

Design and Construction of the Standard Inverse and Constant Time Overcurrent Relay Simulator Based on Arduino

Rizky Aprylianto Susilo¹, Abdul Hamid Kurniawan², Bella Cahya Ningrum³, Ilham Maulana⁴, Alfie Fatieh⁵,
Wahyu Setiawan⁶

^{1,2,3,4,5,6} Department of Electrical Engineering, Samarinda State Polytechnic

ABSTRACT: Overcurrent relay as one of the protection systems in the electricity distribution network has been improved in performance through the implementation of microcontrollers. To simulate the work of overcurrent relays, an Arduino module based on Atmega328P can be used to study the working algorithm of overcurrent relays. This research aims to design and build an Arduino-based overcurrent relay simulator with two working time characteristics, namely standard inverse and constant time. The simulator is equipped with a CT-based current sensor and a PZEM-004T module to read the current, as well as using a 20x4 I2C LCD and a 4x4 Keypad as the user interface. Once the simulator is designed, the next step is testing to measure the accuracy of the sensor readings and the performance of the relay at various variations of current and timing settings. The test is performed at a voltage of 220 Volt Alternating Current (AC) and at a variety of current variations i.e., 0.5 A, 1 A and 1.5 A currents. The test results showed that the system was able to work according to the characteristics of standard inverse and constant time with an average error of measurement of the relay working time of less than 2% for standard inverse and 0% for constant time. This proves that this Arduino-based overcurrent protection system is accurate and responsive.

KEYWORDS: Arduino, Constant Time, Overcurrent Relay, Standard Inverse.

I. INTRODUCTION

The protection of the electric power system is an important aspect to ensure the safety and reliability of distribution network operations. One common form of interference is overcurrent, which can cause damage to electrical equipment as well as pose a risk of fire if not treated immediately. For this reason, an overcurrent relay is used which functions to cut off the flow of electricity automatically when the current exceeds the safe limit. Overcurrent relays have several working characteristics, two of the most commonly used are standard inverse and constant time. In the standard inverse characteristic, the greater the interference current, the faster the disconnection time. In contrast, at constant time, the disconnection time is fixed as long as the current exceeds a predetermined limit. The combination of these two characteristics allows for a more flexible protection system according to the needs of electrical installations.

As technology has evolved, the use of microcontrollers in protection systems has become a widely used solution. Microcontrollers such as Arduino offer programming flexibility, easy integration with a variety of sensors, and the ability to respond to system conditions in real-time. This provides an advantage in designing a protection system that is efficient, adaptive, and easy to develop.

Various previous studies have tried to implement microcontroller-based overflow protection systems. One of the studies by Becky Arya Wijaya, et al., developed a current protection system with more inverse standard characteristics using Arduino and equipped with Time Multiplier Setting (TMS) [1]. Another study by Arbain, Rizky Aprylianto Susilo, et al., designed a relay with very inverse characteristics using an Arduino Uno and a PZEM-004T sensor, and verified it through ETAP simulations and experimental testing [2]. Meanwhile, Rusdiansyah, et al., developed a more than one-phase current protection system with constant time characteristics focused on household applications [3].

However, all of these studies focused on only one characteristic of working time. No research has explicitly combined two characteristic modes, namely standard inverse and constant time, into a single integrated microcontroller-based system with an interactive interface. In fact, the integration of these two characteristics will provide greater flexibility for users to adjust the protection settings according to the needs of the system.



Against this background, this research has a novelty value because it combines two modes of overcurrent protection in one Arduino-based simulator device. The simulator is designed not only for practical protection applications, but also as a medium for learning and technical testing. This research aims to design and build an Arduino-based overcurrent relay simulator that can operate in two protection modes, namely standard inverse and constant time. The system uses a CT current sensor and PZEM-004T module for current reading, and is equipped with an I2C LCD and keypad as a user interface. Other supporting components are LED as an indicator and SolidState Relay (SSR) for power cut-off. This simulator tests the working algorithm of the overcurrent relay according to variations in current and time settings of certain settings.

II. LITERATURE REVIEW

A. Electric Power Protection System

Electrical power system protection is an automatic mechanism designed to detect faults or abnormal conditions in the power grid, and then quickly isolate the affected parts. This system aims to maintain the continuity of electricity distribution reliably and stably, as well as protect electrical equipment from potential damage due to disturbances. Thus, the risk of loss can be minimized, blackout times are reduced, operational safety is improved, and the quality and continuity of electrical power to the end user is maintained. [4]

B. Requirements of Electric Power Protection System

In electric power systems, protection serves to protect or isolate parts that are disturbed. The goal is to prevent, stop, and limit the impact of interference by only cutting off the disturbed part without disrupting other systems. Detection is carried out by measuring the amount of electricity to distinguish normal and abnormal conditions [5]. In its application, there are several important criteria that must be considered when installing a protection system on a series of electric power systems, namely:

1) Sensitivity

Sensitivity is the ability of a protection relay to respond appropriately to interference within its protection area. The level of sensitivity is determined by how small the amount of drive can trigger the protection operation. The smaller the value, the higher the sensitivity, and this is closely related to the minimum interference current in the protected region. [5]

2) Speed

The protection system must have an appropriate working speed to guarantee service quality, safety, equipment protection, and operation stability. However, because power systems have a stability limit and interference is often temporary, relays, although designed quickly, sometimes need to be timed to avoid responding prematurely. [5]

3) selectivity and discrimination

Selectivity means that the protection system is able to isolate only the disturbed parts without affecting other parts that are still normal. Discrimination is the system's ability to distinguish between normal and abnormal conditions, as well as determine whether interference occurs inside or outside the protected area. With both, protective measures can be carried out appropriately and efficiently. [5]

4) Reability

A protection system is said to be reliable if it is able to operate as expected in every condition that requires it. On the other hand, the system is considered unreliable if it fails to function when needed or is actually active when it is not needed. [5]

5) Economical

Good technical planning must of course consider economic aspects. Therefore, the selection of protection relays should be done by considering cost efficiency, while still maintaining its function and level of reliability. [5]

C. Overcurrent Relay

An overcurrent relay (OCR) is a protective relay that works based on the magnitude of the current passing through the system. OCR has important parameters such as pickup current value and operation time. If the current is more than the value of the pickup, then the relay will activate the trip signal after a certain interval of time. There are several types of OCR based on their time characteristics, such as inverse time and constant time relay. In the inverse time type, the greater the interference current, the faster the relay works, while the constant time type has a fixed working time without depending on the size of the current. [6]

D. Characteristics of Inverse Time

The inverse time characteristic is an operating characteristic in which the relay's working time is inversely proportional to the magnitude of the detected interference current. It can be interpreted that the greater the fault current that occurs, the faster the trip time generated by the protection system to cut off the flow of current and prevent further damage to equipment or power grids. The equation of [1] inverse time characteristics can be seen in Equation (1).

$$t = \beta \frac{TMS}{\left(\frac{I}{I_s}\right)^\alpha - 1} \tag{1}$$

Information:

- T = Time Trip (seconds)
- TMS = Time Multiplier Setting
- I = Current interference
- Is = Current Settings

The inverse time characteristic in accordance with IEC 60255 contains the values of the parameters α (alpha) and β (beta) as determining factors in the relay working time equation. These values can be seen in Table 1.

TABLE 1. INVERSE CHARACTERISTIC STANDARD [1] ACCORDING TO IEC 60255

Description of Curve	α	β
Standard Inverse	0,02	0,14
Very Reverse	1	13,5
Extremely Inverse	2	80
Long Time Inverse	1	120

Table 1 shows the inverse characteristic standard as per IEC 60255. There are 4 curves, namely standard, very, extreme, and long time inverse. Each curve has different α (alpha) and β (beta) parameter values, which determine the speed of the relay's response to different levels of measured interference current. The inverse time characteristic curve can be seen in Figure 1.

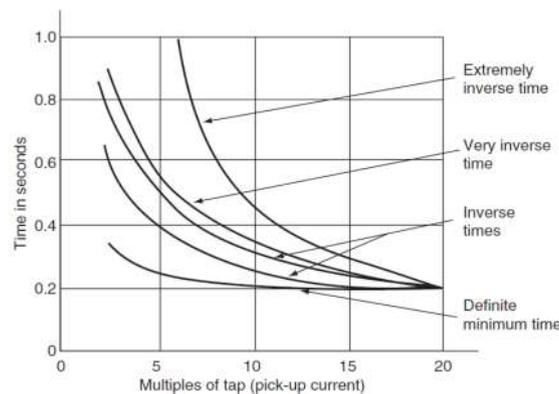


Figure 1. Inverse time characteristic curve [7]

Figure 1 shows the characteristic curve of inverse time. The curve has 2 axes, namely the x-axis and the y-axis. The x-axis indicates the current and the y-axis indicates the trip time in units of seconds. The inverse time characteristic curve shows that the larger the measured interference current, the faster the trip time occurs.

E. Characteristics of Constant Time (Definitive Time)

The characteristic of constant time or definitive time is a protection relay operation with a trip time that remains in accordance with the setting, without being affected by the amount of overcurrent. Once the current exceeds the threshold (pickup), the relay calculates the delay time according to the setting and disconnects the circuit once that time is reached. The characteristic curve of [8] constant time or definitive time can be seen in Figure 2.

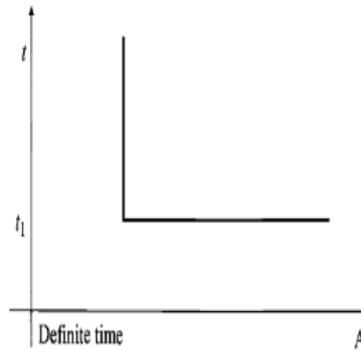


Figure 2. Constant time or definitive time characteristic curve [8]

Figure 2 shows the characteristic curve of constant time or definitive time. The curve has 2 axes, namely the x-axis and the y-axis. The x-axis indicates the current in Ampere units and the y-axis indicates the time of the trip that occurred.

F. Microcontroller

A microcontroller is a computer system whose components are all or part of it integrated into a single IC chip, so it is often known as a single-chip microcomputer. A microcontroller also serves as a computer system designed to perform one or more specific tasks, primarily in handling input, processing, and output functions [9].

G. Arduino Uno

The Arduino Uno is an open-source microcontroller board based on the ATmega328P that is programmed using the Arduino language via a computer. This board can read inputs, process data, and generate outputs to control electronic devices. The Arduino Uno has 14 digital pins (6 support PWM), 6 analog inputs, as well as support for serial, I2C, and SPI communication for external module [10] connections. The Arduino Uno can be seen in Figure 3.



Figure 3. Arduino Uno [10]

H. PZEM-004Tv30

PZEM-004Tv30 is a sensor module for measuring current, voltage, power, and energy in single-phase AC systems. The module uses TTL serial communication and can be connected to a microcontroller such as Arduino directly. Generally, this module is equipped with a built-in CT 3 mm diameter that is capable of detecting currents up to 100A in real-time and accurately. PZEM-004Tv30 can be seen in [11] Figure 4.



Figure 4. PZEM-004Tv30 [11]

I. Solid State Relay (SSR)

Solid State Relay (SSR) is an electronic relay that differs from electromagnetic relays in that it has no moving parts and does not produce sound when operating. Using electronic components, the SSR can be controlled at low voltage from a microcontroller but is capable of controlling loads with large output currents. [12] Solid State Relay can be seen in Figure 5.



Figure 5. Solid State Relay (SSR) [12]

III. RESEARCH METHODOLOGY

A. Time and Location

This study was carried out over a period of 16 weeks. Research activities began in February 2025 and ended in May 2025. This time span is used for all stages, from planning to evaluation of research results. The place where the research was carried out was at the Protection and Microprocessor Laboratory, Department of Electrical Engineering, Samarinda State Polytechnic.

B. Types and Sources of Data

This study uses two types of data, namely primary data and secondary data. Primary data were obtained through direct observation and testing of the designed overcurrent relay system, including current readings by PZEM-004T sensors, relay working time, as well as system response to current variations and working modes, which were collected through experiments at the Protection and Microprocessor Laboratory, Department of Electrical Engineering, Samarinda State Polytechnic. Secondary data came from various scientific journals that discussed the working principle of overcurrent relays, inverse time and constant time characteristics, and the application of Arduino microcontrollers, and were used to strengthen the theoretical foundation and analysis of test results.

C. System Overview

The general system overview of the design of the Arduino-based standard inverse and constant time overcurrent relay simulator is to shield the electrical load from overcurrent using two types of characteristics, namely standard inverse and constant time, with Arduino as the system controller. A block diagram of the Arduino-based standard inverse and constant time overcurrent relay type design system can be seen in Figure 6.

