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Controlling Three-Phase Induction Motor with an Internet of Things (IoT) Smart Industrial Panel

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Abstract: With the transition from manual to auto systems, technology has been advancing globally. The smart control panel is the subject of this study. The electrical components of appliances can be inductive, resistive, or capacitive. The majority of inductive devices are motors. a three-stage There are many uses for induction motors in the global power system because of its many benefits, including low starting power, low maintenance cost, and widespread use. This paper discusses fault analysis in induction motors using MATLAB/SIMULINK, providing optimal protection combining traditional and IoT for both automatic and manual methods, and making it fully controllable according to the requirements of protection engineers for various loads. This is important for the economy and the motors' longevity, as it ensures that they operate optimally with the best smart protection techniques. In this setup, the control elements include a molded-case circuit breaker for safety, a temperature and vibration sensor with an Internet of Things (IoT) based remote data collecting method for automatic protection, and a selector switch for human control and automatic operation.
Keywords: IoT- Internet of Things, CT- Current Transformer, LFL - Linear Fluorescent Lamp, MATLAB/SIMULINK

I. INTRODUCTION

Inductive, capacitive, and resistive loads are all very common. In particular, inductive loads, which include AC and DC motors, see heavy use in a wide range of manufacturing processes. The desirable properties of induction machines—three-phase ims in industries and single-phase ims in homes including sturdy construction, cheap maintenance and operation cost, high starting torque, efficiency, and reliability make them the preferred choice for both types of machines [1-2-3]

More than that, there are a lot of problems that can happen to motors, such as problems with the stator, rotor, bearings, windings, lubrication, cooling, temperature rise, and vibrations [4-5]. In order to prevent any loss, condition monitoring is essential, as even a tiny malfunction might result in a significant motor failure and economic hardship for the industry [6].

There are a plethora of methods for controlling and monitoring motor operations. No matter the issue—operations, electrical, or mechanical—the Internet of Things (iot) has changed countless industries around the globe. The continual contact between machines ensures the crucial role of the internet of things.

As part of the M2M (Machine-to-Machine) communication requirements, machine-type concerns are currently being highlighted [4]. Connecting various pieces of hardware with an intelligence backbone to make operations smart and enable them to speak with one another without separate configuration is the essence of the Internet of Things (IoT).

The term "Internet of things" (IOT) describes a network that allows various devices to communicate with one another and receive intelligence, thereby turning them into smart objects. As a result, physical devices can exchange data with one another and set themselves up autonomously [8]. In 1999, Kevin Ashton coined the term "Internet of Things" (IOT) to describe a worldwide network [9]. We now routinely utilize the "IOT"- Internet of Things to sense, trace, address, and measure items through the Internet, or by radio frequency identification (RFID) [10], wireless networks [11], wide area networks (WAN) [12], etc. The items in question, which include not just consumables and building materials but also various electrical equipment [9, 13–16].

Using both manual and Internet of Things (IoT) methods to control loads is the focus of this article. We can utilize the automatic controlling system from anywhere over Wi-Fi, and it's really efficient and comfortable. There is no need for physical labor to operate the system, making its operation easy and rapid. If there is an issue with the automatic system, we may easily operate it manually. Additionally, we are concentrating on three-phase induction motor temperature and vibration abnormalities. Figure 1 is a flow diagram of the entire process.

