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Design and Development of Overcurrent Protection Relay Inverse Definite Minimum Time Type Based on Arduino Uno

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ABSTRACT: An overcurrent protection relay is an essential component in electrical system to protect devices from damage due to excessive current. The Inverse Definite Minimum Time (IDMT) type has a trip time that depends on the magnitude of the overcurrent, with faster trip times for higher overcurrent levels. Arduino Uno can be used as a microcontroller platform to build an IDMT with relatively low cost and ease of implementation. This research aims to design and construct an Arduino Uno-based IDMT. The system consists of a current sensor, Arduino Uno, and a relay. The current sensor is used to detect the current flowing through the load. The Arduino Uno processes the data from the current sensor and determines if the current exceeds a predefined limit. If the current exceeds the limit, the Arduino Uno will activate the relay to cut off the current flow to the load. The IDMT trip time is implemented using an algorithm that considers the magnitude of the overcurrent and the minimum trip time. The system is tested using a simulator and actual load. Test results show that the Arduino Uno-based IDMT system works well and can protect the load from damage due to overcurrent.

KEYWORDS: Algorithm, Arduino Uno, Current Sensor, Inverse Definite Minimum Time, Relay, Overcurrent protection relay, Testing.

1. INTRODUCTION

One of the most important parts of an electrical power system is the protection system. As a result, the utilized electrical power system is guaranteed to be safe. Electrical availability cannot be efficiently distributed to loads without using electrical current protection, making an appropriate safety system essential. A common disturbance is a current surge, which is caused by overload or short circuit in the circuit. An Over Current Relay based on Arduino has the necessary capabilities to achieve an optimal system quality level because reliable and precise protective performance can address disturbances as effectively as possible. In principle, a relay is a switch contact with a conductor winding on an iron core. Relays vary widely depending on their usage and function. Problems in electrical power systems can be categorized into two types: permanent issues and temporary issues. Some disturbances may not be eliminated. The protection of the electrical power framework can be separated into two types, namely essential assurance and reinforcement protection. If there is an issue, primary protection functions, and backup protection operates if the primary protection fails. Protection in electrical circuits plays a crucial role in ensuring the quality of voltage distribution to the load, as it is an important component needed to reduce the potential for problems in the electrical system. With the implementation of an Over Current Relay based on Arduino in the electrical circuit, it is expected to minimize various problems that can disrupt system reliability as much as possible [1].

2. MATERIAL AND METHODS

2.1 Revious Research

Several references were used in the design of the Inverse Definite Minimum Time Overcurrent Relay Based on Arduino Uno. From the research conducted by Deni Almanda and Habil Yusuf titled "Design of a Prototype for Overcurrent Protection in DC Loads Using a Microcontroller," the overcurrent protection system designed using an Arduino Nano microcontroller and the ACS712 5A current sensor has been able to effectively protect against overcurrent [2]. The research by Wahyono, Wiwik Purwati Widyaningsih, and Ajie Pribadi N, Choirul Nur H, Fidiyan Kelfin M, and Fitri Shafira titled "Performance Testing of a 3-Phase Inverse Time Overcurrent Relay for Supporting Protection System Practicum" demonstrates a theory that can be used to support the research on

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the Inverse Definite Minimum Time Overcurrent Relay Based on Arduino Uno [3]. From the research conducted by Alfi Syahri and Andik Bintoro Kolom titled "Monitoring and Controlling Power Based on Arduino Uno Using PZEM-004T Sensor," the application of the PZEM-004T sensor as a current sensor that can be used in this study is shown [4]. The research by Aria Kharisma and Galang Nazharullah titled "Overcurrent Protection Relay Based on Arduino Microcontroller" describes the design of an overcurrent protection relay using a current sensor from a shunt resistor and Op-Amp, tested by comparing it with an ammeter. The results show that the device works well in protecting against overcurrent [5]. The research conducted by Verdiano Frandhiyawan et al. titled "Design and Development of an Overcurrent Relay Based on Internet of Things (IoT) Monitoring and Arduino as a 1-Phase Electronic Protection" shows that the overcurrent relay operates with 3 characteristics: standard inverse, very inverse, and extremely inverse, which can serve as a reference for this research, particularly on the standard inverse characteristic [6]. The research by Ali Abdulsattar Hameed et al. titled "Design and Implementation of a New Real-Time Overcurrent Relay Based on Arduino" uses an Arduino Nano as the microcontroller and the ACS712 current sensor as the main sensor to measure current in the circuit and is tested in real time [7]. The research by Muhammad Fahreza titled "Design of Overcurrent Protection Control Based on Arduino" uses a GSM SIM800A Modem Module to send alerts before overcurrent occurs and indicators when overcurrent happens [8]. Most of the references above focus mainly on controlling and disconnecting the power supply but do not extensively discuss protection principles. This study will delve more into protection principles, specifically the Inverse Definite Minimum Time type.

