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Real-time protection and monitoring of three phase induction motor using arduino

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ABSTRACT

Electric motor protection in modern industry is increasingly important along with technological developments and the need to maintain operational reliability and prevent unwanted disturbances. This research develops an Arduino Mega-based three-phase induction motor protection system that uses PZEM-004T sensors to monitor current and voltage, and MAX6675 sensors to accurately measure motor temperature. The monitoring data is displayed in real-time on the ILI9341 TFT LCD screen, enabling early detection of abnormal conditions such as overheat, over current, and voltage imbalance. The system provides a quick response to protect motors from potential damage, ultimately preventing significant losses and ensuring operational continuity and energy efficiency in increasingly complex industrial environments.

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1. INTRODUCTION

Today's business relies heavily on induction motors, particularly in the production sector [1]-[2]. The popularity of induction motors can be attributed to their strength, durability, ease of use, and affordability. A variety of production equipment, including cooling towers in steam power plants and conveyors in the food sector, are powered by induction motors. Humans can more easily regulate the motion of machines in accordance with industrial requirements when induction motors are used [3]-[5].

It is necessary to have a technology to identify motor damage before it becomes more serious since long-term use of electric motors can harm the industry and result in losses. Electric motors frequently experience abnormal temperature, vibration, and current variations due to a variety of issues, including misalignment, load imbalance, bearing corrosion, motor winding insulation failure, and other issues. Industry is currently focusing on monitoring the motor's temperature, current, and voltage characteristics in order to discover motor issues early [6]-[9]. Overload current and imbalanced voltage are two signs of electric motor problems that can lead to overheating. So, the best option for the electric motor protection system is to use voltage and temperature sensors [10].

This research aims to design and build a more efficient three-phase induction motor disturbance monitoring and protection tool. This system uses simple features but is able to provide real-time information about motor conditions through complex sensor readings, including temperature, voltage, and current. Data obtained from the sensors will be processed using Arduino Mega and displayed on the Thin Film Transistor Liquid Crystal Display (TFT). If there is an increase in temperature, current, or voltage that exceeds the safe limit, the system will issue a warning via an alarm on the buzzer. If the abnormal condition continues and reaches a dangerous level, the relay will be activated to stop the motor so that the potential for greater damage can be avoided.

2. METHOD

Designing a tool is a very important thing to do in determining what components are used when making a final assignment. This design process aims to ensure that the tool created can work as desired so that the results obtained can be optimal and appropriate. In this context, the design and creation of the final assignment is carried out using a comprehensive research method, including the design and creation of hardware and software. Hardware design is carried out using the inventor application, which is an application specifically designed to create 3D designs of component placement construction. This application allows us to design and visualize how the components will be arranged in the tool realistically before making it physically. On the other hand, software design uses the Fritzing application to create electronic circuit diagrams and the Arduino IDE to create tool programming sketches. Fritzing helps in describing the relationship between various electronic components, while the Arduino IDE is used to write, test, and upload code to the microcontroller that will control the tool.

In this final project, the process of creating the tool starts with the hardware, which entails arranging the parts in a secure location and in compliance with the created design. This step is crucial to ensuring that every component is correctly placed and resistant to harm. Using the Arduino IDE to program the sensors and other parts comes next when the hardware is finished. This allows the tool to work as intended. The accompanying block diagram shows every component utilized in this final project and gives a thorough description of how each component relates to the others and how it functions in the system that was created. Figure 1 shows the block diagram of the proposed system.