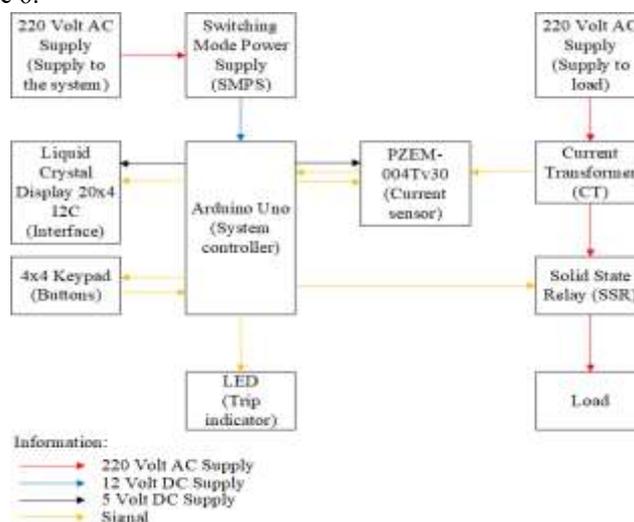


Figure 6. Block diagram of the system design and construction of the standard inverse and constant time overcurrent relay type simulator based on Arduino



D. Equipment and Materials

The equipment and materials used in the design of Arduino-based overcurrent relay type, standard, inverse and constant time can be seen in Table 2.

TABLE 2 EQUIPMENT AND MATERIALS

No.	Equipment	Material
1	AC Power Supply	Arduino One
2	Amp meter	PZEM-004Tv30
3	Variable resistor	Solid State Relay (SSR)
4	Laptop	Liquid Crystal Display 20x4 I2C
5	Cable stripping pliers	Ligth Emitting Diode (LED)
6	Solder	220 Ω resistor
7	Screwdriver Plus	4x4 Keypad
8	Combination pliers	Switching Mode Power Supply (SMPS)
9	Drill	Female banana socket
10	Grindstone	NYAF 1.5 mm cable
11		Cable jumper male to female
12		Cable jumper male to male
13		Cable jumper female to female
14		Tin
15		Double layer Printed Circuit Board (PCB)
16		Spacers
17		Spacer bolts
18		Spacer wall
19		Bolt 7 cm
20		Bolt wall 7 cm
21		Acrylic 5 mm

E. Flowchart

The flowchart designed and built an Arduino-based standard inverse and constant time overcurrent relay type simulator serves to facilitate understanding the workflow of the designed protection system. This flowchart visually represents the stages of system logic, starting from the reading of the current by the sensor, the selection of the working mode by the user through the keypad, to the trip process when there is an overcurrent and the reset process after the interference is overcome. The preparation of flowcharts aims to ensure that every process and decision-making in the system is identified clearly, systematically, and easily understood, so that it can facilitate the process of designing, analyzing, and further developing the system. The complete flowchart of this system can be seen in Figure 7.

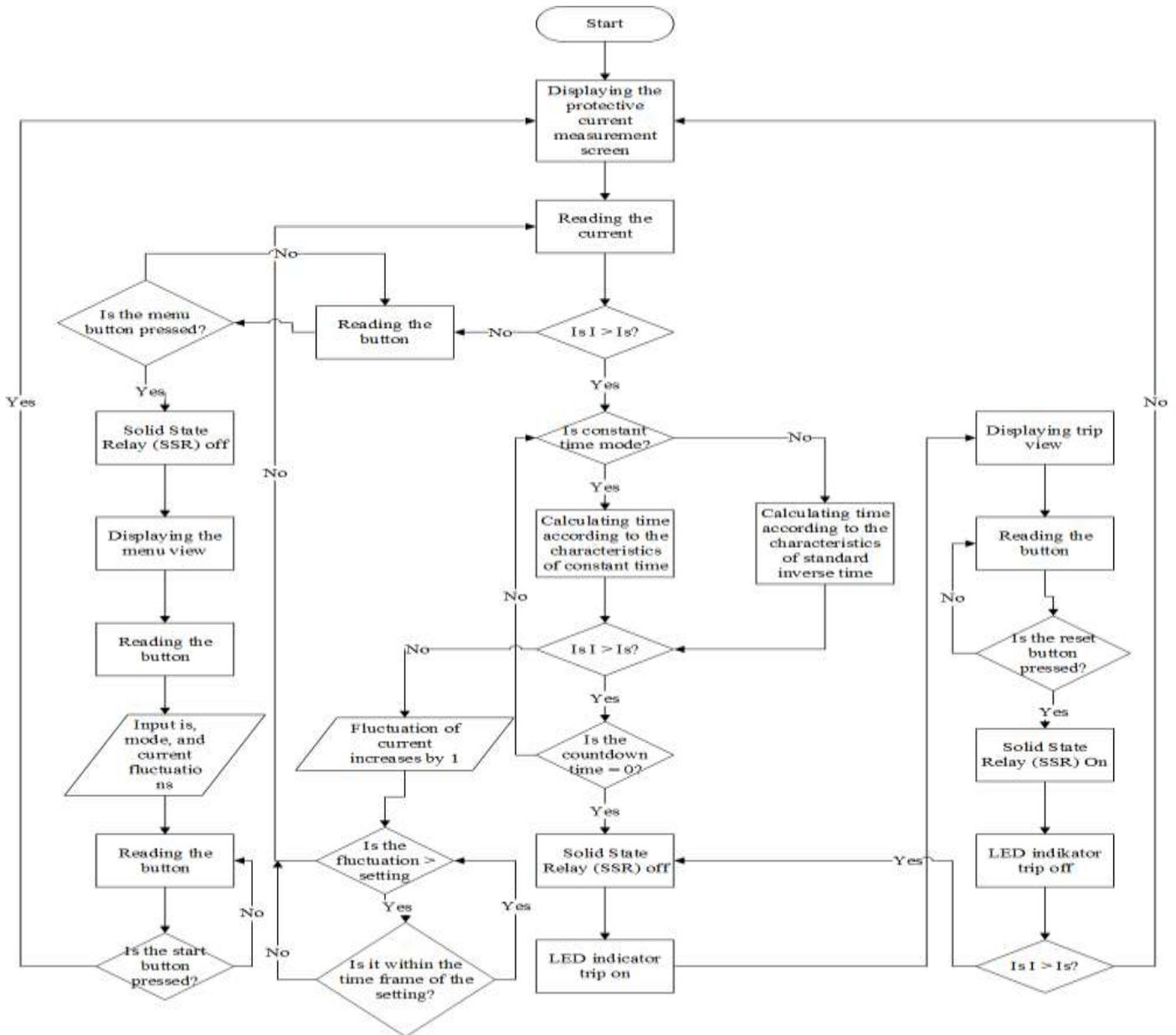


Figure 7. Flowchart design and construction of an Arduino-based standard inverse and constant time overcurrent relay type simulator

Figure 7 shows the flowchart of the design of an Arduino-based overcurrent relay simulator. This flowchart serves as a visual representation of the system's workflow, making it easier to understand the logical processes that take place within it. The stages in the flowchart include system initialization, current reading by sensors, selection of work mode by the user (inverse time or constant time), calculation of delay time based on the selected mode, to the trip process when overcurrent is detected and the reset process is by the user. Each process is described in chronological order to ensure that the system's workflow can be understood systematically and thoroughly. Flowcharts are also useful in technical documentation as a reference for developers or other technicians involved in the project. With a good flowchart design, the effectiveness and reliability of the protection system are more guaranteed. In addition, flowcharts help speed up the debugging process when logical errors occur in the system.

F. Wiring Diagram

The wiring diagram of the Arduino-based standard inverse and constant time overcurrent relay simulator functions to facilitate the understanding of the relationship between components in the designed protection system. This diagram represents the electrical connections between the main modules such as Arduino Uno, PZEM-004T, Solid State Relay (SSR), 20x4 I2C LCD, keypad, indicator LED, and current transformer (CT) thoroughly and systematically. The preparation of wiring diagrams aims to ensure that connections between components are carried out precisely and safely, thereby minimizing assembly errors and facilitating the process of maintenance, modification, and future development of the system. These diagrams also help speed up the installation process, avoid technical errors, and ensure each connection is in accordance with the design that has been set. The wiring diagram of the design and construction of the overcurrent relay simulator type standard inverse and constant time can be seen in Figure 8.

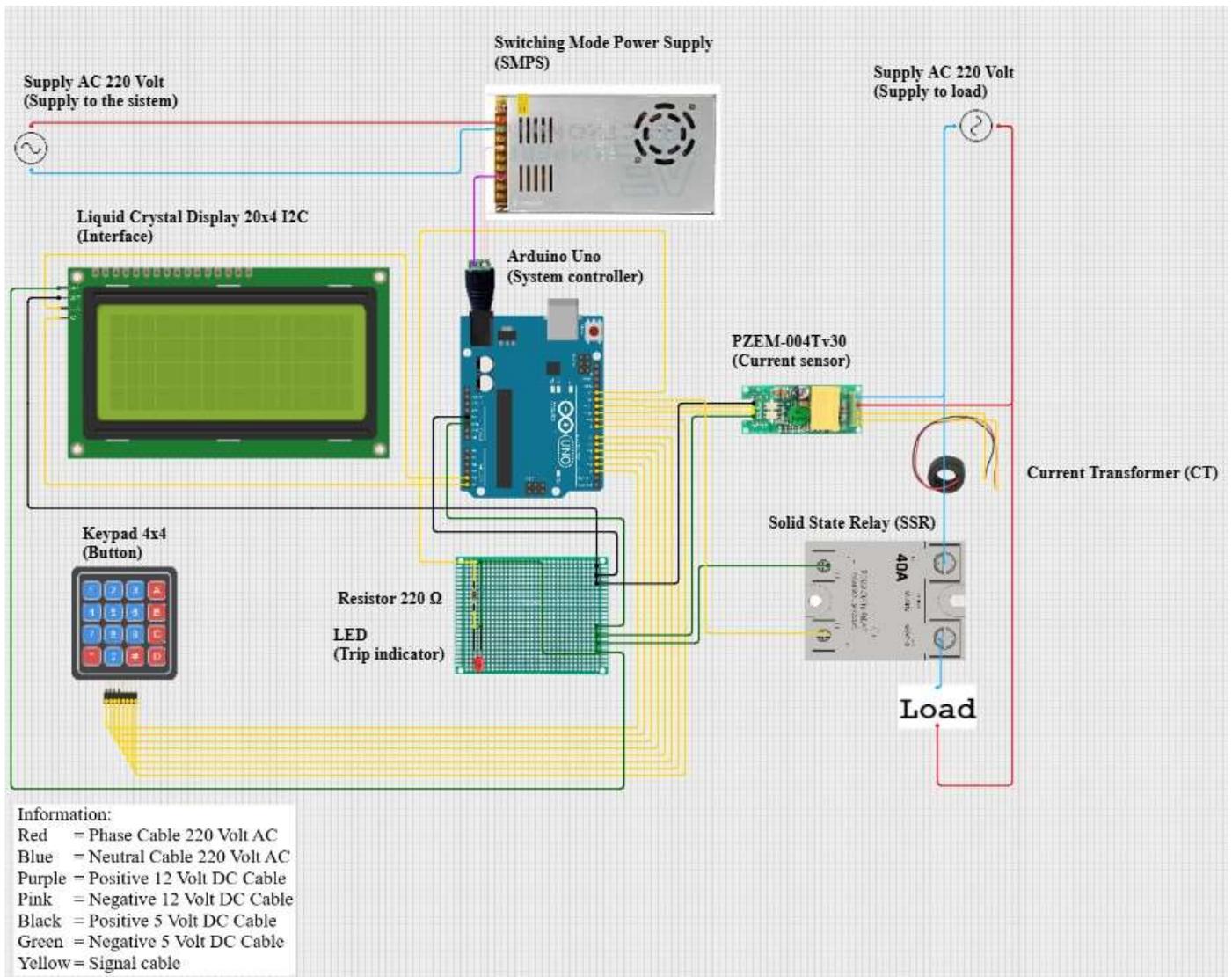


Figure 8. Wiring diagram design and construction of the standard inverse and constant time overcurrent relay simulator based on Arduino

Figure 8 shows the wiring diagram of the Arduino Uno based overcurrent protection system consisting of PZEM-004T v3.0, SSR, 20x4 I2C LCD, 4x4 keypad, LED indicator, and CT. The Arduino Uno acts as the main controller that reads the current from the PZEM-004T, receives input from the keypad, displays data on the LCD, and controls the SSR to disconnect or connect

the current. The LCD displays information such as load current, setting current, working mode, and system status. The keypad is used to select modes, set parameters, and reset the system in case of trip conditions. PZEM-004T reads AC current via CT and sends it to Arduino serially. In the event of an overcurrent, the Arduino activates the LED as a visual indicator and cuts off the current to the load through the SSR as a protective measure. The system uses a 12V DC power supply to supply the Arduino and supplies 5 VDC from the arduino to other digital components. Each cable in the diagram is color-coded to make it easier to identify and minimize installation errors. Wiring between components is arranged with space efficiency and ease of assembly in mind. All digital components are connected to the Arduino via a systematically defined input/output pin. The input and output pins used can be seen in Table 3.

