International Journal of Current Science Research and Review

ISSN: 2581-8341

Volume 07 Issue 09 September 2024

DOI: 10.47191/ijcsrr/V7-i9-44, Impact Factor: 7.943

IJCSRR @ 2024

www.ijcsrr.org

Design and Construction of Thermal Overload Relay (Siemens 3ua50) Based on Arduino Uno

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ABSTRACT: A Thermal Overload Relay (TOR) is a device in an electric motor protection system designed to safeguard the motor from damage due to overheating or overcurrent. This research discusses the design and implementation of a Thermal Overload Relay (TOR) based on Arduino Uno, which is a popular and flexible microcontroller platform. This design includes the PZEM-004T sensor to detect the electrical current and temperature of the electric motor. The design integrates the advantages of the PZEM-004T sensor in accurately measuring current and voltage with the flexibility and programming capabilities of Arduino in control and data processing. This system utilizes Arduino's communication capabilities to transmit current and temperature data in real-time, enabling remote monitoring and quick response to potentially hazardous conditions. The result of this project is a tool that can replace the function of the TOR itself, where the characteristics produced are close to those of conventional TORs, and the thermal principle in the TOR is regulated with a time delay disconnection in the Arduino program.

KEYWORDS: Arduino, Microcontroller, Pzem-004t, Thermal Overload Relay.

1. INTRODUCTION

The Thermal Overload Relay (TOR) is a crucial component in electrical systems that serves as a safeguard against overcurrent, which can cause damage to electronic equipment[1]. TOR operates based on the principle of heat, where the current passing through the relay generates heat that is then used to disconnect the electrical flow if the current exceeds a predetermined limit. The maximum current that TOR can handle can be adjusted by turning the current setting screw with a screwdriver until the desired value is reached[2].

This system uses Arduino as the main controller and a temperature sensor to detect conditions where the temperature exceeds the allowable limit. When the temperature exceeds this limit, TOR will cut off the load current to prevent potential damage. The design and construction of TOR can help improve the safety and reliability of electrical systems and prevent damage that may arise from excessive current or overload.

2. THEORETICAL BASIS

2.1. Previous research

There are several references used in the design and development of the Arduino Uno-based Thermal Overload Relay.

From the research conducted by Tiya Puspita and Ilham Akbar Darmawan titled “Thermal Overload Relay (TOR) as a Protection System for 3-Phase Induction Motors on the Biofuel Pelletizer Molding Machine at PT. Sejin Lestari Furniture.” This research involves data analysis related to TOR, its physical form, contact numbering, and the importance of setting the trip current value higher than the motor's nominal current to prevent current surges and involves Research and Development (R&D) to develop and test the effectiveness of the TOR protection system[3].

Previous research conducted by Hari Hardiana, regarding the “Design and Development of a Variable Current Injector with a Maximum Current Capacity of 40A.” This research resulted in a current injection that can be varied up to 40A using an autotransformer as the power regulator on the primary side of the transformer[4].

From the research conducted by Mispan, Ahmad Antares Adam, Baso Mukhlis, Nurhani Amin, Muh. Aristo Indrajaya, Yulius S. Pirade, regarding the “Design and Development of a Thermal Overload Relay Monitoring System on 3-Phase Induction Motors.” The research was conducted to analyze the Thermal Overload Relay (TOR) and understand the effect of heat on the bimetal as well as the trip time of the TOR, which depends on the setting value and the load current flowing. The voltage supplied to the contactor coil must be within the range of 85% - 110% of the contactor's working voltage to prevent damage. The design and research results show that the Thermal Overload Relay monitoring system on 3-phase induction motors can accurately measure voltage and current[5].

2.2. Thermal Overload Relay Protection System Rules

Here are some rules for using Thermal Overload Relay (TOR) in protection systems:

1. TOR can be used in a star-delta system, functioning as protection if the network experiences electrical overloads[6].
2. Setting TOR is used in the protection system of a three-phase induction motor, which works based on the principle of a bimetal object[7].
3. When the temperature reaches or exceeds the set threshold, the internal relay mechanism works to disconnect the power circuit to the motor. This can be in the form of electromechanical contacts or semiconductor devices such as transistors or triacs.
4. Thermal overload relay is activated by excessive temperature or higher current passing through the motor. Circuit breakers are activated by current surges or short circuits that occur in the electrical circuit[8].
5. Some thermal overload relay protection systems are equipped with monitoring and reporting features that allow operators or management systems to track overheating incidents and identify potentially problematic patterns.
6. After the motor is protected by the thermal overload relay, the system must have an option to reset the relay so the motor can be restarted once the cause of overheating is addressed. The reset can be performed automatically after the temperature drops to a safe level or manually by an operator.
7. Thermal overload relay protection systems are usually integrated with other protection systems, such as overcurrent protection, undervoltage protection, or more advanced motor management systems, to provide more comprehensive protection for motors and other electrical equipment.