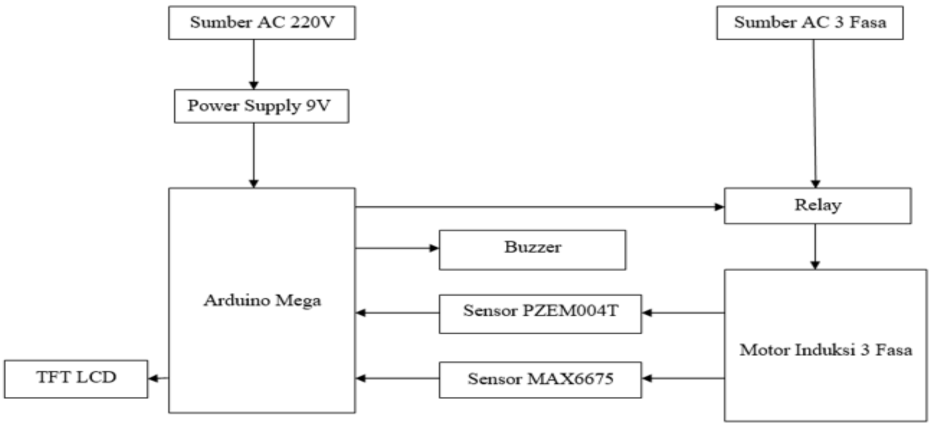


Figure 1. Diagram block of the proposed system

Based on the block diagram in Figure 1, the design of each block diagram has the following functions: Three-phase Induction Motor as a tool or object of application of this tool, PZEM Sensor as input to the microcontroller that will detect current and voltage where the detected current and voltage will be an indicator of the buzzer and relay on or off, MAX6675 Sensor as input to the microcontroller that will detect temperature where the detected temperature will be an indicator of the relay and buzzer on or off [11]-[13], Arduino mega functions as a microcontroller that is used to program and process input data from several sensors and also to control turning on the relay and buzzer connected to the motor [14], TFT LCD as output from the microcontroller that is used as a monitoring tool and display of temperature, current and voltage values that have been detected by the installed sensors, Relay as output from the microcontroller that is used as an on/off switch or protection on the three-phase induction motor [15]-[16], Buzzer is used as an alarm or early warning if the temperature, current, and voltage indicators reach the set limit [17]-[18], Power supply is used to supply Arduino and the sensors to be installed.

The working principle of the designed tool is by processing data from AC voltage sensors, AC current, and temperature on the motor through reading the PZEM voltage and current sensors and the MAX6675 temperature sensor. The data received from the sensor will be processed through a microcontroller, which will then initiate a buzzer as an alarm and a relay as protection. This data will also be displayed on the TFT LCD screen. The PZEM-004T sensor is used to monitor unbalanced voltage with a setting limit according to the ANSI C84 standard, which is no more than 3%. If there is a voltage deviation of more than 3% in one phase, the relay will turn off the motor to prevent damage. The same sensor is also used to detect overcurrent, with settings based on the nominal value of the motor. If the current exceeds the set limit, the buzzer will sound as an early warning, and if the current reaches a certain higher value, the relay will be triggered to turn off the motor automatically.

The MAX6675 sensor is used to monitor the motor temperature with a temperature setting limit determined based on the motor class. For standard settings, a temperature above 38°C will activate the buzzer as an initial alarm, and a temperature above 40°C will trigger the relay to turn off the motor to prevent damage due to overheating. For testing purposes, the temperature limit is reduced to 33°C for alarm and 35°C for relay protection. Data from these three parameters are displayed in real time on the TFT LCD screen, providing clear and up-to-date information about the motor condition. If a disturbance occurs, information about the disturbance value will be displayed on the screen, facilitating the monitoring and analysis process by the operator. Thus, this tool not only provides reliable protection for three-phase induction motors, but also ensures that all critical parameters are always within safe limits through continuous and integrated monitoring.