TABLE 3. PIN INPUTS AND OUTPUTS USED

No.Pin	Pin Mode	Component	Information
2 to 9	Input	4x4 Keypad	Used to input modes and parameters by the user
10 and 11	Input and Output	PZEM-004Tv30	Serial communication with current and voltage measuring modules
12	Input	Solid State Relay (SSR)	Receives trip control signal to break the load current
13	Output	LED	System status indicator, illuminated during trip conditions
SDA and SCL	Output	LCD 20x4 I2C	Displays flow information, working mode, trip time, and system status

Table 3 shows the input and output pins on the standard inverse and constant time type overcurrent relay simulator. Pins 2–9 are used for the 4x4 keypad as user input in mode and parameter settings. Pin 11 is used for communication with the PZEM-004Tv30 module. Pin 12 controls the Solid State Relay (SSR) to automatically cut off the load current, and pin 13 for the trip indicator LED. The SDA and SCL pins are used by the 20x4 I2C LCD as the main interface of the system display.

IV.RESULT AND DISCUSSION

A. Current Sensor Accuracy Testing PZEM-004Tv30

The purpose of this test is to test the accuracy of the current reading results on the PZEM-004Tv30 current sensor with an Ampere meter measuring device. The test results of the PZEM-004Tv30 current sensor can be seen in Figure 9.



Figure 9. Results of the current sensor of PZEM-004Tv30 with the measurement

Figure 9 shows the test results of the PZEM-004Tv30 current sensor with an Ampere meter measuring device. The test results showed that there was a difference between the PZEM-004Tv30 current sensor and the Ampere meter measuring device. So a test was carried out eighteen times to find out how much the average PZEM-004Tv30 current sensor error was with the measuring tool. The results of the accuracy test of the PZEM-004Tv30 current sensor with the measuring instrument can be seen in Table 4.



TABLE 4. RESULTS OF CURRENT SENSOR ACCURACY TEST PZEM-004TV30 WITH MEASURING INSTRUMENT

No.	Ampere meter gauge	PZEM-004Tv30 current sensor	Difference	Error(%)
1	0,503	0,503	0	0
2	0,6	0,6	0	0
3	0,705	0,706	0,001	0,14
4	0,805	0,807	0,002	0,25
5	0,902	0,905	0,003	0,33
6	1,004	1,007	0,003	0,30
7	1,105	1,109	0,004	0,36
8	1,203	1,208	0,005	0,42
9	1,31	1,316	0,006	0,46
10	1,405	1,412	0,007	0,50
11	1,531	1,539	0,008	0,52
12	1,605	1,613	0,008	0,50
13	1,7	1,709	0,009	0,53
14	1,813	1,823	0,01	0,55
15	1,938	1,949	0,011	0,57
16	2,001	2,0 13	0,012	0,60
17	2,139	2,152	0,013	0,61
18	2,2	2,213	0,013	0,59
Average			0,006	0,40

Table 4 shows the results of the accuracy test of the PZEM-004TV30 current sensor by comparing the current values read by the sensor and the measuring instrument (Ampere meter). The test was conducted at 18 points with a current range of 0.503 A to 2.213 A. The reading difference ranged from 0 to 0.013 A, with the highest error percentage of 0.75% and the lowest 0%. The average difference of 0.006 A and the mean error of 0.40% indicate that this sensor is sufficiently accurate and consistent for current monitoring applications with medium accuracy requirements. Therefore, these sensors are reliable for use in microcontroller-based protection systems.

B. Solid State Relay (SSR) Testing

The purpose of this test is to find out if this Solid State Relay (SSR) is still in a normal state. The way to know that the Solid State Relay (SSR) is still in normal state is to provide a signal to the Solid State Relay (SSR). If the Solid State Relay (SSR) is given a HIGH signal, the Solid State Relay (SSR) is working marked by the Solid State Relay (SSR) indicator light that is on and there is a current flowing to the load. Meanwhile, if the Solid State Relay (SSR) is given a LOW signal, then the Solid State Relay (SSR) does not work, characterized by an indicator light that does not turn on and it looks that the flowing current is very small or it can be said that there is no flowing current because it is very small. The Solid State Relay (SSR) test given a HIGH signal can be seen in Figure 10.



Figure 10. Solid State Relay (SSR) testing is given a HIGH signal

Figure 10 shows the Solid State Relay (SSR) test given a HIGH signal. This test shows that when the Solid State Relay (SSR) is given a HIGH signal then the Solid State Relay (SSR) will work as can be seen with the indicator light on the Solid State Relay (SSR) on and the presence of current flowing to the load. Furthermore, the Solid State Relay (SSR) test given a LOW signal can be seen in Figure 11.



Figure 11. Solid State Relay (SSR) testing is given a LOW signal

Figure 11 shows the Solid State Relay (SSR) test given a LOW signal. This test shows that when the Solid State Relay (SSR) is given a LOW signal then the Solid State Relay (SSR) will not work can be seen with the indicator light on the Solid State Relay (SSR) which is not on and it can be seen that the flowing current is very small or it can be said that there is no flowing current because the flowing current is very small, which is 0.007 A. Solid State Relay Test Results (SSR) can be seen in Table 5.

TABLE 5. SOLID STATE RELAY (SSR) TESTING

Signal	Indicator light	Current
HIGH	Live	Exist
LOW	Die	None

Table 5 shows the results of the Solid State Relay (SSR) test. The test results show that this Solid State Relay (SSR) is still in a normal state. This can be seen in Table 5, when the Solid State Relay (SSR) is given a HIGH signal, then the SSR will work, which is characterized by the indicator light coming on and the presence of current flowing to the load stably and according to the expectations of the pre-designed circuit to support the expected protection function and maintain continuity of supply power to load with no meaningful interruption during the test. This condition indicates that the logic signal from the microcontroller successfully triggers the SSR work responsively. In addition, the current value detected under this condition is consistent with the load requirements tested. Meanwhile, when the Solid State Relay (SSR) is given a LOW signal, the SSR does not work, which is



characterized by an off indicator light and a non-existent or very small current, which is only about 0.007 A. This test proves that the Solid State Relay (SSR) is still functioning properly and is suitable for use in the design of this overcurrent protection system.

C. Accuracy Testing of Overcurrent Relay Type Standard Inverse

The purpose of this test is to test that the device is designed to be in accordance with the standard inverse time characteristics and accuracy of the tool. The test was carried out at an AC voltage of 220 V. This test was carried out in three stages, each using a setting current (Is) of 0.5 A, 1 A, and 1.5 A. At each stage, the test was carried out with a variation of Time Multiplier Setting (TMS) of 0.05, 0.1, and 0.2.

The first stage of testing was carried out fifty times at a setting current (Is) of 0.5 A with variations of Time Multiplier Setting (TMS) of 0.05, 0.1, and 0.2. The purpose of this test is to test the device designed to be built according to the standard inverse time characteristics and the accuracy of the device at a setting current (Is) of 0.5 A with a Time Multiplier Setting (TMS) variation of 0.05, 0.1, and 0.2. The comparison between the test results and the calculation of overcurrent relay type standard inverse time at the setting current (Is) 0.5 A with the variation of the Time Multiplier Setting (TMS) of 0.05, 0.1, and 0.2 can be seen in Table 6.

TABLE 6. COMPARISON BETWEEN TEST RESULTS AND CALCULATION OF OVERCURRENT RELAY TYPE STANDARD INVERSE TIME AT SETTING CURRENT (IS) 0.5 A WITH TIME MULTIPLIER SETTING (TMS) VARIATIONS OF 0.05, 0.1, AND 0.2

No.	IS(A)	I(A)	I/Is(A)	TMS 0.05			TMS 0.1			TMS 0.2		
				Calculated trip time (seconds)	Test trip time (sec)	Error(%)	Calculated trip time (seconds)	Test trip time (sec)	Error(%)	Calculated trip time (seconds)	Test trip time (sec)	Error(%)
1	0,5	0,505	1,01	35,17	35,02	0,43	70,34	70,04	0,43	140,68	140,08	0,43
2	0,5	0,51	1,02	17,67	17,4	1,53	35,34	34,8	1,53	70,68	69,6	1,53
3	0,5	0,515	1,03	11,84	11,47	3,12	23,67	24,5	3,51	47,35	45,88	3,10
4	0,5	0,52	1,04	8,92	8,32	6,73	17,84	16,64	6,73	35,68	34,86	2,30
5	0,5	0,525	1,05	7,17	7,04	1,81	14,34	13,56	5,44	28,68	27,12	5,44
6	0,5	0,53	1,06	6,00	5,91	1,50	12,01	11,83	1,50	24,01	23,65	1,50
7	0,5	0,535	1,07	5,17	4,97	3,87	10,34	9,94	3,87	20,68	19,87	3,92
8	0,5	0,54	1,08	4,54	4,49	1,10	9,09	8,99	1,10	18,18	17,98	1,10
9	0,5	0,545	1,09	4,06	3,94	2,96	8,12	8,04	0,99	16,23	16,08	0,92
10	0,5	0,55	1,1	3,67	3,57	2,72	7,34	7,14	2,72	14,67	14,55	0,82
11	0,5	0,555	1,11	3,35	3,27	2,39	6,70	6,65	0,75	13,40	12,86	4,03
12	0,5	0,56	1,12	3,08	3,06	0,65	6,17	6,03	2,27	12,34	12,25	0,73
13	0,5	0,565	1,13	2,86	2,8	2,10	5,72	5,53	3,32	11,44	11,21	2,01
14	0,5	0,57	1,14	2,67	2,65	0,75	5,34	5,24	1,87	10,67	10,47	1,87
15	0,5	0,575	1,15	2,50	2,46	1,60	5,00	4,91	1,80	10,00	10,2	2,00
16	0,5	0,58	1,16	2,35	2,29	2,55	4,71	4,53	3,82	9,42	9,37	0,53
17	0,5	0,585	1,17	2,23	2,19	1,79	4,45	4,43	0,45	8,90	8,77	1,46
18	0,5	0,59	1,18	2,11	2,08	1,42	4,22	4,16	1,42	8,44	8,24	2,37
19	0,5	0,595	1,19	2,01	1,98	1,49	4,02	4	0,50	8,03	8	0,37
20	0,5	0,6	1,2	1,92	1,88	2,08	3,83	3,78	1,31	7,66	7,57	1,17
21	0,5	0,605	1,21	1,83	1,8	1,64	3,67	3,65	0,54	7,33	7,31	0,27
22	0,5	0,61	1,22	1,76	1,73	1,70	3,51	3,47	1,14	7,03	6,89	1,99
23	0,5	0,615	1,23	1,69	1,66	1,78	3,37	3,36	0,30	6,75	6,68	1,04
24	0,5	0,62	1,24	1,62	1,59	1,85	3,25	3,24	0,31	6,49	6,48	0,15
25	0,5	0,625	1,25	1,56	1,54	1,28	3,13	3,12	0,32	6,26	6,2	0,96
26	0,5	0,63	1,26	1,51	1,47	2,65	3,02	2,97	1,66	6,04	5,99	0,83