2.3. Relay

Relay is an electrically powered switch consisting of a mechanical switch and an electromagnet (coil) as its main components. [9] The relay operates the switch with low voltage to conduct high voltage electric current using electromagnetic principles. For instance, a relay that operates at 5V and 50mA can be switched to conduct electricity at 220V and 2A. The shape and symbol of the relay can be seen in Figure I below[10].

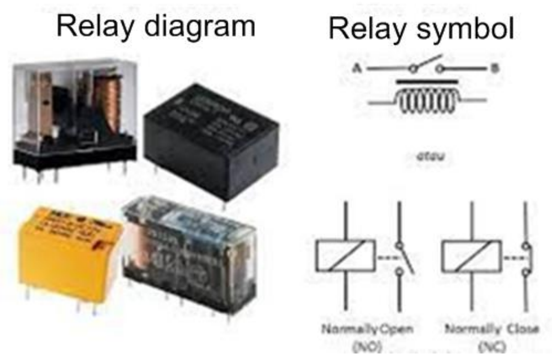

Figure I. Relay shapes and symbols [9].

2.4. Arduino Uno

The microcontroller board called Arduino is based on the ATmega328. The Arduino UNO comes with everything needed to support the microcontroller, and you can quickly connect it to a computer using a USB cable, power it with an AC to DC adapter, or supply it with a battery[11].

New code can be uploaded to the ATmega328 on the Arduino Uno without using an additional hardware programmer thanks to the bootloader included with the ATmega328. In other words, all input and output components are controlled by the Arduino UNO microcontroller[12].

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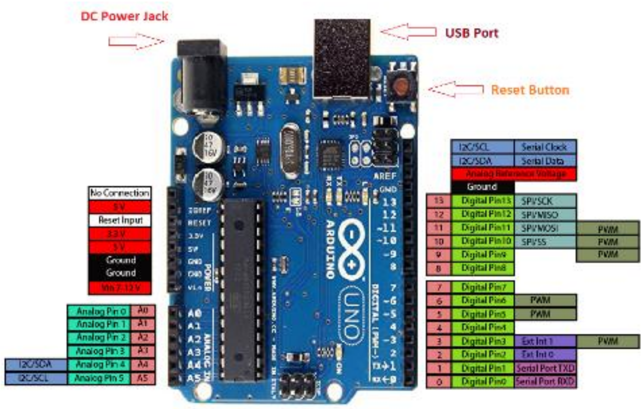

Figure II. Pins on Arduino UNO[11].

In Table I. You can see the pins on the Arduino UNO.

Table I. Used Input and Output

No. Pins	Type	Description
0-13	Digital I/O	Digital input/output port 0 to 13
A0-A5	Analog I/O	Analog input channel 0 to 5
Vin	PWR	Supply Voltage
GND	PWR	Supply Ground
+5 V	Output	+5V output (from on-board regulator)
SCL & SDA	Output	Output to I2C
Reset	Input	Reset (active low)
AREF	Input	ADC Refrence
+3.5 V	Output	+3.5V output

2.5. PZEM-004T

The PZEM-004T sensor is used to measure voltage, current, power, and energy from AC electricity. This sensor has the ability to output data via serial communication, allowing it to be connected to devices such as Arduino[13]. The PZEM-004T module is combined with a current transformer coil with a diameter of 3mm that can be used to measure a maximum current of 100A. The PZEM-004T can be seen in Figure III below[14].

Figure III. PZEM-004T[14].

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2.6. Display LCD 16x2

LCD is one of the electronic components that functions as a display for data, including characters, letters, or graphics. LCDs require low voltage and power, making them commonly used in applications such as calculators, digital watches, and electronic instruments like digital multimeters. LCDs utilize silicon and gallium in the form of liquid crystals for light emission. On an LCD screen, each matrix is a two-dimensional array of pixels divided into rows and columns[15].

To access a 16x2 LCD using Arduino, you can use the LiquidCrystal_I2C library to control the LCD via the I2C bus. You can write code to set the cursor position, write text, and control the backlight on a 16x2 LCD[16].