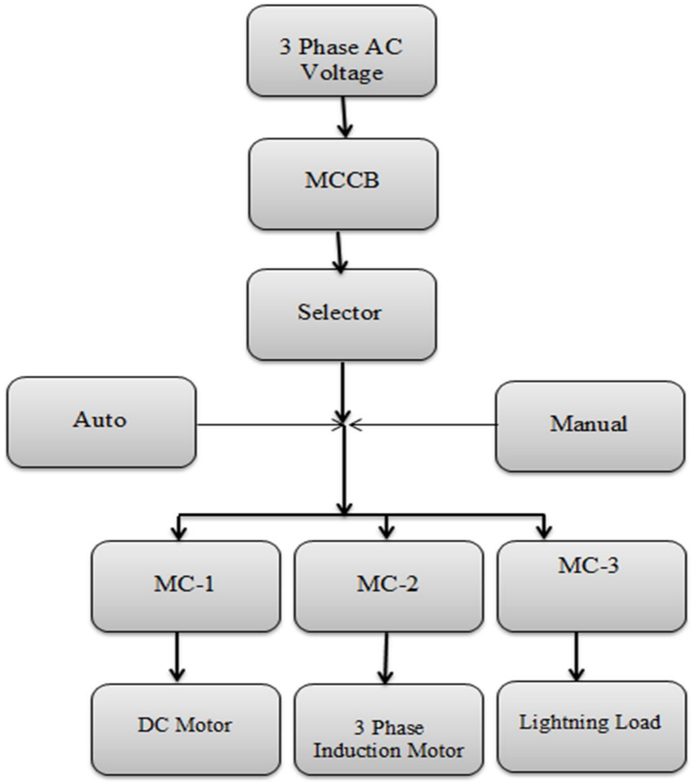

Figure1. Flow Chart

In Section-II, the suggested sensors and hardware are detailed. In Section-III, the methodology for the entire system is detailed. In Section-IV, the results and Taking into account and assessing all of the facts and statistics in the study, the conclusion is given in Section-V.

II. EQUIPMENT AND SENSORS SUGGESTED

This study discusses the use of inductive loads, specifically a linear fluorescent lamp (LFL), both manually and through the internet of things (IoT). We have recently focused on inductive loads and how they function in both typical and non-standard environments. To run, control, and safeguard both motors, the following apparatus is employed.

1) MCCB (Molded case circuit Breaker)
2) Magnetic contactor
3) Selector Switch
4) Toggle switch
5) Pilot Devices
6) Current transformer (CT)
7) Single-Phase Transformer
8) Diode Bridge
9) VA Hz Meter
10) Node MCU
11) Relay Bunch
12) Temperature sensor
13) Vibration Sensor
14) AC motor (Three-phase Induction Motor)
15) DC motor
16) Linear Fluorescent Lamp (LFL)

The enlisted equipment is shown in Figure 2.

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Figure 2. Proposed Sensors and Components

III. METHODOLGY

Software and hardware are the two main components of methodology. We have simulated several errors in the software and observed their results. As for the hardware, we have constructed a control panel that allows us to operate the motor.

A. Software Part

Undervoltage, imbalanced supply, overloading, earth faults, inter-turn faults, and single phasing are some of the most common motor defects. Undervoltage and overload are two of the issues that are detailed in this section for induction motors. It is crucial to safeguard the motor from irregularities, and the primary reason to think about these defects is that they cause the motor to overheat. As illustrated in Figure 3(a) and Figure 3(b), two MATLAB models have been developed to mimic undervoltage and overloading scenarios, respectively.