No.	IS(A)	I(A)	I/Is(A)	TMS 0.05			TMS 0.1			TMS 0.2			
				Calculated trip time (seconds)	Test trip time (sec)	Error(%)	Calculated trip time (seconds)	Test trip time (sec)	Error(%)	Calculated trip time (seconds)	Test trip time (sec)	Error(%)	
27	0,5	0,635	1,27	1,46	1,44	1,37	2,92	2,91	0,34	5,84	5,79	0,86	
28	0,5	0,64	1,28	1,41	1,39	1,42	2,83	2,82	0,35	5,66	5,61	0,88	
29	0,5	0,645	1,29	1,37	1,35	1,46	2,74	2,7	1,46	5,48	5,41	1,28	
30	0,5	0,65	1,3	1,33	1,32	0,75	2,66	2,64	0,75	5,32	5,25	1,32	
31	0,5	0,655	1,31	1,29	1,27	1,55	2,59	2,57	0,77	5,17	5,13	0,77	
32	0,5	0,66	1,32	1,26	1,24	1,59	2,51	2,5	0,40	5,03	4,94	1,79	
33	0,5	0,665	1,33	1,22	1,21	0,82	2,45	2,44	0,41	4,90	4,84	1,22	
34	0,5	0,67	1,34	1,19	1,17	1,68	2,38	2,37	0,42	4,77	4,74	0,63	
35	0,5	0,675	1,35	1,16	1,14	1,72	2,33	2,3	1,29	4,65	4,62	0,65	
36	0,5	0,68	1,36	1,13	1,12	0,88	2,27	2,24	1,32	4,54	4,53	0,22	
37	0,5	0,685	1,37	1,11	1,09	1,80	2,22	2,2	0,90	4,43	4,39	0,90	
38	0,5	0,69	1,38	1,08	1,06	1,85	2,17	2,14	1,38	4,33	4,29	0,92	
39	0,5	0,695	1,39	1,06	1,05	0,94	2,12	2,1	0,94	4,24	4,23	0,24	
40	0,5	0,7	1,4	1,04	1,03	0,96	2,07	2,06	0,48	4,15	4,11	0,96	
41	0,5	0,705	1,41	1,02	1,01	0,98	2,03	2,01	0,99	4,06	4,01	1,23	
42	0,5	0,71	1,42	0,99	0,98	1,01	1,99	1,98	0,50	3,98	3,95	0,75	
43	0,5	0,715	1,43	0,98	0,96	2,04	1,95	1,93	1,03	3,90	3,85	1,28	
44	0,5	0,72	1,44	0,96	0,94	2,08	1,91	1,9	0,52	3,83	3,81	0,52	
45	0,5	0,725	1,45	0,94	0,93	1,06	1,88	1,87	0,53	3,75	3,74	0,27	
46	0,5	0,73	1,46	0,92	0,91	1,09	1,84	1,83	0,54	3,69	3,67	0,54	
47	0,5	0,735	1,47	0,90	0,9	0,00	1,81	1,8	0,55	3,62	3,6	0,55	
48	0,5	0,74	1,48	0,89	0,88	1,12	1,78	1,76	1,12	3,56	3,53	0,84	
49	0,5	0,745	1,49	0,87	0,87	0	1,75	1,74	0,57	3,50	3,47	0,86	
50	0,5	0,75	1,5	0,86	0,85	1,16	1,72	1,71	0,58	3,44	3,4	1,16	
Average error						1,66				1,35			

Table 6 shows the comparison between the test results of the overcurrent relay type standard inverse time at the setting current (Is) 0.5 A and the variation of the Time Multiplier Setting (TMS) of 0.05, 0.1, and 0.2. The comparison shows that the average error is below 2 percent. The average error for Time Multiplier Setting (TMS) 0.05 is 1.66 percent, Time Multiplier Setting (TMS) 0.1 is 1.35 percent, and Time Multiplier Setting 0.02 is 1.27 percent. This value shows that the device is designed to be built with a setting current (Is) of 0.5 A and a variation of Time Multiplier Setting (TMS) of 0.05, 0.1, and 0.2 has been in accordance with the characteristics of standard inverse time with an average error of less than 2 percent. A comparison graph between the test results and the calculation of the overcurrent relay type standard inverse time at the setting current (Is) 0.5 A with the variation of the Time Multiplier Setting (TMS) of 0.05, 0.1 and 0.2 can be seen in Figure 12.

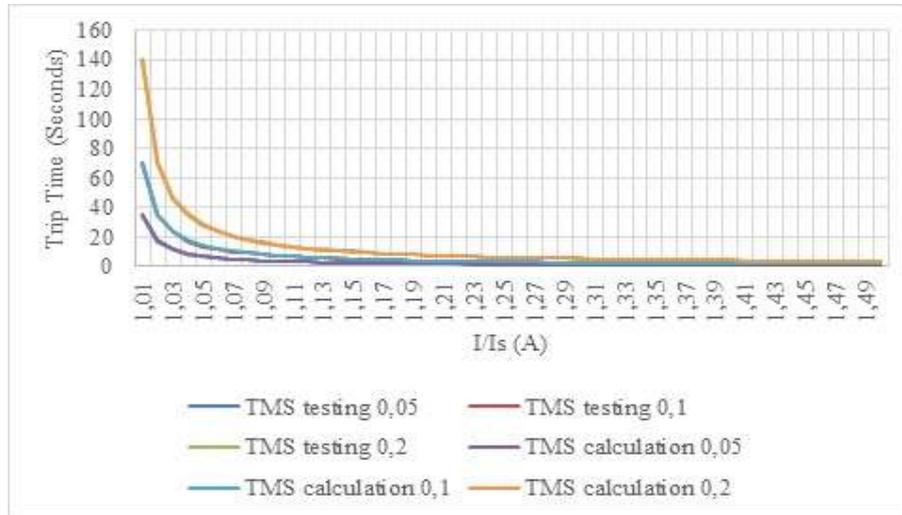


Figure 12. Comparison chart between test results with the calculation of overcurrent relay type standard inverse at setting current (Is) 0.5 A with Time Multiplier Setting (TMS) variation of 0.05, 0.1, and 0.2

Figure 12 shows a comparison graph between the test results and the calculation of the overcurrent relay type standard inverse at the setting current (Is) 0.5 A with the Time Multiplier Setting (TMS) variation of 0.05, 0.1, and 0.2. The graph has 2 axes, namely, the x axis I/Is in units of Ampere and the y axis which shows the time of the trip in units of seconds. There are 6 curves on this graph, namely the test curve and calculation at TMS 0.05, 0.1 and 0.2. The test curve colors on TMS 0.05, 0.1 and 0.2 are blue, red, and green. Meanwhile, the calculation curves on TMS 0.05, 0.1, and 0.2 are purple, light blue, and orange. These curves show that the larger the current flowing, the faster the trip time occurs. Conversely, the greater the Time Multiplier Setting (TMS) value, the longer the trip time will be. This shows that the device is designed to be built with a setting current (Is) of 0.5 A and a variation of Time Multiplier Setting (TMS) of 0.05, 0.1, and 0.2 has been in accordance with the characteristics of standard inverse time. The second stage of testing was carried out 50 times at the current setting (Is) 1 A with a Time Multiplier Setting (TMS) variation of 0.05, 0.1, and 0.2. The purpose of this test is to test the device designed to be built according to the characteristics of the standard inverse time and the accuracy of the tool at the setting current (Is) 1 A with a Time Multiplier Setting (TMS) variation of 0.05, 0.1, and 0.2. The comparison between the test results and calculation of overcurrent relay type standard inverse time at the setting current (Is) 1 A with the variation of Time Multiplier Setting (TMS) of 0.05, 0.1, and 0.2 can be seen in Table 7.

TABLE 7. COMPARISON BETWEEN TEST RESULTS AND CALCULATION OF OVERCURRENT RELAY TYPE STANDARD INVERSE TIME AT CURRENT SETTING (IS) 1 A WITH TIME MULTIPLIER SETTING (TMS) VARIATIONS OF 0.05, 0.1, AND 0.2

No.	IS(A)	I(A)	I/Is(A)	TMS 0.05			TMS 0.1			TMS 0.2		
				Calculated trip time (seconds)	Test trip time (sec)	Error(%)	Calculated trip time (seconds)	Test trip time (sec)	Error(%)	Calculated trip time (seconds)	Test trip time (sec)	Error(%)
1	1	1,01	1,01	35,17	35,59	1,19	70,34	71,18	1,19	140,68	142,36	1,19
2	1	1,02	1,02	17,67	17,84	0,96	35,34	33,99	3,82	70,68	67,98	3,82
3	1	1,03	1,03	11,84	11,94	0,84	23,67	22,4	5,37	47,35	44,81	5,36
4	1	1,04	1,04	8,92	8,99	0,78	17,84	17,55	1,63	35,68	35,97	0,81
5	1	1,05	1,05	7,17	7,09	1,12	14,34	14,45	0,77	28,68	28,31	1,29
6	1	1,06	1,06	6,00	6,05	0,83	12,01	11,72	2,41	24,01	23,81	0,83
7	1	1,07	1,07	5,17	5,14	0,58	10,34	10,27	0,68	20,68	20,83	0,73



No.	IS(A)	I(A)	I/Is(A)	TMS 0.05			TMS 0.1			TMS 0.2			
				Calculated trip time (seconds)	Test trip time (sec)	Error(%)	Calculated trip time (seconds)	Test trip time (sec)	Error(%)	Calculated trip time (seconds)	Test trip time (sec)	Error(%)	
8	1	1,08	1,08	4,54	4,58	0,88	9,09	9,38	3,19	18,18	18,09	0,50	
9	1	1,09	1,09	4,06	4,09	0,74	8,12	8	1,48	16,23	16,35	0,74	
10	1	1,1	1,1	3,67	3,63	1,09	7,34	7,32	0,27	14,67	14,92	1,70	
11	1	1,11	1,11	3,35	3,43	2,39	6,70	6,69	0,15	13,40	13,61	1,57	
12	1	1,12	1,12	3,08	3,13	1,62	6,17	6,12	0,81	12,34	12,53	1,54	
13	1	1,13	1,13	2,86	2,84	0,70	5,72	5,72	0,00	11,44	11,61	1,49	
14	1	1,14	1,14	2,67	2,65	0,75	5,34	5,34	0,00	10,67	10,67	0,00	
15	1	1,15	1,15	2,50	2,53	1,20	5,00	5	0,00	10,00	10,07	0,70	
16	1	1,16	1,16	2,35	2,37	0,85	4,71	4,74	0,64	9,42	9,48	0,64	
17	1	1,17	1,17	2,23	2,23	0,00	4,45	4,43	0,45	8,90	8,87	0,34	
18	1	1,18	1,18	2,11	2,11	0,00	4,22	4,25	0,71	8,44	8,5	0,71	
19	1	1,19	1,19	2,01	2,02	0,50	4,02	4,02	0,00	8,03	8,05	0,25	
20	1	1,2	1,2	1,92	1,92	0,00	3,83	3,86	0,78	7,66	7,65	0,13	
21	1	1,21	1,21	1,83	1,83	0,00	3,67	3,64	0,82	7,33	7,38	0,68	
22	1	1,22	1,22	1,76	1,75	0,57	3,51	3,52	0,28	7,03	6,99	0,57	
23	1	1,23	1,23	1,69	1,69	0,00	3,37	3,34	0,89	6,75	6,74	0,15	
24	1	1,24	1,24	1,62	1,62	0,00	3,25	3,24	0,31	6,49	6,51	0,31	
25	1	1,25	1,25	1,56	1,57	0,64	3,13	3,16	0,96	6,26	6,28	0,32	
26	1	1,26	1,26	1,51	1,52	0,66	3,02	3,03	0,33	6,04	6,04	0,00	
27	1	1,27	1,27	1,46	1,46	0,00	2,92	2,94	0,68	5,84	5,88	0,68	
28	1	1,28	1,28	1,41	1,42	0,71	2,83	2,83	0,00	5,66	5,66	0,00	
29	1	1,29	1,29	1,37	1,38	0,73	2,74	2,76	0,73	5,48	5,5	0,36	
30	1	1,3	1,3	1,33	1,34	0,75	2,66	2,67	0,38	5,32	5,31	0,19	
31	1	1,31	1,31	1,29	1,29	0,00	2,59	2,59	0,00	5,17	5,15	0,39	
32	1	1,32	1,32	1,26	1,25	0,79	2,51	2,52	0,40	5,03	5,03	0,00	
33	1	1,33	1,33	1,22	1,22	0,00	2,45	2,45	0,00	4,90	4,93	0,61	
34	1	1,34	1,34	1,19	1,19	0,00	2,38	2,38	0,00	4,77	4,76	0,21	
35	1	1,35	1,35	1,16	1,16	0,00	2,33	2,32	0,43	4,65	4,66	0,22	
36	1	1,36	1,36	1,13	1,13	0,00	2,27	2,28	0,44	4,54	4,55	0,22	
37	1	1,37	1,37	1,11	1,11	0,00	2,22	2,23	0,45	4,43	4,41	0,45	
38	1	1,38	1,38	1,08	1,08	0,00	2,17	2,15	0,92	4,33	4,33	0,00	
39	1	1,39	1,39	1,06	1,05	0,94	2,12	2,12	0,00	4,24	4,18	1,42	
40	1	1,4	1,4	1,04	1,03	0,96	2,07	2,07	0,00	4,15	4,14	0,24	
41	1	1,41	1,41	1,02	1,02	0,00	2,03	2,03	0,00	4,06	4,07	0,25	
42	1	1,42	1,42	0,99	0,99	0,00	1,99	1,99	0,00	3,98	3,97	0,25	
43	1	1,43	1,43	0,98	0,98	0,00	1,95	1,95	0,00	3,90	3,89	0,26	
44	1	1,44	1,44	0,96	0,96	0,00	1,91	1,9	0,52	3,83	3,83	0,00	
45	1	1,45	1,45	0,94	0,94	0,00	1,88	1,88	0,00	3,75	3,76	0,27	
46	1	1,46	1,46	0,92	0,92	0,00	1,84	1,84	0,00	3,69	3,69	0,00	
47	1	1,47	1,47	0,90	0,91	1,11	1,81	1,81	0,00	3,62	3,62	0,00	
48	1	1,48	1,48	0,89	0,89	0,00	1,78	1,78	0,00	3,56	3,55	0,28	
49	1	1,49	1,49	0,87	0,88	1,15	1,75	1,75	0,00	3,50	3,5	0,00	
50	1	1,5	1,5	0,86	0,86	0,00	1,72	1,73	0,58	3,44	3,43	0,29	
Average error						0,52				0,67			

Table 7 shows the comparison between the test results and the calculation of the overcurrent relay type standard inverse time at the setting current (I_s) 1 A with the Time Multiplier Setting (TMS) variation of 0.05, 0.1, and 0.2. The comparison shows that the average error is below 1 percent. The average error for Time Multiplier Setting (TMS) 0.05 is 0.52 percent, Time Multiplier Setting (TMS) 0.1 is 0.67 percent, and Time Multiplier Setting 0.02 is 0.66 percent. This value shows that the device designed to build with a setting current (I_s) of 1 A and a variation of Time Multiplier Setting (TMS) of 0.05, 0.1, and 0.2 has been in accordance with the characteristics of standard inverse time with an average error of less than 1 percent. A comparison graph between the test results and the calculation of overcurrent relay type standard inverse time at the setting current (I_s) 1 A with the variation of Time Multiplier Setting (TMS) of 0.05, 0.1 and 0.2 can be seen in Figure 13.