Specifications of the 16×2 LCD. The available features include:

1. Consists of 16 columns and 2 rows.
2. Equipped with backlight.
3. Contains 192 stored characters.
4. Can be addressed in 4-bit and 8-bit modes.
5. Has a programmable character generator.

Figure IV. LCD 16X2[15].

2.7. I2C (Inter-Integrated Circuit)

The I2C (Inter-Integrated Circuit) module is a communication module used for sending and receiving data between electronic devices. I2C is a serial communication protocol developed by Philips (now NXP Semiconductors) in 1982. The I2C module uses two wires, SDA (Serial Data) and SCL (Serial Clock), which allow for synchronous data transfer between devices[17]. The I2C module defines two types of devices in the communication path: master and slave. The master is the device that initiates and controls the communication path, while the slave is the device that responds[17]. In practice, the master device is usually a microcontroller, such as an Arduino, and the slave devices are sensors or other electronic devices[17].

The I2C module is used to control electronic devices, such as LCDs, in an efficient manner and simplifies the connection between devices. For example, in programming an LCD with Arduino, the I2C module is used to control a 16x2 or 20x4 LCD through the SDA and SCL connections[18].

Figure V. I2C Module [18].

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2.8. Push Button

A push button is a simple device/switch that functions to connect or disconnect the flow of electrical current with an unlock push mechanism (non-locking). The unlock mechanism here means that the switch will function as a device to connect or disconnect the electrical current when the button is pressed, and when the button is not pressed (released), the switch will return to its normal condition[19]. Due to its operation, the push button is one of the important components in control systems, especially used as a trigger input in systems[20].

3. RESEARCH METHODOLOGY

3.1. Time and Location

The time allocated for the design of this PBL (Project-Based Learning) will take place from February 2024 to May 2024 in the microcontroller laboratory and protection laboratory.

3.2. Research Design

Research design refers to the process of measurement and data collection. Initially, the research design involves scheduling, after which equipment borrowing from the Electrical Engineering laboratory and purchasing components not available in the Electrical Engineering laboratory will follow. Then, work on the equipment will begin, starting with calibrating components and programming them. This will be followed by cutting acrylic boards to serve as the enclosure for the equipment and installing spacers as stands for the components to be assembled. The final stage involves collecting data to obtain a curve that fits the performance of the Thermal Overload Relay and adjusting all components to be integrated into the Arduino IDE program.

3.3. System Overview

An overview of the system to be designed in the PBL Thermal Overload Relay based on the Arduino microcontroller can be seen in Figure VI.

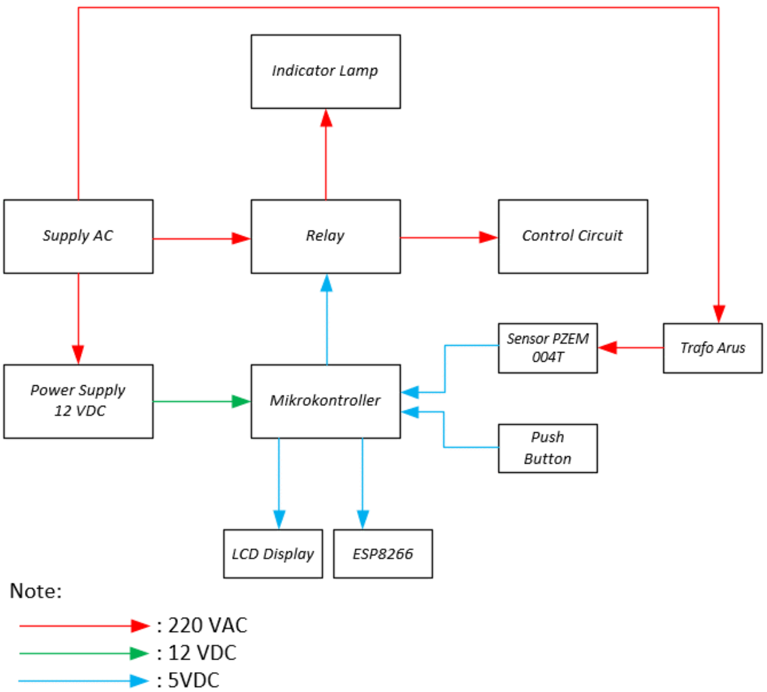

Figure VI. System Block Diagram.