2.2 Protection System Principle

The prototype of the Inverse Definite Minimum Time Overcurrent Relay will be designed according to the basic requirements of a protection relay, which are:

1. Speed. The protection relay must be able to isolate the affected part as quickly as possible. To minimize the time needed to disconnect the disturbed section from the healthy system, the protection relay must have high speed.
2. Sensitivity. Sensitivity in a protection relay refers to its ability to operate correctly with minimal deviation from its characteristics.
3. Reliability. Reliability means that the protection relay must function correctly and effectively under all planned disturbance conditions for which the relay is designed.
4. Simplicity. Simplicity means that the protection relay should meet conditions of good material quality, accurate design, ease of installation, ease of operation, and ease of maintenance. These factors greatly influence the reliability of the relay.
5. Economical. In a protection system, the economic factor is crucial. To achieve a well-designed protection system, cost factors play an important role in integrating all the basic requirements of the protection relay mentioned above. In practice, a compromise is necessary to ensure that the protection system is economical without compromising the required basic needs. Applying too high a level of protection is as detrimental as using a low level of protection. Therefore, the level of protection used must be appropriate to the protection needs. Thus, the protection system should be optimally designed with appropriate costs.

2.3 Mikrokontroller Arduino Uno

The Arduino Uno is an open-source electronic circuit board that operates using an AVR microcontroller chip. This board can be programmed using the Arduino programming language and IDE (Integrated Development Environment). It can detect conditions through inputs such as sensors and perform control actions on devices like LEDs or actuators. The layout and pins on the Arduino are shown in Figure 1 [9].

Figure I. Pins on Arduino Uno [9].

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2.4 Relay

Relay can be used as a switch to control the ON/OFF state of various electronic devices. The ON/OFF control of the switch is determined by the output value of the sensor used. After processing by the microcontroller, it will instruct the relay to perform the ON/OFF command. A relay module is an electronic switch operated by electrical current. Essentially, a relay is a switch lever with a wire winding around a piece of iron (solenoid) nearby. When the solenoid is energized by electrical current, the lever is pulled due to the magnetic force generated by the solenoid, causing the switch contacts to close. The shape and symbol of the relay can be seen in Figure 2 [12].

Figure II. Relay shapes and symbols [12].

2.5 PZEM-004T

PZEM-004T is a versatile and cost-effective power sensor that can be a valuable tool for various energy-related research and projects. The PZEM-004T can measure voltage (V), current (A), active power (W), reactive power (VAR), power factor (PF), energy (kWh), and frequency (Hz) with high accuracy. In this research, the PZEM-004T sensor is specifically used for measuring current. With its ability to measure and monitor various electrical power parameters with high accuracy, the PZEM-004T can provide valuable data for analysis, research, and the development of innovative energy control systems. The shape and symbol of the PZEM-004T can be seen in Figure 3 [10].

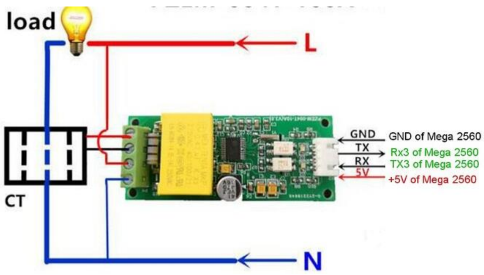

Figure III. PZEM-004T [10].

2.6 LCD 16x2

The LCD 16x2 is an electronic device used to display data and messages, known as the LCD 16×2. As its name implies, it features 16 columns and 2 rows, allowing it to display a total of 32 characters (16×2 = 32). Each character is composed of 5×8 (40) pixel dots. Therefore, the total number of pixels in this LCD can be calculated as 32 x 40 or 1280 pixels. The pins present on the LCD 16x2 can be seen in Figure 4 [11].

Figure IV. Shape and Pins on a 16x2 LCD [11].

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2.7 Push Button (Reset)

A push button switch is a simple device that functions to connect or disconnect the flow of electrical current with a push-to-unlock mechanism (non-locking system). The unlock mechanism here means that the switch will act as a connector or disconnector of the electrical current when the button is pressed, and when the button is not pressed (released), the switch will return to its normal condition. The physical form of this component can be seen in Figure 5 [12].