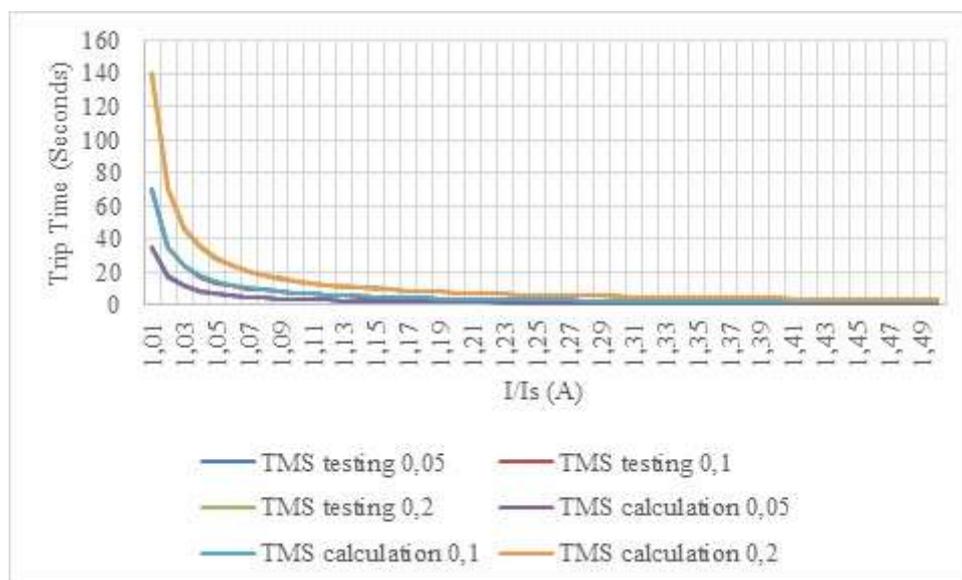


Figure 13. Comparison chart between test results and calculation of overcurrent relay type standard inverse at setting current (I_s) 1 A with Time Multiplier Setting (TMS) variations of 0.05, 0.1, and 0.2

Figure 13 shows a comparison graph between the test results and the calculation of the overcurrent relay type standard inverse time at the setting current (I_s) with the Time Multiplier Setting (TMS) variation of 0.05, 0.1, and 0.2. The graph has 2 axes, namely, the x axis I/I_s in units of Ampere and the y axis which shows the time of the trip in units of seconds. There are 6 curves on this graph, namely the test curve and calculation at TMS 0.05, 0.1 and 0.2. The test curve colors on TMS 0.05, 0.1 and 0.2 are blue, red, and green. Meanwhile, the calculation curves on TMS 0.05, 0.1, and 0.2 are purple, light blue, and orange. These curves show that the larger the current flowing, the faster the trip time occurs. Conversely, the greater the Time Multiplier Setting (TMS) value, the longer the trip time will be. This shows that the device is designed to be built with a setting current (I_s) of 1 A and a variation of Time Multiplier Setting (TMS) of 0.05, 0.1, and 0.2 has been in accordance with the characteristics of standard inverse time. The third stage of testing was carried out 50 times at a setting current (I_s) of 1.5 A with a variation of Time Multiplier Setting (TMS) of 0.05, 0.1, and 0.2. The purpose of this test is to test the device designed to be built according to the characteristics of the standard inverse time and the accuracy of the device at the setting current (I_s) of 1.5 A with a Time Multiplier Setting (TMS) variation of 0.05, 0.1, and 0.2. The comparison between the test results and the calculation of the overcurrent relay type standard inverse time at the setting current (I_s) of 1.5 A with the variation of Time Multiplier Setting (TMS) of 0.05, 0.1, and 0.2 can be seen in Table 8.



TABLE 8. COMPARISON BETWEEN TEST RESULTS AND CALCULATION OF OVERCURRENT RELAY TYPE STANDARD INVERSE TIME AT SETTING CURRENT (IS) 1.5 A WITH TIME MULTIPLIER SETTING (TMS) VARIATIONS OF 0.05, 0.1, AND 0.2

No.	IS(A)	I(A)	I/Is(A)	TMS 0.05			TMS 0.1			TMS 0.2		
				Calculated trip time (seconds)	Test trip time (sec)	Error(%)	Calculated trip time (seconds)	Test trip time (sec)	Error(%)	Calculated trip time (seconds)	Test trip time (sec)	Error(%)
1	1,5	1,515	1,01	35,17	36,82	4,69	70,34	73,63	4,68	140,68	137,76	2,08
2	1,5	1,53	1,02	17,67	17,54	0,74	35,34	35,09	0,71	70,68	70,18	0,71
3	1,5	1,545	1,03	11,84	12,34	4,22	23,67	24,68	4,27	47,35	49,36	4,24
4	1,5	1,56	1,04	8,92	8,58	3,81	17,84	17,16	3,81	35,68	34,32	3,81
5	1,5	1,575	1,05	7,17	7,18	0,14	14,34	14,36	0,14	28,68	28,72	0,14
6	1,5	1,59	1,06	6,00	5,89	1,83	12,01	11,54	3,91	24,01	23,08	3,87
7	1,5	1,605	1,07	5,17	5,05	2,32	10,34	10,1	2,32	20,68	20,2	2,32
8	1,5	1,62	1,08	4,54	4,42	2,64	9,09	8,84	2,75	18,18	17,95	1,27
9	1,5	1,635	1,09	4,06	4,1	0,99	8,12	8,2	0,99	16,23	16,4	1,05
10	1,5	1,65	1,1	3,67	3,59	2,18	7,34	7,23	1,50	14,67	14,37	2,04
11	1,5	1,665	1,11	3,35	3,36	0,30	6,70	6,73	0,45	13,40	13,46	0,45
12	1,5	1,68	1,12	3,08	3,08	0,00	6,17	6,23	0,97	12,34	12,27	0,57
13	1,5	1,695	1,13	2,86	2,83	1,05	5,72	5,66	1,05	11,44	11,49	0,44
14	1,5	1,71	1,14	2,67	2,66	0,37	5,34	5,34	0,00	10,67	10,53	1,31
15	1,5	1,725	1,15	2,50	2,49	0,40	5,00	4,96	0,80	10,00	9,97	0,30
16	1,5	1,74	1,16	2,35	2,35	0,00	4,71	4,68	0,64	9,42	9,43	0,11
17	1,5	1,755	1,17	2,23	2,24	0,45	4,45	4,41	0,90	8,90	8,85	0,56
18	1,5	1,77	1,18	2,11	2,09	0,95	4,22	4,19	0,71	8,44	8,34	1,18
19	1,5	1,785	1,19	2,01	2,01	0,00	4,02	4,01	0,25	8,03	8,05	0,25
20	1,5	1,8	1,2	1,92	1,92	0,00	3,83	3,84	0,26	7,66	7,63	0,39
21	1,5	1,815	1,21	1,83	1,82	0,55	3,67	3,64	0,82	7,33	7,28	0,68
22	1,5	1,83	1,22	1,76	1,75	0,57	3,51	3,5	0,28	7,03	7,01	0,28
23	1,5	1,845	1,23	1,69	1,68	0,59	3,37	3,37	0,00	6,75	6,73	0,30
24	1,5	1,86	1,24	1,62	1,63	0,62	3,25	3,24	0,31	6,49	6,45	0,62
25	1,5	1,875	1,25	1,56	1,56	0,00	3,13	3,12	0,32	6,26	6,25	0,16
26	1,5	1,89	1,26	1,51	1,51	0,00	3,02	3	0,66	6,04	6,02	0,33
27	1,5	1,905	1,27	1,46	1,45	0,68	2,92	2,92	0,00	5,84	5,85	0,17
28	1,5	1,92	1,28	1,41	1,42	0,71	2,83	2,83	0,00	5,66	5,64	0,35
29	1,5	1,935	1,29	1,37	1,37	0,00	2,74	2,73	0,36	5,48	5,47	0,18
30	1,5	1,95	1,3	1,33	1,32	0,75	2,66	2,66	0,00	5,32	5,32	0,00
31	1,5	1,965	1,31	1,29	1,29	0,00	2,59	2,57	0,77	5,17	5,15	0,39
32	1,5	1,98	1,32	1,26	1,25	0,79	2,51	2,5	0,40	5,03	5,02	0,20
33	1,5	1,995	1,33	1,22	1,22	0,00	2,45	2,44	0,41	4,90	4,88	0,41
34	1,5	2,01	1,34	1,19	1,19	0,00	2,38	2,38	0,00	4,77	4,75	0,42
35	1,5	2,025	1,35	1,16	1,16	0,00	2,33	2,32	0,43	4,65	4,64	0,22
36	1,5	2,04	1,36	1,13	1,13	0,00	2,27	2,27	0,00	4,54	4,52	0,44
37	1,5	2,055	1,37	1,11	1,11	0,00	2,22	2,21	0,45	4,43	4,43	0,00
38	1,5	2,07	1,38	1,08	1,08	0,00	2,17	2,15	0,92	4,33	4,33	0,00
39	1,5	2,085	1,39	1,06	1,05	0,94	2,12	2,09	1,42	4,24	4,22	0,47
40	1,5	2,1	1,4	1,04	1,03	0,96	2,07	2,06	0,48	4,15	4,12	0,72
41	1,5	2,115	1,41	1,02	1,01	0,98	2,03	2,02	0,49	4,06	4,05	0,25



No.	IS(A)	I(A)	I/Is(A)	TMS 0.05			TMS 0.1			TMS 0.2			
				Calculated trip time (seconds)	Test trip time (sec)	Error(%)	Calculated trip time (seconds)	Test trip time (sec)	Error(%)	Calculated trip time (seconds)	Test trip time (sec)	Error(%)	
42	1,5	2,13	1,42	0,99	0,99	0,00	1,99	1,99	0,00	3,98	3,97	0,25	
43	1,5	2,145	1,43	0,98	0,97	1,02	1,95	1,94	0,51	3,90	3,88	0,51	
44	1,5	2,16	1,44	0,96	0,95	1,04	1,91	1,89	1,05	3,83	3,8	0,78	
45	1,5	2,175	1,45	0,94	0,94	0,00	1,88	1,87	0,53	3,75	3,75	0,00	
46	1,5	2,19	1,46	0,92	0,92	0,00	1,84	1,84	0,00	3,69	3,68	0,27	
47	1,5	2,205	1,47	0,90	0,91	1,11	1,81	1,82	0,55	3,62	3,63	0,28	
48	1,5	2,22	1,48	0,89	0,89	0,00	1,78	1,77	0,56	3,56	3,54	0,56	
49	1,5	2,235	1,49	0,87	0,87	0,00	1,75	1,74	0,57	3,50	3,49	0,29	
50	1,5	2,25	1,5	0,86	0,86	0,00	1,72	1,7	1,16	3,44	3,42	0,58	
Average error						0,77				0,89			

Table 8 shows the comparison between the test results and the calculation of the overcurrent relay type standard inverse time at the setting current (Is) of 1.5 A with the variation of Time Multiplier Setting (TMS) of 0.05, 0.1, and 0.2. The comparison shows that the average error is below 1 percent. The average error for Time Multiplier Setting (TMS) 0.05 is 0.77 percent, Time Multiplier Setting (TMS) 0.1 is 0.89 percent, and Time Multiplier Setting is 0.02 is 0.74 percent. This value shows that the device is designed to be built with a setting current (Is) of 1.5 A and a variation of Time Multiplier Setting (TMS) of 0.05, 0.1, and 0.2 has been in accordance with the characteristics of standard inverse time with an average error of less than 1 percent. A comparison graph between the test results and the calculation of the overcurrent relay type standard inverse time at the setting current (Is) 1.5 A with the variation of Time Multiplier Setting (TMS) of 0.05, 0.1 and 0.2 can be seen in Figure 14.