From the block diagram in Figure 6, an explanation of the system operation of the device can be obtained as follows:

1. The power supply used to activate the Arduino Uno R3 system is a 7-12 VDC power supply, and the load supply is 380 VAC 3 phase.

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2. The output voltage from the Arduino Uno R3 is connected to a breadboard, which will be used as a 5 VDC power source for the relay, LCD display, and PZEM 004T current sensor.
3. When the current sensor reads that the current flowing through the current transformer exceeds the set current limit, the current sensor will send a signal to the Arduino Uno R3.
4. When the Arduino Uno R3 receives the signal from the current sensor, it will process the signal and then send it to the relay, which will interrupt the electrical current.
5. When the electrical current is interrupted, the Arduino Uno R3 sends a signal to the LCD Display, and the indicator light will also turn on.

The push button here functions as a reset button to restart the program.

3.4. Equipment and Materials

The equipment and materials used can be seen in Table 2 below:

Table II. Equipment and Materials

Equipment	Material
Power Supply AC 220	Arduino Uno R3
Ampere Meter	5V Relay Module
Adaptor 7-12 V	PZEM-004T
Laptop	Push Button Active High
Grinding	PCB Board
Drill	Acrylic
Solder	bolt
Power Supply DC 7-25	Spacer
	Cable (Female-Female), (Male-Male), (Female-Male) and cable 1,5 mm Banana Plug
	Skun Ring
	LCD I2C 16 x 2

4. RESEARCH METHODOLOGY

4.1. Design Results

The development of a thermal overload relay based on the Arduino microcontroller is still in the prototype stage, with the hope that it can eventually be implemented for public and industrial use. Figure 7 below shows the results of the creation of the Arduino-based thermal overload relay.

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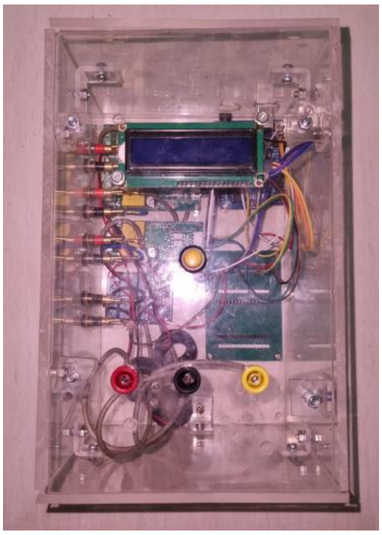

Figure VII. Arduino Microcontroller Based Thermal Overload Relay tool model.

4.2. Testing

In testing the Arduino-based thermal overload relay, the load on the motor is adjusted so that the current can be regulated, resulting in the desired characteristics. Here, current measurement is performed using three PZEM-004T sensors, with one sensor dedicated to measuring each phase. The comparison of current and trip time is shown in Table III below.

Table III. Thermal Overload Relay Testing Results

Current	Trip Time (seconds)
2.1	9000
2.2	8100
2.3	7200
2.4	6000
2.5	4800
2.6	3900
2.7	3300
2.8	3000
2.9	2700
3	2400
3.1	2310
3.2	2240
3.3	2160
3.4	2100
3.5	1950
3.6	1860
3.7	1700
3.8	1600

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3.9	1500
4	1300
4.1	1200
4.2	1100
4.3	900
4.4	720
4.5	600
4.6	480
4.7	360
4.8	240
4.9	200
5	180
5.1	60
5.2	45
5.3	35
5.4	25
5.5	22
5.6	18
5.7	15
5.8	12
5.9	10
6	5

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusions

From the Project-Based Learning about the design of a Thermal Overload Relay Based on Arduino Uno in the Protection Systems Laboratory, the following conclusions can be drawn:

1. The Arduino-based TOR system can enhance the safety and performance of electric motor protection by utilizing the latest sensor technology and a flexible microcontroller platform.
2. This report describes the design process, the components used, the research methodology, the test results, and the conclusions of the Arduino Uno-based Thermal Overload Relay design project.

5.2. Suggestion

Based on the provided PBL report, I can offer the following recommendations:

1. Conduct further testing with varying loads and operational conditions to evaluate the system's performance and reliability more comprehensively.
2. Consider integrating additional features such as wireless communication (WiFi or Bluetooth) to enable remote monitoring and control.
3. Optimize the code and circuit design to improve efficiency and reduce power consumption.
4. Explore the possibility of using additional temperature sensors or other heat detection methods to enhance the accuracy and reliability of the system.

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