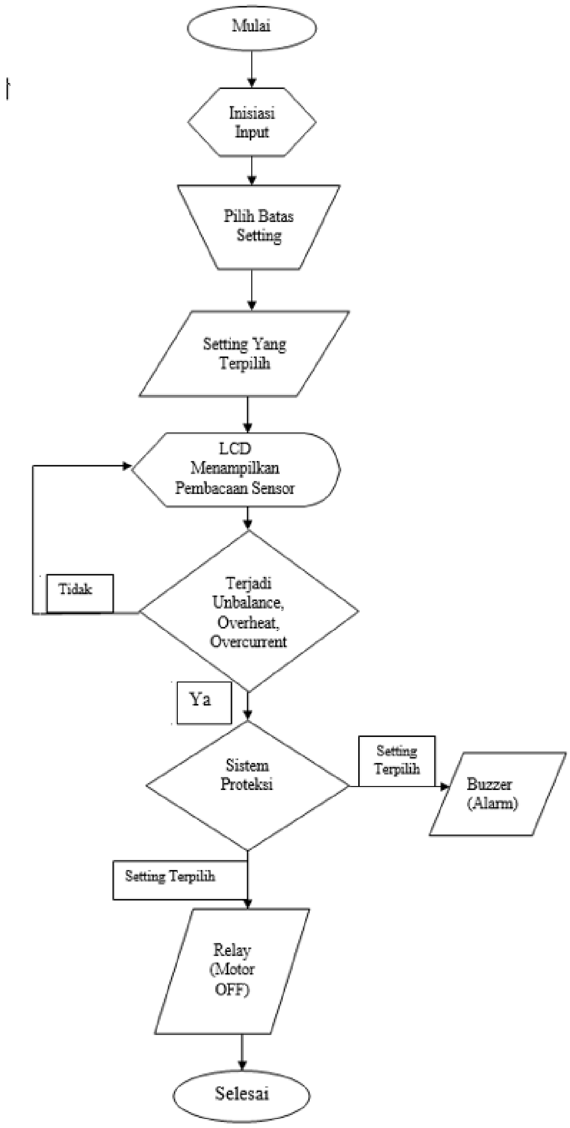


Figure 2. Flowchart of three-phase induction motor monitoring and protection system

Figure 2 is a flowchart of a three-phase induction motor monitoring and protection device that explains how the device works. The process begins with reading data from temperature, voltage, and current sensors. After that, the user can select the desired settings before the data is displayed on the TFT LCD screen. If the system detects an abnormal condition such as an increase in temperature or excessive current, an alarm will sound as a warning, and if the condition continues to worsen, a relay will activate protection to turn off the motor to prevent further damage. The process ends after all steps are completed and the motor is in a safe condition.

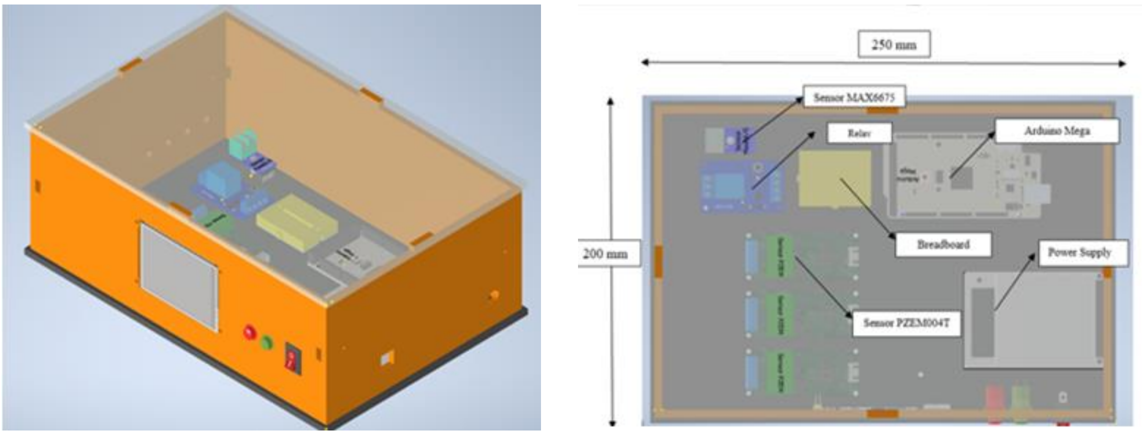


Figure 3. Design of three-phase induction motor monitoring and protection equipment

Figure 3 shows the design of a three-phase induction motor monitoring and protection device that uses acrylic as the main platform. Acrylic was chosen because it is lightweight, durable, and able to provide protection from external physical disturbances. In this design, acrylic is used as a base to place various main components such as sensors, power supplies, Arduino Mega as a data processing center, relays for protection settings, and a Thin Film Transistor (TFT) screen that functions as a data display media. This device is designed with dimensions of 250 mm in length, 200 mm in width, and 80 mm in height, thus providing sufficient space for neat and organized component placement. The position of the TFT placed on the side of the device allows users to monitor the condition of the motor directly and in real-time. This design not only ensures that the operational function of the device runs well, but also considers safety and aesthetic aspects. Acrylic material provides stability and resistance to impacts or other physical disturbances, ensuring that the device continues to function optimally in various industrial environmental conditions. Overall, this design aims to create a device that is not only effective in monitoring and protecting induction motors, but also easy to use and durable.