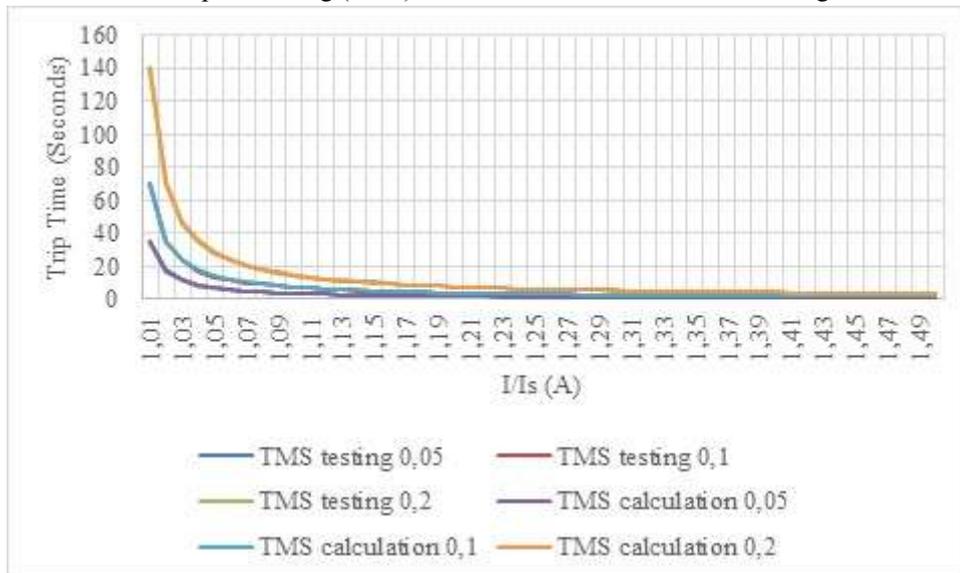


Figure 14. Graph of the comparison between the test results and the calculation of the overcurrent relay type standard inverse at the setting current (Is) 1.5 A with the variation of Time Multiplier Setting (TMS) of 0.05, 0.1, and 0.2

Figure 14 shows a comparison graph between the test results and the calculation of the overcurrent relay type standard inverse at the setting current (Is) of 1.5 A with the Time Multiplier Setting (TMS) variation of 0.05, 0.1, and 0.2. The graph has 2 axes, namely, the x axis I/Is in units of Ampere and the y axis which shows the time of the trip in units of seconds. There are 6 curves on this graph, namely the test curve and calculation at TMS 0.05, 0.1 and 0.2. The test curve colors on TMS 0.05, 0.1 and 0.2 are



blue, red, and green. Meanwhile, the calculation curves on TMS 0.05, 0.1, and 0.2 are purple, light blue, and orange. These curves show that the larger the current flowing, the faster the trip time occurs. Conversely, the greater the Time Multiplier Setting (TMS) value, the longer the trip time will be. This shows that the device is designed to be built with a setting current (Is) of 1.5 A and a variation of Time Multiplier Setting (TMS) of 0.05, 0.1, and 0.2 has been in accordance with the characteristics of the standard inverse time. Based on the results of the overcurrent relay type standard inverse time test from the first to the third stage, it can be concluded that the designed tool works according to the characteristics of the standard inverse curve consistently and accurately. This is proven through testing on the variation of the current setting (Is) and Time Multiplier Setting (TMS) which shows very low errors. At a setting current of 0.5 A with TMS variations of 0.05, 0.1, and 0.2, the average error is all below 2 percent. Meanwhile, in the Setting 1 A and 1.5 A currents with the same TMS variation, the average error is less than 1 percent. Thus, the designed tool successfully meets the performance criteria according to the characteristics of the standard inverse time and demonstrates stability and reliability under various test conditions.

D. Constant Time Type Overcurrent Relay Accuracy Testing

Constant time overcurrent relay type accuracy testing is carried out to determine that the designed tool is in accordance with the characteristics of constant time and accuracy of the tool. This test is carried out at an AC voltage of 220 V. Testing is carried out in four stages, namely, the first stage of testing with a variation of setting current (Is) of 0.5 A, 1 A, and 1.5 A with a fixed setting time of 10 seconds. Furthermore, the second to fourth stages were tested with each at the setting current (Is) of 0.5 A, 1 A, and 1.5 A with a setting time variation of 5, 10, and 15 seconds. The first stage of testing was carried out fifty times at a variation of setting currents (Is) of 0.5 A, 1 A, and 1.5 A with a setting time of 10 seconds. The purpose of this test is to test the device designed to be built according to the constant time characteristics and accuracy of the device at the variation of setting currents (Is) of 0.5 A, 1 A, and 1.5 A with a fixed setting time of 10 seconds. The results of the overcurrent relay test type constant time at setting currents (Is) 0.5 A, 1 A, and 1.5 A with a fixed setting time of 10 seconds can be seen in Table 9.

TABLE 9. TEST RESULTS OF OVERCURRENT RELAY TYPE CONSTANT TIME AT SETTING CURRENT VARIATIONS (IS) OF 0.5 A, 1 A, AND 1.5 A WITH A FIXED SETTING TIME OF 10 SECONDS

No.	I(A)	Is 0.5 A			Is 1 A			Is 1.5		
		Setting time(sec)	Trip time (sec)	Error(%)	Setting time(sec)	Trip time (sec)	Error(%)	Setting time(sec)	Trip time (sec)	Error(%)
1	1,51	10	10	0	10	10	0	10	10	0
2	1,52	10	10	0	10	10	0	10	10	0
3	1,53	10	10	0	10	10	0	10	10	0
4	1,54	10	10	0	10	10	0	10	10	0
5	1,55	10	10	0	10	10	0	10	10	0
6	1,56	10	10	0	10	10	0	10	10	0
7	1,57	10	10	0	10	10	0	10	10	0
8	1,58	10	10	0	10	10	0	10	10	0
9	1,59	10	10	0	10	10	0	10	10	0
10	1,6	10	10	0	10	10	0	10	10	0
11	1,61	10	10	0	10	10	0	10	10	0
12	1,62	10	10	0	10	10	0	10	10	0
13	1,63	10	10	0	10	10	0	10	10	0
14	1,64	10	10	0	10	10	0	10	10	0
15	1,65	10	10	0	10	10	0	10	10	0
16	1,66	10	10	0	10	10	0	10	10	0
17	1,67	10	10	0	10	10	0	10	10	0
18	1,68	10	10	0	10	10	0	10	10	0
19	1,69	10	10	0	10	10	0	10	10	0



No.	I(A)	Is 0.5 A			Is 1 A			Is 1.5			
		Setting time(sec)	Trip time (sec)	Error(%)	Setting time(sec)	Trip time (sec)	Error(%)	Setting time(sec)	Trip time (sec)	Error(%)	
20	1,7	10	10	0	10	10	0	10	10	0	
21	1,71	10	10	0	10	10	0	10	10	0	
22	1,72	10	10	0	10	10	0	10	10	0	
23	1,73	10	10	0	10	10	0	10	10	0	
24	1,74	10	10	0	10	10	0	10	10	0	
25	1,75	10	10	0	10	10	0	10	10	0	
26	1,76	10	10	0	10	10	0	10	10	0	
27	1,77	10	10	0	10	10	0	10	10	0	
28	1,78	10	10	0	10	10	0	10	10	0	
29	1,79	10	10	0	10	10	0	10	10	0	
30	1,8	10	10	0	10	10	0	10	10	0	
31	1,81	10	10	0	10	10	0	10	10	0	
32	1,82	10	10	0	10	10	0	10	10	0	
33	1,83	10	10	0	10	10	0	10	10	0	
34	1,84	10	10	0	10	10	0	10	10	0	
35	1,85	10	10	0	10	10	0	10	10	0	
36	1,86	10	10	0	10	10	0	10	10	0	
37	1,87	10	10	0	10	10	0	10	10	0	
38	1,88	10	10	0	10	10	0	10	10	0	
39	1,89	10	10	0	10	10	0	10	10	0	
40	1,9	10	10	0	10	10	0	10	10	0	
41	1,91	10	10	0	10	10	0	10	10	0	
42	1,92	10	10	0	10	10	0	10	10	0	
43	1,93	10	10	0	10	10	0	10	10	0	
44	1,94	10	10	0	10	10	0	10	10	0	
45	1,95	10	10	0	10	10	0	10	10	0	
46	1,96	10	10	0	10	10	0	10	10	0	
47	1,97	10	10	0	10	10	0	10	10	0	
48	1,98	10	10	0	10	10	0	10	10	0	
49	1,99	10	10	0	10	10	0	10	10	0	
50	2	10	10	0	10	10	0	10	10	0	
Average error (%)				0					0		

Table 9 shows the results of the overcurrent relay type constant time test at the variation of setting current (Is) of 0.5 A, 1 A, and 1.5 A with a fixed setting time of 10 seconds. The results of the test showed that the average error of all variations in the setting current (Is) was 0 percent. This shows that the device designed to be built with a variation of setting currents (Is) of 0.5 A, 1 A, and 1.5 A with a fixed setting time of 10 seconds has been in accordance with the characteristics of constant time with an average error of all variations of 0 percent. The graph of the results of the overcurrent relay type constant time test at the variation of setting currents (Is) of 0.5 A, 1 A, and 1.5 with a fixed setting time of 10 seconds can be seen in Figure 15.

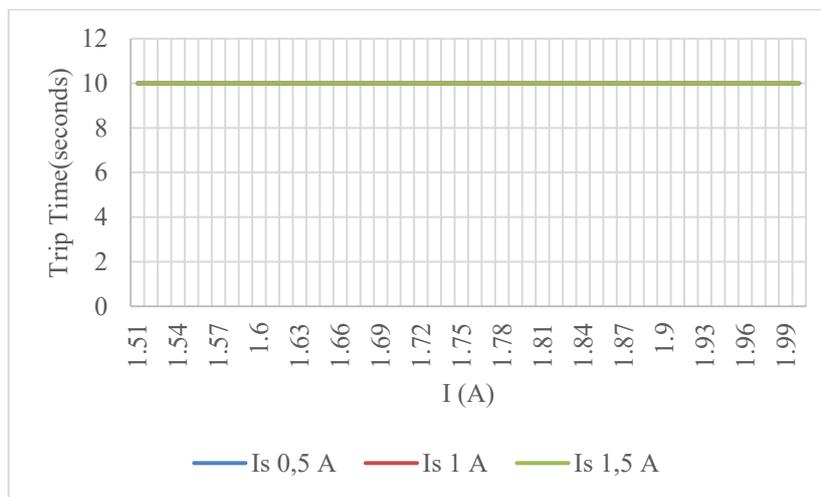


Figure 15. Graph of the results of the overcurrent relay type constant time test at the variation of setting current (Is) of 0.5 A, 1 A, and 1.5 A with a fixed setting time of 10 seconds

Figure 15 shows a graph of the results of the overcurrent relay type constant time test at the variation of setting currents (Is) of 0.5 A, 1 A, and 1.5 A. The graph has 2 axes, namely, the x axis I with the unit of Ampere and the y axis which shows the trip time in units of seconds. There are 3 curves, namely, the Is curve 0.5 A, 1 A, and 1.5 A with the color of the curve Is 0.5 A blue, Is 1 A red and Is 1.5 A green. These curves show that no matter how much current flows, the time of the trip that occurs is according to the setting time. This shows that the device is designed to be built with a variation of setting currents (Is) of 0.5 A, 1 A, and 1.5 A and a fixed setting time of 10 seconds has been in accordance with the characteristics of constant time.

The second stage of testing was carried out fifty times at a setting current (Is) of 0.5 A with a setting time variation of 5, 10, and 15 seconds. The purpose of this test is to test the device that is designed to be built according to the characteristics of the constant time and accuracy of the device at the setting current (Is) 0.5 A with a setting time variation of 5, 10, and 15 seconds. The results of the overcurrent relay type constant time test at the setting current (Is) 0.5 A with a setting time variation of 5, 10, and 15 seconds can be seen in Table 10.