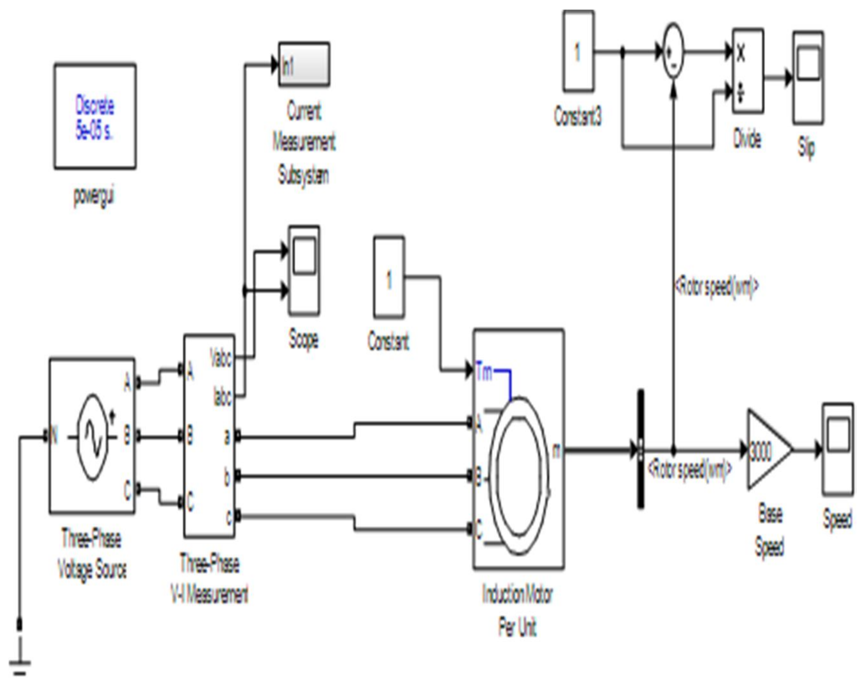

Figure 3(a). Simulink model for under voltage

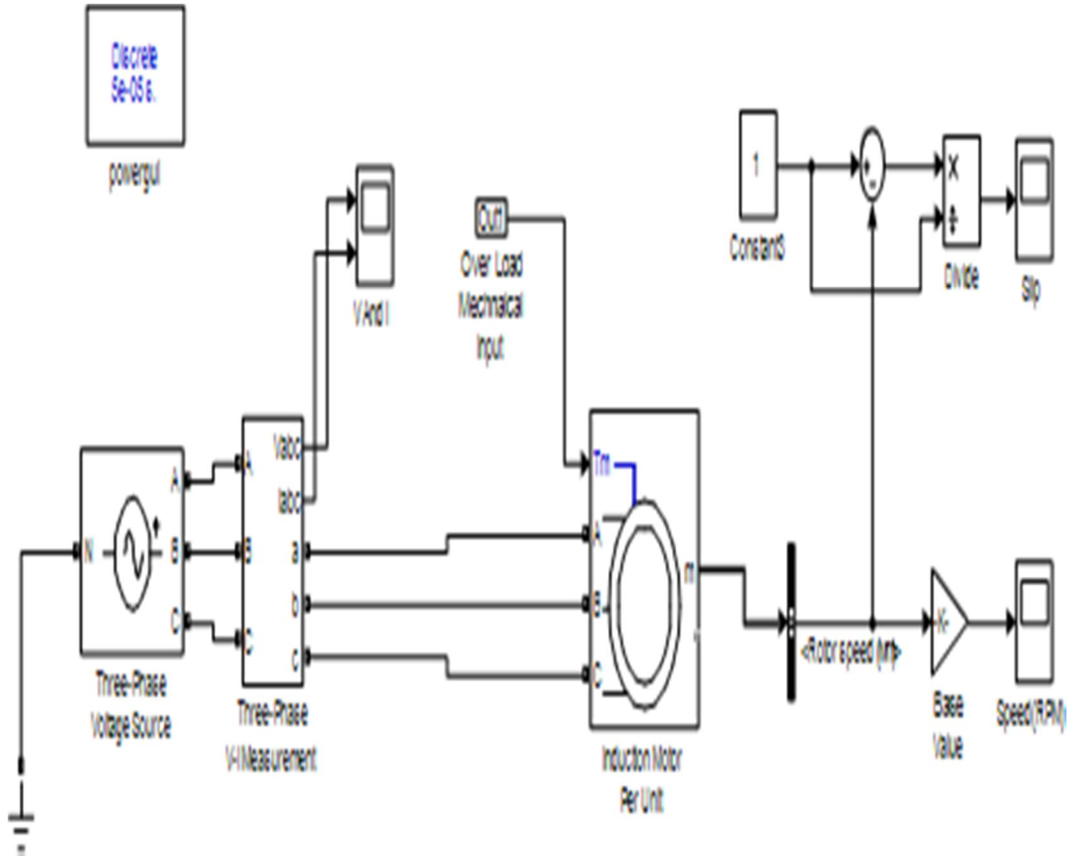

Figure 3(b). Simulink model for Overloading

B. Hardware Part

The suggested equipment's interconnections are detailed in the methodology. In order to manually and remotely monitor and regulate the operation of three-phase induction motors and DC motors, there must be connections between various pieces of equipment. When it comes to loads like IMs, DC motors, and LFLs, there are two distinct kinds of wiring diagrams: one for power wiring and another for controlling them. To choose between manual and Internet of Things (IoT) operation of loads, a selection is provided. Using the Multisim software, we were able to create the circuit diagram in figure-04, which illustrates all of the loads and equipment clearly. A molded case circuit breaker (MCCB) serves as a safety mechanism in this control panel, activating in the event of a motor short circuit. Although there are numerous other circuit breakers in use, MCCBs are most often seen on the load side, which is also known as the secondary distribution. Three magnetic contactors are utilized in a parallel loop because of the important role they play in motor control and their incorporation into the control panel. Both approaches make use of magnetic contactors. We begin by controlling the contactors automatically using a