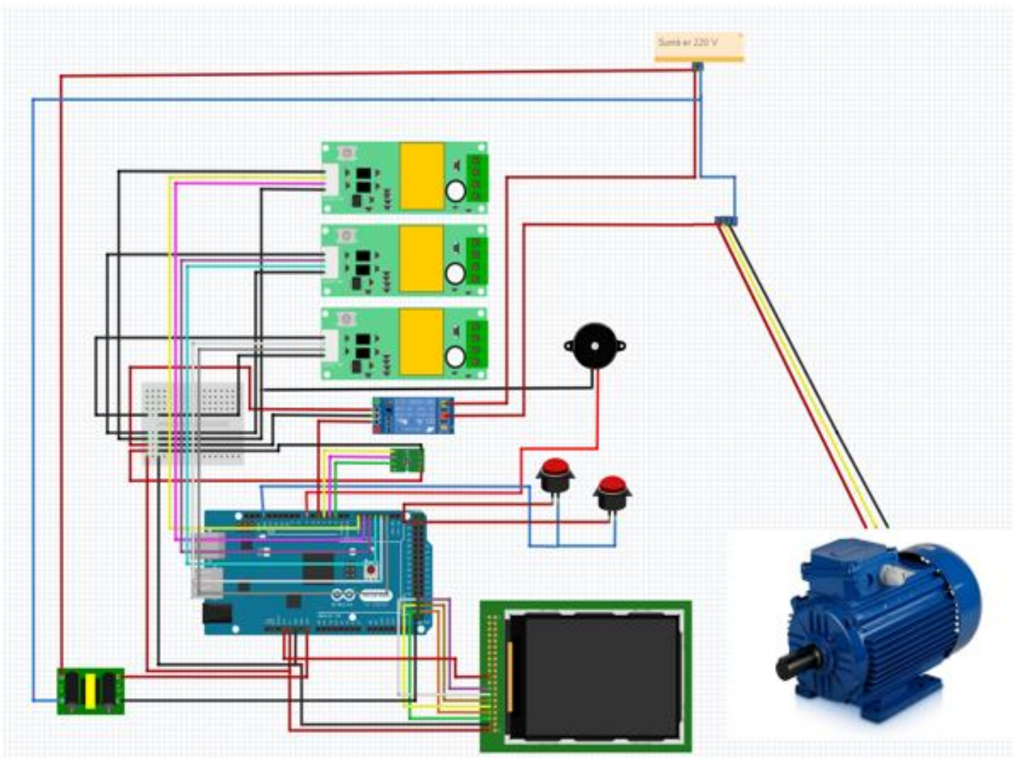
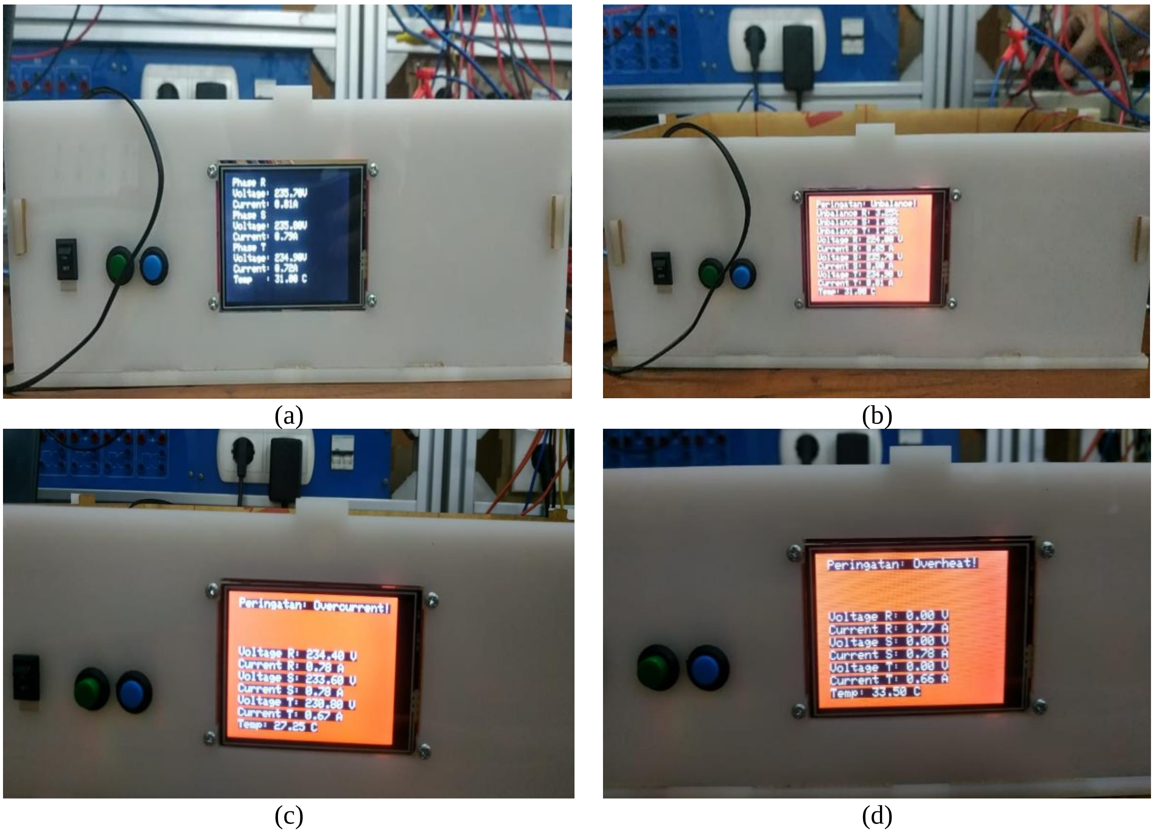