TABLE 10. TEST RESULTS OF OVERCURRENT RELAY TYPE CONSTANT TIME AT SETTING CURRENT (IS) 0.5 A WITH SETTING TIME VARIATIONS OF 5, 10, AND 15 SECONDS

No.	IS(A)	I(A)	Setting time(sec)	Trip time (sec)	Error(%)	Setting time(sec)	Trip time (sec)	Error(%)	Setting time(sec)	Trip time (sec)	Error(%)
1	0,5	1,51	5	5	0	10	10	0	15	15	0
2	0,5	1,52	5	5	0	10	10	0	15	15	0
3	0,5	1,53	5	5	0	10	10	0	15	15	0
4	0,5	1,54	5	5	0	10	10	0	15	15	0
5	0,5	1,55	5	5	0	10	10	0	15	15	0
6	0,5	1,56	5	5	0	10	10	0	15	15	0
7	0,5	1,57	5	5	0	10	10	0	15	15	0
8	0,5	1,58	5	5	0	10	10	0	15	15	0
9	0,5	1,59	5	5	0	10	10	0	15	15	0
10	0,5	1,6	5	5	0	10	10	0	15	15	0
11	0,5	1,61	5	5	0	10	10	0	15	15	0
12	0,5	1,62	5	5	0	10	10	0	15	15	0
13	0,5	1,63	5	5	0	10	10	0	15	15	0



No.	IS(A)	I(A)	Setting time(sec)	Trip time (sec)	Error(%)	Setting time(sec)	Trip time (sec)	Error(%)	Setting time(sec)	Trip time (sec)	Error(%)
14	0,5	1,64	5	5	0	10	10	0	15	15	0
15	0,5	1,65	5	5	0	10	10	0	15	15	0
16	0,5	1,66	5	5	0	10	10	0	15	15	0
17	0,5	1,67	5	5	0	10	10	0	15	15	0
18	0,5	1,68	5	5	0	10	10	0	15	15	0
19	0,5	1,69	5	5	0	10	10	0	15	15	0
20	0,5	1,7	5	5	0	10	10	0	15	15	0
21	0,5	1,71	5	5	0	10	10	0	15	15	0
22	0,5	1,72	5	5	0	10	10	0	15	15	0
23	0,5	1,73	5	5	0	10	10	0	15	15	0
24	0,5	1,74	5	5	0	10	10	0	15	15	0
25	0,5	1,75	5	5	0	10	10	0	15	15	0
26	0,5	1,76	5	5	0	10	10	0	15	15	0
27	0,5	1,77	5	5	0	10	10	0	15	15	0
28	0,5	1,78	5	5	0	10	10	0	15	15	0
29	0,5	1,79	5	5	0	10	10	0	15	15	0
30	0,5	1,8	5	5	0	10	10	0	15	15	0
31	0,5	1,81	5	5	0	10	10	0	15	15	0
32	0,5	1,82	5	5	0	10	10	0	15	15	0
33	0,5	1,83	5	5	0	10	10	0	15	15	0
34	0,5	1,84	5	5	0	10	10	0	15	15	0
35	0,5	1,85	5	5	0	10	10	0	15	15	0
36	0,5	1,86	5	5	0	10	10	0	15	15	0
37	0,5	1,87	5	5	0	10	10	0	15	15	0
38	0,5	1,88	5	5	0	10	10	0	15	15	0
39	0,5	1,89	5	5	0	10	10	0	15	15	0
40	0,5	1,9	5	5	0	10	10	0	15	15	0
41	0,5	1,91	5	5	0	10	10	0	15	15	0
42	0,5	1,92	5	5	0	10	10	0	15	15	0
43	0,5	1,93	5	5	0	10	10	0	15	15	0
44	0,5	1,94	5	5	0	10	10	0	15	15	0
45	0,5	1,95	5	5	0	10	10	0	15	15	0
46	0,5	1,96	5	5	0	10	10	0	15	15	0
47	0,5	1,97	5	5	0	10	10	0	15	15	0
48	0,5	1,98	5	5	0	10	10	0	15	15	0
49	0,5	1,99	5	5	0	10	10	0	15	15	0
50	0,5	2	5	5	0	10	10	0	15	15	0
Average error (%)					0						0

Table 10 shows the results of the overcurrent relay type constant time test at the setting current (Is) 0.5 A with a setting time variation of 5, 10, and 15 seconds. The test results showed that the average error on all settings time variations was 0 percent. This shows that the device is designed to wake up at a setting current (Is) of 0.5 A and the setting time variations of 5, 10, and 15 seconds have been in accordance with the characteristics of constant time with an average error of all setting time variations of 0 percent. Figure Graph of the results of the overcurrent relay type constant time test at the setting current (Is) 0.5 A with a setting time variation of 5, 10, and 15 seconds can be seen in Figure 16.

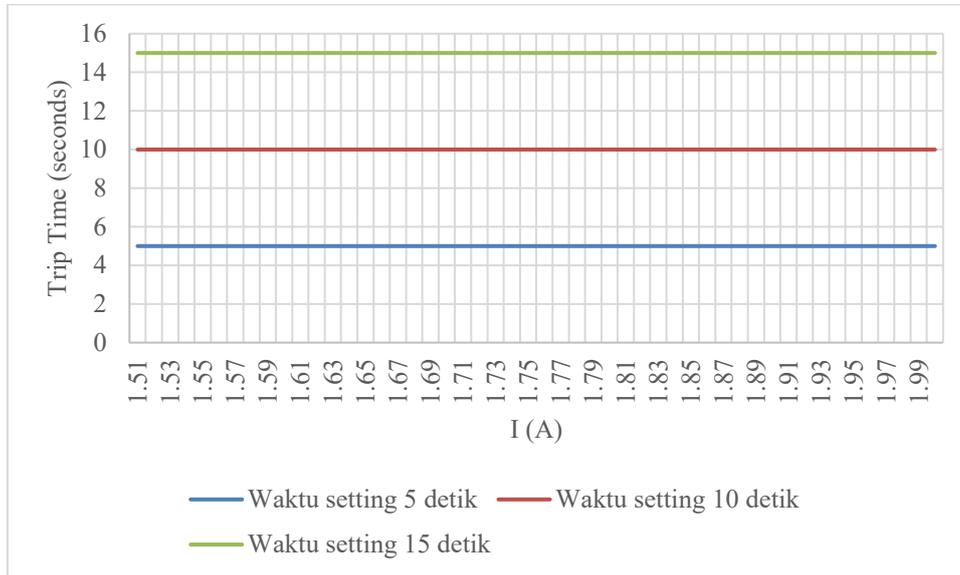


Figure 16. Graph of the results of the overcurrent relay type constant time test at the setting current (Is) 0.5 A with a setting time variation of 5, 10, and 15 seconds

Figure 16 shows a graph of the results of the overcurrent relay type constant time test at the setting current (Is) 0.5 A with a setting time variation of 5, 10, and 15 seconds. The graph has 2 axes, namely, the x I axis with the unit A and the y axis which shows the trip time in units of seconds. There are 3 curves, namely, the setting time curve of 5, 10, and 15 seconds with the color of the setting time curve of 5 seconds blue, 10 seconds red, and 15 seconds green. These curves show that whatever current flows during the trip that occurs according to the setting time. This shows that the device is designed to wake up with a setting current (Is) of 0.5 A and a setting time variation of 5, 10, and 15 seconds has been in accordance with the characteristics of constant time. The third stage of testing is the overcurrent relay type constant time test at the setting current (Is) 1 A with a setting time variation of 5, 10, and 15 seconds. This test was carried out to test the device designed to be built according to the characteristics of the constant time and accuracy of the tool at the setting current (Is) 1 A with a setting time variation of 5, 10, and 15 seconds. The results of the overcurrent relay type constant time test at the setting current (Is) 1 A with a setting time variation of 5, 10, and 15 seconds can be seen in Table 11.

TABEL11. HASIL TEST THE ACCURACY OF OVERCURRENT RELAY TYPE CONSTANT TIME AT SETTING CURRENT (IS) 1 A WITH SETTING TIMES OF 5, 10, AND 15 SECONDS

No.	IS(A)	I(A)	Setting time(sec)	Trip time (sec)	Error(%)	Setting time(sec)	Trip time (sec)	Error(%)	Setting time(sec)	Trip time (sec)	Error(%)
1	1	1,51	5	5	0	10	10	0	15	15	0
2	1	1,52	5	5	0	10	10	0	15	15	0
3	1	1,53	5	5	0	10	10	0	15	15	0
4	1	1,54	5	5	0	10	10	0	15	15	0
5	1	1,55	5	5	0	10	10	0	15	15	0
6	1	1,56	5	5	0	10	10	0	15	15	0
7	1	1,57	5	5	0	10	10	0	15	15	0
8	1	1,58	5	5	0	10	10	0	15	15	0
9	1	1,59	5	5	0	10	10	0	15	15	0
10	1	1,6	5	5	0	10	10	0	15	15	0
11	1	1,61	5	5	0	10	10	0	15	15	0



No.	IS(A)	I(A)	Setting time(sec)	Trip time (sec)	Error(%)	Setting time(sec)	Trip time (sec)	Error(%)	Setting time(sec)	Trip time (sec)	Error(%)
12	1	1,62	5	5	0	10	10	0	15	15	0
13	1	1,63	5	5	0	10	10	0	15	15	0
14	1	1,64	5	5	0	10	10	0	15	15	0
15	1	1,65	5	5	0	10	10	0	15	15	0
16	1	1,66	5	5	0	10	10	0	15	15	0
17	1	1,67	5	5	0	10	10	0	15	15	0
18	1	1,68	5	5	0	10	10	0	15	15	0
19	1	1,69	5	5	0	10	10	0	15	15	0
20	1	1,7	5	5	0	10	10	0	15	15	0
21	1	1,71	5	5	0	10	10	0	15	15	0
22	1	1,72	5	5	0	10	10	0	15	15	0
23	1	1,73	5	5	0	10	10	0	15	15	0
24	1	1,74	5	5	0	10	10	0	15	15	0
25	1	1,75	5	5	0	10	10	0	15	15	0
26	1	1,76	5	5	0	10	10	0	15	15	0
27	1	1,77	5	5	0	10	10	0	15	15	0
28	1	1,78	5	5	0	10	10	0	15	15	0
29	1	1,79	5	5	0	10	10	0	15	15	0
30	1	1,8	5	5	0	10	10	0	15	15	0
31	1	1,81	5	5	0	10	10	0	15	15	0
32	1	1,82	5	5	0	10	10	0	15	15	0
33	1	1,83	5	5	0	10	10	0	15	15	0
34	1	1,84	5	5	0	10	10	0	15	15	0
35	1	1,85	5	5	0	10	10	0	15	15	0
36	1	1,86	5	5	0	10	10	0	15	15	0
37	1	1,87	5	5	0	10	10	0	15	15	0
38	1	1,88	5	5	0	10	10	0	15	15	0
39	1	1,89	5	5	0	10	10	0	15	15	0
40	1	1,9	5	5	0	10	10	0	15	15	0
41	1	1,91	5	5	0	10	10	0	15	15	0
42	1	1,92	5	5	0	10	10	0	15	15	0
43	1	1,93	5	5	0	10	10	0	15	15	0
44	1	1,94	5	5	0	10	10	0	15	15	0
45	1	1,95	5	5	0	10	10	0	15	15	0
46	1	1,96	5	5	0	10	10	0	15	15	0
47	1	1,97	5	5	0	10	10	0	15	15	0
48	1	1,98	5	5	0	10	10	0	15	15	0
49	1	1,99	5	5	0	10	10	0	15	15	0
50	1	2	5	5	0	10	10	0	15	15	0
Average error (%)					0						0

Table 11 shows the results of the overcurrent relay type constant time test at the setting current (Is) 1 A with a setting time variation of 5, 10, and 15 seconds. The test results showed that the average error in all the setting time variations was 0 percent. This value shows that the device is designed to build on the setting current (Is) 1 A with a setting time variation of 5, 10, and 15 seconds has been in accordance with the characteristics of constant time with an average error in all setting time variations of 0



percent. Figure Graph of the test results of the overcurrent relay type constant time at the setting current (Is) 0.5 A with a variation of 5, 10, and 15 seconds can be seen in Figure 17.