NodeMCU, which communicates with one another and the outside world using Wi-Fi signals. In response to a command sent by the mobile app, the NodeMCU powers on the relay, which in turn activates the contactors. A three-phase power source is linked to the load via contactors. Because we have installed the contactors separately and can operate them individually through NodeMCU, we can individually connect the loads according to our requirements if we provide the command from our mobile device.

Next, we manually adjust the switches to operate the magnetic contactors and connect the load to the three-phase supply. As a backup, we also employ the manual switching technique. If our auto system fails to function because of a technical failure, we can simply link the load and supply by operating the contactor by hand.Although a dc supply is required for controlling the motor, we have been using it with a three-phase supply. By utilizing a rectifier in conjunction with a single-phase step-down transformer, we were able to convert the AC voltage to DC voltage, which the rectifier could then easily handle. Under normal and abnormal conditions, the pilot devices are operated using the three indicators: red, yellow, and blue. Because of their importance to motor operation, the meters measure voltage, current, and frequency.

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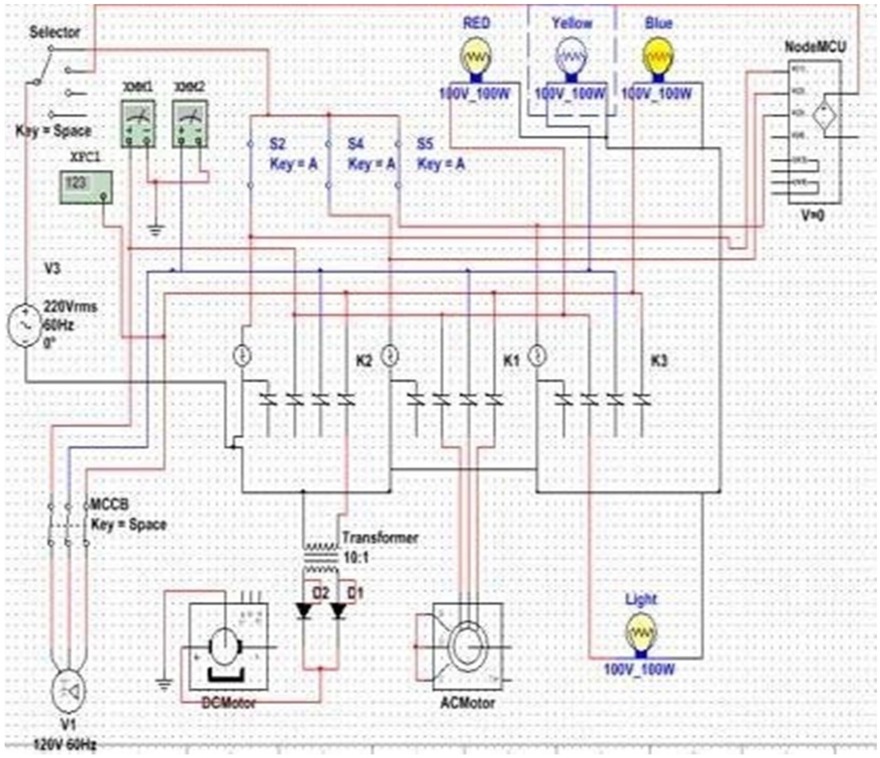