Figure V. Shape of Push Button (Reset) [12].

2.8 I2C (Inter-Integrated Circuit)

I2C is a communication protocol used for data exchange between microcontroller devices and sensors or other devices. I2C is designed to connect various devices in a system using a shared communication line, as shown in Figure 6 [13].

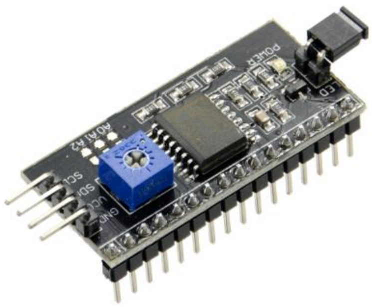

Figure VI. The form of the I2C (Inter-Integrated Circuit) component [13].

2.9 Piezoelectric

A piezoelectric buzzer is a type of buzzer that uses the piezoelectric effect to produce sound. The sound generated by this buzzer results from mechanical vibrations induced by the piezoelectric crystal inside it. A DC power source connected to the piezoelectric material causes mechanical movement, which in turn produces a sound that can be heard by the human ear using a diaphragm and resonator. This can be seen in Figure 7, which illustrates the shape, structure, and symbol of the buzzer component.

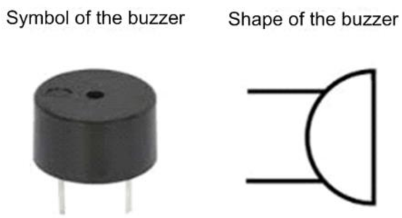

Figure VII. Shape and symbols of buzzer components.

2.10 Time and Location System Overview

The development of this tool will take place over 16 weeks, starting from January 23, 2024, to May 8, 2024. The creation of this tool will be conducted at the Protection Systems and Microprocessor Laboratory, Electrical Engineering Department, Politeknik Negeri Samarinda.

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2.11 Data Types and Data Sources

In this PBL (Project-Based Learning) design, there are three stages: pre-design, design, and operational parameters. The types and sources of data used during the pre-design stage are datasheets, also known as component specifications. The types of data sources used during the design stage include books, websites, journals, and circuit simulations using the Proteus software. Operational parameters refer to data obtained from the implementation of the PBL project on Overcurrent Protection Relay Based on Arduino Microcontroller in the Microcontroller Laboratory.

2.12 System Overview

An overview of the system to be designed in the PBL Overcurrent Protection Relay Based on Arduino Microcontroller can be seen in Figure 8. The microcontroller system receives a voltage supply from a 5V adapter. The microcontroller has three outputs and three inputs, which include a push button and current sensors.

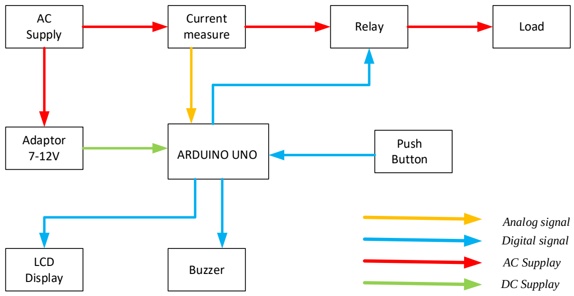

Figure VIII. General image of an overcurrent protection relay system based on an Arduino microcontroller

In Table- I can be seen for the Input and Output used on the Arduino Uno.

Table I : Used Input and Output

Pin Mode	No. Pin	Name Pin	Description
Input	RESET	Reset	Functions as a reset button when the protection relay is active and as a back button when setting the menu
Output	2	Relay	Serves as an output that controls the relay to cut off the current to the load when the read current exceeds the set current.
Output	3	Buzzer	Acts as an output that generates sound as a signal when the relay is active.
Output	10	Push Button	Functions as the output for the reset button when the protection relay is active and as a back button when setting the menu
Input	11	RX (PZEM-004T)	Serves as an input that receives data on the Arduino.
Output	12	TX (PZEM-004T)	Functions as an output that sends data on the Arduino.
Output	SCL and SDA	Display	Used to manage data communication between Arduino and LCD.

