. Irfan, N. Saad, R. Ibrahim, and V. S. Asirvadam, "Development of an intelligent condition monitoring system for AC induction motor using PLC," in Proc. IEEE Bus. Eng. Ind. Appl. Colloq., 2013.