Figure 4. Circuit diagram

The ability to regulate the motor's speed in response to changes in operating temperature and vibration is the primary need for the entire panel.therefore, temperature and vibration sensors are also employed to monitor the motor's health. The following block diagram in Figure 5 clearly explains the entire process for the smart control panel.

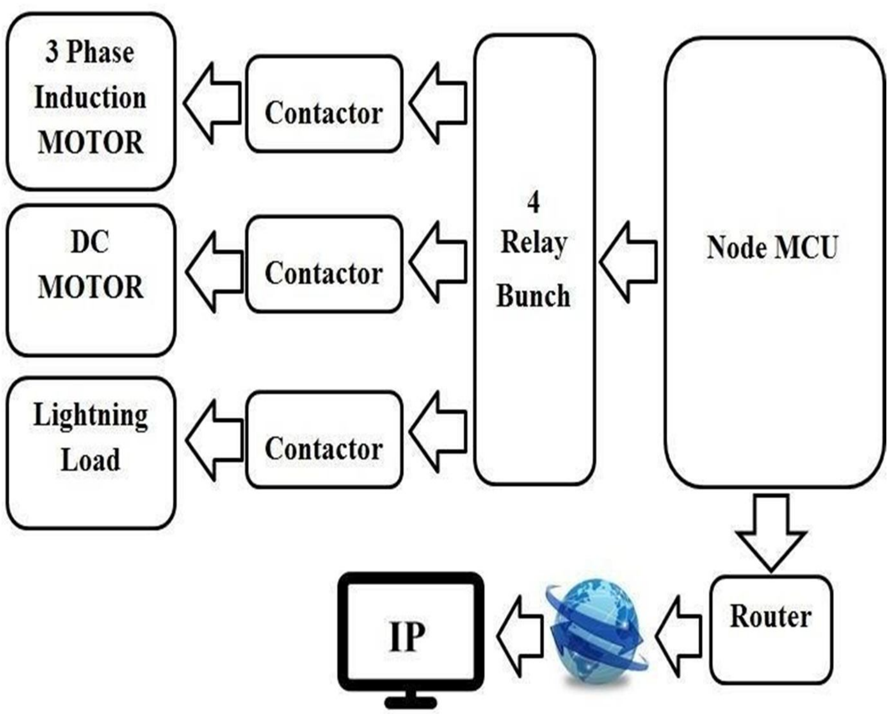

Figure 5. Block diagram

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IV. RESULTS

Given that we have labored on both hardware and software. Results from MATLAB software are detailed in the first section, while hardware is covered in the second.

A. *Software Results*

To begin, Figures 6(a)–(d) display the results of the simulations conducted on the under-voltage failure condition in three-phase induction motors.