Figure 4. Three-phase induction motor monitoring and protection control circuit

Figure 4 shows the complete design of the components that will be used in the Three-Phase Induction Motor Monitoring and Protection Device. In this circuit diagram, it is clearly visible how each component is connected and interacts with each other. The circuit includes the relationship between sensors, relays, buzzers, and other components, which work together to ensure the three-phase induction motor operates safely and efficiently. This design also illustrates how the monitoring and protection system is integrated as a whole, making it easier to understand the function and working mechanism of the device. 4 is the design of the components that will be used in the three-phase induction motor monitoring and protection device.

3. RESULTS AND DISCUSSION

Testing of this tool is done after the design of the tool where the sensors are connected to other components, the components used are Arduino Mega microcontroller, PZEM sensor, MAX6675 sensor, relay, buzzer, LCD and several other supporting components. Before testing the tool as a whole, each component is tested one by one using a measuring instrument to test the accuracy of the sensor reading. Overall testing is done on 2 3-phase induction motors with different ratings and rpm. For the first motor with 2820 RPM, it is done without any interference and settings according to the motor standards, and the second motor with 1350 RPM is done with interference and a decrease in the setting limit. Figure 5 shows the experimental process carried out under various conditions.



(a) (b) (c) (d)

Figure 5. Experimental results, (a) Motor condition monitoring test without interference, (b) protection test against unbalance disturbance, (c) alarm and protection test against overcurrent disturbance, (d) alarm and protection test against overheating disturbance

Table 1 shows the results of observations of the condition of the three-phase induction motor in the time interval of 2 to 20 seconds. The voltage on each phase (R, S, and T) was recorded as stable, ranging from 225 to 233 volts, while the current on the three phases also showed consistency with a value of around 0.63 to 0.76 amperes. The motor temperature fluctuated slightly, but remained around 29.75 to 30.75 °C, which is still within the safe range. During the observation period, the condition of the motor was declared safe, indicating that the monitoring and protection system functioned well in protecting the motor from potential damage.

Table. 1 Three phase induction motor testing without disturbance

Time (sec)	Voltage (Volt) R	S	T	Current (A) R	S	T	Temperature °C	Condition
2	233	229	225	0.75	0,76	0,63	30.00	Safe
4	232	228	225	0,75	0,76	0,63	30.25	Safe
6	232	229	225	0,75	0,76	0,63	29.75	Safe
8	233	229	225	0,75	0,76	0,63	30.00	Safe
10	233	228	225	0,75	0,76	0,63	30.00	Safe
12	233	228	225	0,75	0,76	0,63	30.75	Safe
14	233	228	225	0,74	0,76	0,63	29.75	Safe
16	232	228	225	0,75	0,76	0,63	30.25	Safe
18	233	228	225	0,75	0,76	0,63	30.75	Safe
20	232	228	225	0,74	0,76	0,63	30.25	Safe

Table 2 shows the voltage observation data on a three-phase induction motor along with the percentage deviation from the normal value, as well as the condition of the motor during the time interval of 2 to 20 seconds. At the beginning of the observation, the voltage on all three phases (R, S, T) showed stability with a very small deviation, around 0.33%, and the motor condition was declared safe. However, starting from 14 seconds, there was a significant voltage drop on the R phase with a deviation of up to 6.84% at 20 seconds. This condition caused the protection system to activate the "trip" feature to turn off the motor, preventing potential greater damage due to the voltage imbalance that occurred. These data show the importance of continuous voltage monitoring to maintain the operational reliability of the induction motor.