2.13 Operating Parameters

The operating parameters of this microcontroller-based overcurrent protection relay include:

1. Voltage
   The signal generated by the current sensor is in the form of voltage. This voltage is received by the microcontroller as an analog signal ranging from 0 Volts to 5 Volts and converted into a 10-bit digital signal from a value of 0 to 1023. This digital value is then converted into current units displayed on the screen. The current sensor contains a current sensing resistor, and by measuring the voltage drop across the resistor RS, the current flowing through the load and the RS resistor can be calculated.
2. Current
   As a current protection device, the current parameter is very important for this device to function properly. The device's ability to measure the flowing current adjusts to the current-carrying capacity of the current sensor and the relay used, thus obtaining the maximum current value that can be protected.

2.14 Equipment and Materials

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

Table II : Equipment and Materials

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

3. RESULT AND DISCUSSION

3.1 Design Result

In creating a design, thorough planning is necessary to achieve a tool that meets specific standards. Specifically, the design of the Inverse Definite Minimum Time Overcurrent Relay Protection requires careful calculations to facilitate its development process. In Figure 10 below is the design that will be used to arrange the main components so that they can function properly.

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Figure IX. View of the entire tool

3.2 Current Protection Relay Testing

During the protection relay testing, the protection current value and the current reading value are set. It should be noted that the relay used is an active High type relay, so when given a high signal, the relay will operate. In Table- III below are the test results from the Overcurrent Protection Relay Module.

Table III : Testing of Current Protection Releases

NO	Current (A)	Testing on Modules (Second)	Testing On ETAP (A)	Error (%)
1	1.95	999	999	0
2	1.96	999	999	0
3	1.97	999	999	0
4	1.98	999	999	0
5	1.99	999	999	0
6	2	1.08	1	-7,40741
7	2.01	1.05	1	-4,7619
8	2.02	1.01	1	-9,09091
9	2.03	1.05	1	-4,7619
10	2.04	1.08	1	-7,40741
11	2.05	1.08	1	-7,40741
12	2.06	1.09	1	-8,25688
13	2.07	1.11	1	-9,90991
14	2.08	1.07	1	-6,54206
15	2.09	1.05	1	-4,7619
16	2.10	1.06	1	-5,66038
17	2.11	1.09	1	-8,25688

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18	2.12	1.11	1	-9,90991
`9	2.13	1.1	1	-9,09091
20	2.14	1.03	1	-2,91262
21	2.15	1.06	1	-5,66038
22	2.16	1.06	1	-5,66038
23	2.17	1.04	1	-3,84615
24	2.18	1.08	1	-7,40741
25	2.19	1.07	1	-6,54206
26	2.20	1.02	1	-1,96078
27	2.21	1.09	1	-8,25688
28	2.22	1.06	1	-5,66038
29	2.23	1.07	1	-6,54206
30	2.24	1.03	1	-2,91262
31	2.25	1.06	1	-5,66038

It can be seen from Table 3 that the testing of the Overcurrent Protection Relay shows a slight discrepancy between the calculations in ETAP and the tests conducted using a stopwatch, as can be seen in Figure 9. The comparison curve between the Testing and Simulation in the ETAP Application.

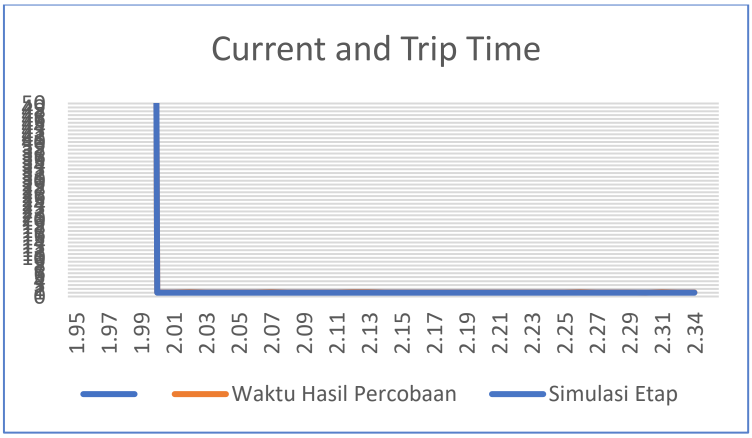

Figure X. IDMT Characteristic Curve Test Time compared to ETAP.

4. CONCLUSION

From the results of the Project-Based Learning on the design and construction of an Inverse Definite Minimum Time Overcurrent Relay Based on Arduino in the Protection System Laboratory and the Microprocessor System Laboratory, the following conclusions can be drawn:

1. Based on the test results, this device works well in protecting against overcurrent and the Inverse Definite Minimum Time characteristic is met according to simulations on ETAP software.
2. This device has good accuracy and produces a fairly low average error rate.

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