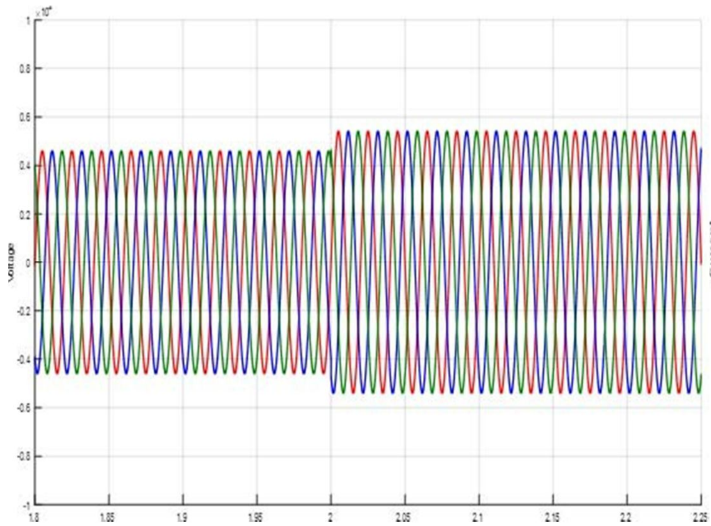

Figure 6(a). Voltage Measurement

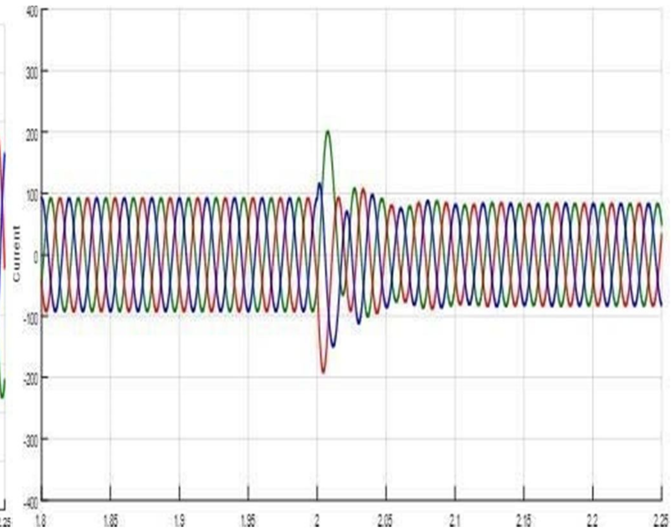

Figure 6(b). Current Measurement

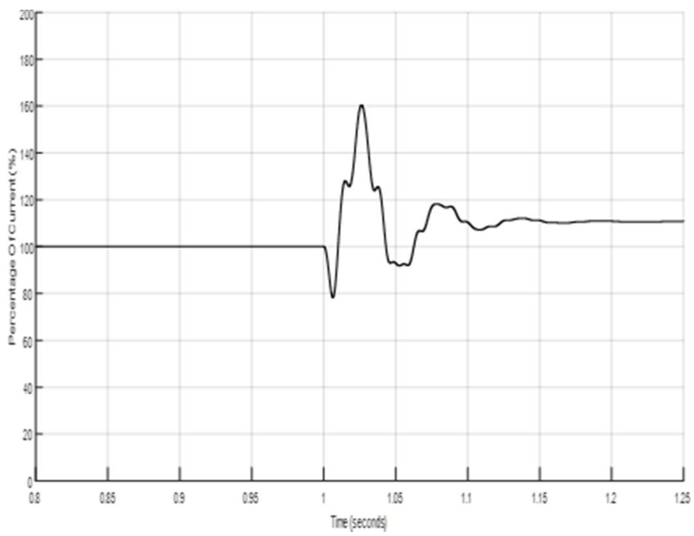

Figure 6(c). Current during under voltage (1sec/sag 15%)