Table 2. Testing results for Unbalance Disturbances

Time (sec)	Voltage (Volt) R	%	S	%	T	%	Condition
2	235	0,33	235	0,33	234	0,33	Safe
4	235	0,33	235	0,33	234	0,33	Safe
6	235	0,33	235	0,33	234	0,33	Safe
8	235	0,33	234	0,33	235	0,33	Safe
10	235	0,33	235	0,33	234	0,33	Safe
12	235	0,33	235	0,33	234	0,33	Safe
14	224	3,25	235	1,80	234	1,45	Trip
16	217	5,15	235	2,78	234	2,44	Trip
18	212	6,54	235	3,38	235	3,16	Trip
20	211	6,84	235	3,53	235	3,31	Trip

Table 3 illustrates the current data flowing in each phase of a three-phase induction motor (R, S, T) and the condition of the motor in a time interval of 2 to 14 seconds. At the beginning of the observation, the measured current was slightly higher than the normal value, especially in the R and S phases which reached 0.78 amperes, while the T phase was at 0.67 amperes. This condition triggered an alarm as an early warning sign. However, in the 4th second and beyond, the current continued to experience a small but significant increase, which resulted in the protection system activating the "trip" feature to cut off the electric current to the motor, in order to prevent further damage. This condition indicates that the protection system successfully detected anomalies in the motor current and acted to protect the motor from potential risks of damage.

Table 3. Testing for over current disturbances

Time (sec)	Current (A) R	S	T	Condition
2	0,78	0,78	0,67	Alarm
4	0,78	0,78	0,67	Trip
6	0,79	0,79	0,68	Trip
8	0,79	0,79	0,67	Trip
10	0,78	0,79	0,68	Trip
12	0,78	0,79	0,68	Trip
14	0,78	0,79	0,69	Trip

Table 4 shows the temperature data read on the three-phase induction motor along with the motor condition in the time interval of 10 to 180 seconds. During the observation up to 160 seconds, the motor temperature remained stable in the range of 28°C to 32°C, which is considered safe. However, at 170 seconds, the temperature began to increase to 34°C, triggering an alarm as a warning that the temperature was approaching a dangerous limit. At 180 seconds, the temperature increased further to 36°C, which caused the protection system to activate the "trip" feature to turn off the motor to prevent damage due to overheating. This data emphasizes the importance of real-time temperature monitoring to keep the motor in safe operational conditions.

Table 4. Testing for overheat

Time (Sec)	Temperature (°C)	Conditon
10	29	Safe
20	29	Safe
30	29	Safe
40	29	Safe
50	28	Safe
60	29	Safe
70	29	Safe
80	29	Safe
90	29	Safe
100	28	Safe
110	29	Safe
120	29	Safe
130	29	Safe
140	29	Safe
150	30	Safe
160	32	Safe
170	34	Alarm
180	36	Trip

After testing the tool with motors one and two operating without and with interference, it is evident that when testing the motor without interference, the measuring device's LCD provides precise sensor values that allow the state of the motor to be tracked. In order to test the tool's alarm system and protection, artificial interference was added to motor two. As shown in the table, the tool can provide notification in the form of an alarm and protection in the form of a relay that can cut off the motor's voltage.

4. CONCLUSION

Based on the test and analysis results, the induction motor protection device designed with Arduino Mega, TFT LCD ILI9341, buzzer, relay, and MAX6675 sensor has proven effective in detecting and responding to various disturbances. This system consistently monitors the condition of the motor, is able to detect voltage imbalance, excessive current, and excessive temperature accurately. Fault notifications are given via the TFT LCD screen and buzzer, while the relay automatically turns off the motor when the parameters exceed the set limits. Thus, this system successfully protects the motor from damage and ensures optimal protection in industrial operations..

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