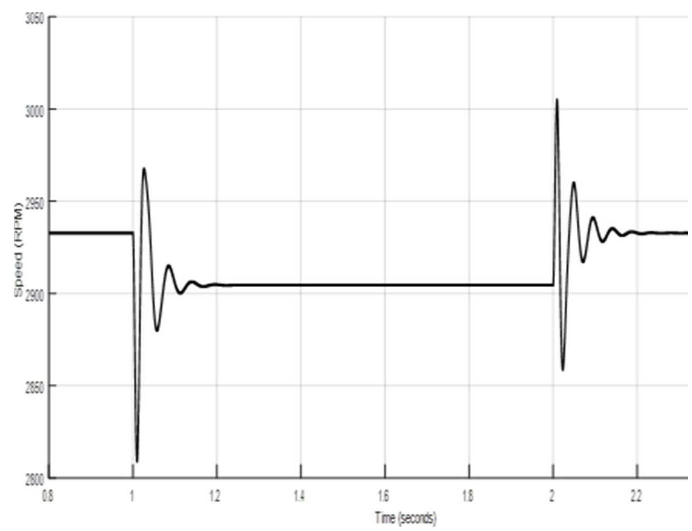

Figure 6(d). Speed variation graph

It is evident from the results that the major motor characteristics altered when the voltage unexpectedly dropped. Under voltage conditions, these values are the motor current and speed. Motor heating can be caused by adjusting these factors. The engine could catch fire if it experiences the dangerously abnormal situation of heating. The prevention of motor abnormalities is of the utmost importance.

Additionally, the results were derived from simulations conducted under the common overloading condition experienced by motors. The data that follow show how the motor parameters might vary. Motor speed (in RPM), voltage (in volts), and current (in amps) are some of these parameters. Figure 6(e) through Figure 6(g) display the results graphically.

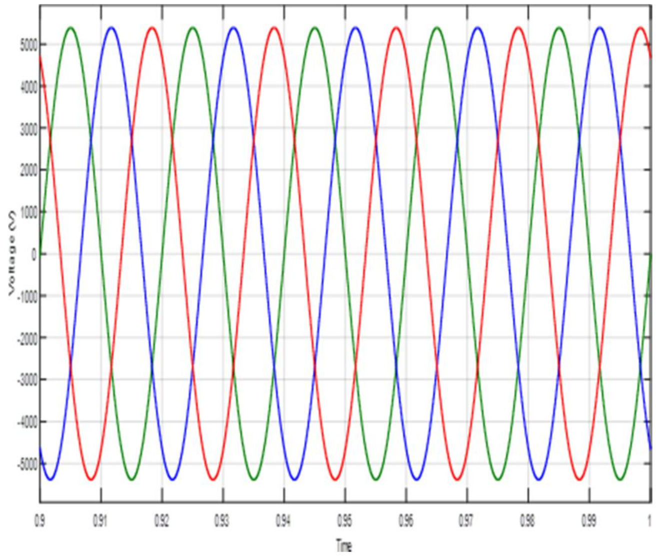

Figure 6 (e). Three phase voltage input to Induction motor

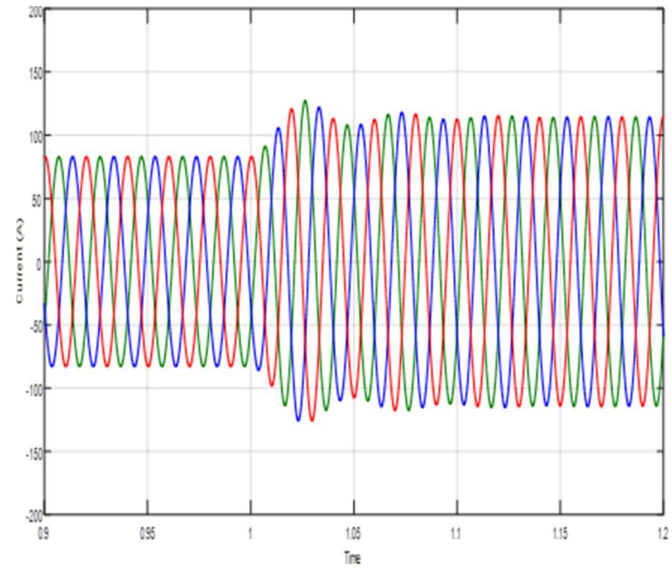

Figure 6 (f). Three phase current drawn by Induction motor in overloading condition

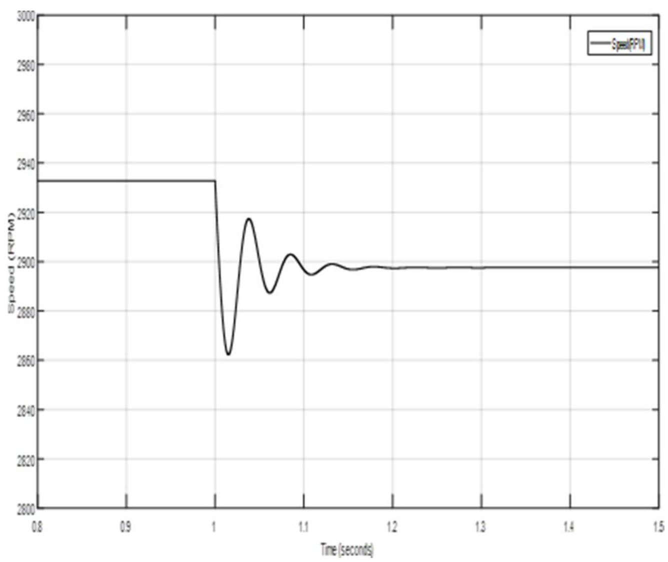

Figure 6(g). Motor speed subjected to overload (1sec)

The preceding data make it quite evident that the motor's speed changes in response to a sudden rise in load. The resulting mechanical load is more than the induction motor's rating. Insulation life is reduced, phase currents increase, machine overheating, high rotor and stator losses, and winding short circuiting are all consequences of overload on induction motors. When we look at the results from both scenarios, we can't help but see the mistakes.

B. Hardware Results

We have completed all of our work after installing all of the equipment. Figure 7(a) and (b) illustrate the wiring connections and equipment inside the panel. For safety reasons, we cannot install components outside of the panels, so most of them are located within.

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Figure 7(a). Inside the panel

Figure 7(b) - Inside the panel

Outside the control panel, you can find the pilot devices—three indicators in red, yellow, and blue—and the voltage, current, and frequency measurement equipment that keeps an eye on all the parameters. You can examine the voltage and current results from all three phases, which allows you to determine if the loads are balanced or not. You can use the selector outside the panel to manage the panel manually or through IoT, and you can use the toggle switches to run the different loads according to your needs. The control panel that operates all the loads is shown clearly in Figure 7(c).

Figure 7(c). Outside the panel with loads

Examining and analyzing motor operation constitutes the bulk of our work following the completion of the circuit and control panel. Internet of things technology is the reason behind the naming of the smart control panel, as stated in the title.

The electrical side and the mechanical side are the two most common types of motor failure. Overloading motors or short circuits are two examples of electrical faults; friction, bearing wear, vibration, and other mechanical issues are examples of mechanical faults. The heating effects in the motor are caused by electrical problems. When a motor fails on the electrical side, it will overheat; when it fails on the mechanical side, it will vibrate. The control panel has two alarm devices—a temperature sensor and a vibration sensor—that go off in the event of either abnormality. In the event that the motor experiences a problem, we can use the Internet of Things to monitor and manage it. Figure 8 displays the results obtained from both sensors.

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Figure 8. IOT results

V. CONCLUSION

The wide variety of uses for inductive loads has led to their widespread adoption in industrial settings. Building a smart system is crucial. With this setup, a smart panel is intended to control the loads by both manual and Internet of Things (IoT) means. Thanks to Wi-Fi, we can access the IoT control system from any location, making it both more efficient and more pleasant. Since no one needs to be physically present, it is a faster and easier operating system than a manual one. Not only will this make the system smarter, but it will also save labor costs. Nevertheless, the manual operating system is also utilized for backup assistance. It is easy to operate the system manually in the event that the automatic system fails to function owing to a technical issue. This smart panel is useful not only for these functions, but also for regulating and protection. If there is an issue with the electrical or mechanical side, we can remotely control it through the IoT. Additionally, MATLAB/SIMULINK takes into account electrical defects such as undervoltage and overloading in three-phase induction motors. When servicing or protecting the control panel, the molded-case circuit breaker is the tool of choice. Industries find this system useful for controlling purposes, and it has the potential to be expanded in the future to handle all kinds of motor defects and their forward and backward operations through the Internet of Things.

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