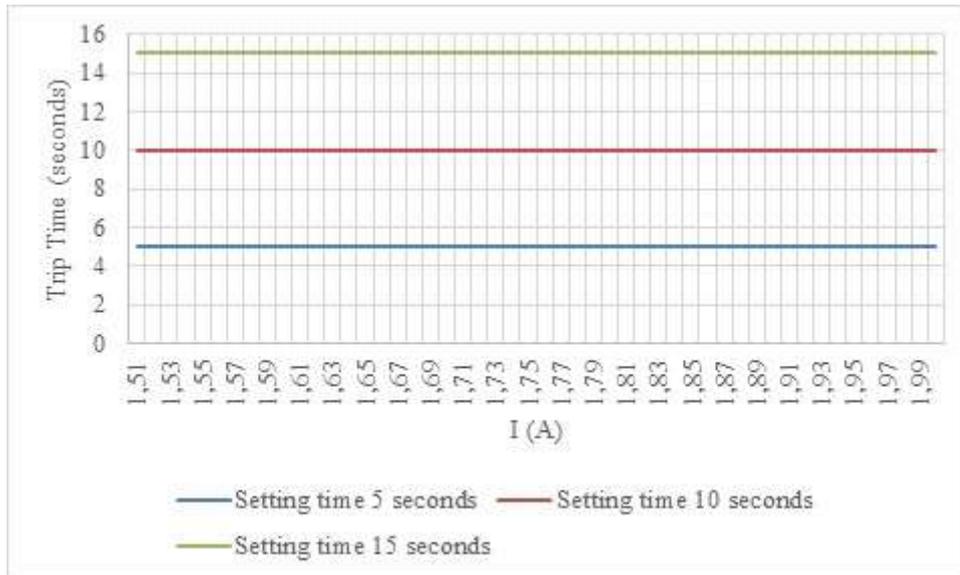


Figure 17. Graph of the results of the overcurrent relay type constant time test at the setting current (Is) 1 A with a setting time variation of 5, 10, and 15 seconds

Figure 17 shows a graph of the results of the overcurrent relay type constant time test at the Setting (Is) current of 0.5 A with a setting time variation of 5, 10, and 15 seconds. The graph has 2 axes, namely, the x I axis with the unit A and the y axis which shows the trip time in units of seconds. There are 3 curves, namely, the setting time curve of 5, 10, and 15 seconds with the color of the setting time curve of 5 seconds blue, 10 seconds red, and 15 seconds green. These curves show that whatever current flows during the trip that occurs according to the setting time. This shows that the device is designed to be built with a setting current (Is) of 1 A and a setting time variation of 5, 10, and 15 seconds has corresponded to the characteristics of constant time. The fourth stage of testing is the overcurrent relay type constant time test at the setting current (Is) 1 A with a setting time variation of 5, 10, and 15 seconds. This test was carried out to test whether the device designed to be built in accordance with the characteristics of the constant time and accuracy of the device at the setting current (Is) of 1.5 A with a setting time variation of 5, 10, and 15 seconds. The results of the overcurrent relay type constant time test at the setting current (Is) 1 A with a setting time variation of 5, 10, and 15 seconds can be seen in Table 12.

TABEL 12. HASIL TEST THE ACCURACY OF THE RELAY TYPE CONSTANT TIME OVERCURRENT AT A SETTING CURRENT (IS) OF 1.5 A WITH SETTING TIMES OF 5, 10, AND 15 SECONDS

No.	IS(A)	I(A)	Setting time(sec)	Trip time (sec)	Error(%)	Setting time(sec)	Trip time (sec)	Error(%)	Setting time(sec)	Trip time (sec)	Error(%)
1	1,5	1,51	5	5	0	10	10	0	15	15	0
2	1,5	1,52	5	5	0	10	10	0	15	15	0
3	1,5	1,53	5	5	0	10	10	0	15	15	0
4	1,5	1,54	5	5	0	10	10	0	15	15	0
5	1,5	1,55	5	5	0	10	10	0	15	15	0
6	1,5	1,56	5	5	0	10	10	0	15	15	0
7	1,5	1,57	5	5	0	10	10	0	15	15	0
8	1,5	1,58	5	5	0	10	10	0	15	15	0



No.	IS(A)	I(A)	Setting time(sec)	Trip time (sec)	Error(%)	Setting time(sec)	Trip time (sec)	Error(%)	Setting time(sec)	Trip time (sec)	Error(%)
9	1,5	1,59	5	5	0	10	10	0	15	15	0
10	1,5	1,6	5	5	0	10	10	0	15	15	0
11	1,5	1,61	5	5	0	10	10	0	15	15	0
12	1,5	1,62	5	5	0	10	10	0	15	15	0
13	1,5	1,63	5	5	0	10	10	0	15	15	0
14	1,5	1,64	5	5	0	10	10	0	15	15	0
15	1,5	1,65	5	5	0	10	10	0	15	15	0
16	1,5	1,66	5	5	0	10	10	0	15	15	0
17	1,5	1,67	5	5	0	10	10	0	15	15	0
18	1,5	1,68	5	5	0	10	10	0	15	15	0
19	1,5	1,69	5	5	0	10	10	0	15	15	0
20	1,5	1,7	5	5	0	10	10	0	15	15	0
21	1,5	1,71	5	5	0	10	10	0	15	15	0
22	1,5	1,72	5	5	0	10	10	0	15	15	0
23	1,5	1,73	5	5	0	10	10	0	15	15	0
24	1,5	1,74	5	5	0	10	10	0	15	15	0
25	1,5	1,75	5	5	0	10	10	0	15	15	0
26	1,5	1,76	5	5	0	10	10	0	15	15	0
27	1,5	1,77	5	5	0	10	10	0	15	15	0
28	1,5	1,78	5	5	0	10	10	0	15	15	0
29	1,5	1,79	5	5	0	10	10	0	15	15	0
30	1,5	1,8	5	5	0	10	10	0	15	15	0
31	1,5	1,81	5	5	0	10	10	0	15	15	0
32	1,5	1,82	5	5	0	10	10	0	15	15	0
33	1,5	1,83	5	5	0	10	10	0	15	15	0
34	1,5	1,84	5	5	0	10	10	0	15	15	0
35	1,5	1,85	5	5	0	10	10	0	15	15	0
36	1,5	1,86	5	5	0	10	10	0	15	15	0
37	1,5	1,87	5	5	0	10	10	0	15	15	0
38	1,5	1,88	5	5	0	10	10	0	15	15	0
39	1,5	1,89	5	5	0	10	10	0	15	15	0
40	1,5	1,9	5	5	0	10	10	0	15	15	0
41	1,5	1,91	5	5	0	10	10	0	15	15	0
42	1,5	1,92	5	5	0	10	10	0	15	15	0
43	1,5	1,93	5	5	0	10	10	0	15	15	0
44	1,5	1,94	5	5	0	10	10	0	15	15	0
45	1,5	1,95	5	5	0	10	10	0	15	15	0
46	1,5	1,96	5	5	0	10	10	0	15	15	0
47	1,5	1,97	5	5	0	10	10	0	15	15	0
48	1,5	1,98	5	5	0	10	10	0	15	15	0
49	1,5	1,99	5	5	0	10	10	0	15	15	0
50	1,5	2	5	5	0	10	10	0	15	15	0
Average error (%)					0				0		

Table 12 shows the results of the overcurrent relay type constant time test at the setting current (Is) 0.5 with a setting time of 5, 10, and 15 seconds. The test results showed that the average error in all the setting time variations was 0 percent. This value shows

that the device is designed to build on the setting current (I_s) 1 A with a setting time variation of 5, 10, and 15 seconds has been in accordance with the characteristics of constant time with an average error in all setting time variations of 0 percent. Figure Graph of the results of the overcurrent relay type constant time test at the setting current (I_s) 0.5 A with a setting time variation of 5, 10, and 15 seconds can be seen in Figure 18.

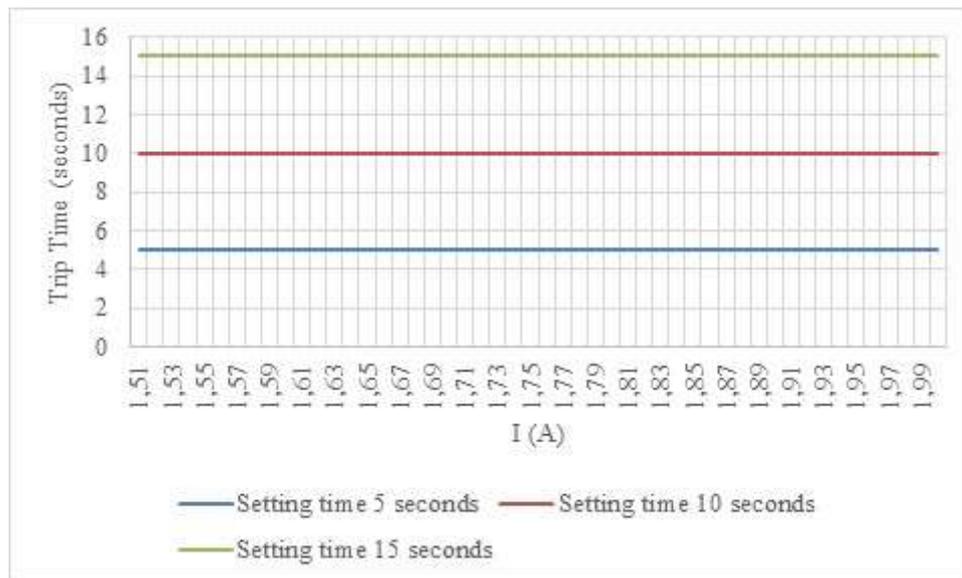


Figure 18. Graph of the results of the overcurrent relay type constant time test at the setting current (I_s) 1.5 A with a setting time variation of 5, 10, and 15 seconds

Figure 18 shows a graph of the results of the overcurrent relay type constant time test at a setting current (I_s) of 0.5 A with a setting time variation of 5, 10, and 15 seconds. The graph has 2 axes, namely, the x I axis with the unit A and the y axis which shows the trip time in units of seconds. There are 3 curves, namely, the setting time curve of 5, 10, and 15 seconds with the color of the setting time curve of 5 seconds blue, 10 seconds red, and 15 seconds green. These curves show that whatever current flows during the trip that occurs according to the setting time. This shows that the device is designed to wake up with a setting current (I_s) of 0.5 A and a setting time variation of 5, 10, and 15 seconds has been in accordance with the characteristics of constant time. Based on the constant time overcurrent relay type test in the first to fourth stages, it can be concluded that the designed and built tool has performed according to the expected constant time characteristics well. The results of the thorough test showed that the relay provided a fixed-time response even though the overcurrent values were different, which is a key characteristic of this type of constant time. In addition, the measurement and analysis of the data showed an average error of 0 percent, which signifies high accuracy and consistency in the performance of the tool during the test.

V. CONCLUSION

Based on the results of this study, it can be concluded that the design of an Arduino-based overcurrent relay is designed to work with two protection modes, namely Standard Inverse and Constant Time. The accuracy test showed that the system had an average trip time error of less than 2% in standard inverse testing and 0% in constant time testing, which means it is very accurate and in accordance with theoretical calculations. In addition, the use of the PZEM-004T module is proven to provide accurate current readings with an average error of only 0.40% compared to the Ampere meter measuring device.

REFERENCES

1. B. A. Wijaya, A. Ihsandi, O. Nainggolan, and P. Murdiyat, "Design and build a more inverse time type current relay with a time multiplier setting of 0.05 seconds based on Arduino," PoliGrid, vol. 5, no. 1, pp. 27–33, Jun 2024, doi: 10.46964/poligrid.v5i1.38.



2. Arbain, R. A. Susilo, A. S. Akbar, M. Wahyu, and M. Risky, "Arduino-based overcurrent relay design with very inverse type," *International Journal of Current Science Research and Review*, vol. 07, no. 11, pp. 8547–8558, Nov 2024, doi: 10.47191/ijcsrr/V7-i11-41.
3. Rusdiansyah, R. A. Susilo, A. S. Kadang, S. M. Setiaji, and A. Ihsandi, "Design of constant time overcurrent relay single phase based on arduino uno," *International Journal of Current Science Research and Review*, vol. 07, no. 11, pp. 8559–8565, Nov 2024, doi: 10.47191/ijcsrr/V7-i11-42.
4. E. Fauziyah and U. Sultan Ageng Tirtayasa, "Analysis of generator protection system using over current relay at PT. Indonesia Power," *Scientific Journal of Information Technology d'Computare*, vol. 12, pp. 1–9, Jul 2022.
5. T. Aryanto and S. Sunardiyo, "Frequency of disturbance to the performance of the protection system at the 150 kv Jepara substation," *Journal of Electrical Engineering*, vol. 5, no. 2, pp. 107–115, Jul 2013.
6. A. Azis, D. Irine, and K. Febrianti, "Analysis of overcurrent protection system in sandalwood feeders at the Palembang substation," *AMPERE JOURNAL*, vol. 4, no. 2, pp. 332–344, Dec. 2019.
7. M. Pujiantara et al., "TDS Overcurrent Relay Calculation Using Adaptive Modified Firefly Algorithm," *INTAKE*, vol. 10, no. 2, pp. 67–72, Oct 2019.
8. F. Sirait, "Effective design of a current relay coordination system uses fuzzy logic," *Jl. Meruya Selatan*, vol. 7, no. 1, pp. 1–7, Dec. 2022.
9. Susanna and M. Murdianto, "Testing of Internet of Things (IoT)-based sensor and actuator practicum teaching aids using blynk and thingspeak ESP8266 applications," *PoliGrid*, vol. 5, no. 2, pp. 42–49, Nov 2024, doi: 10.46964/poligrid.v5i2.51.
10. Alan Yuandika and Bintang Nur Jati, "Water Level, Humidity, and Temperature Monitoring System in the Samarinda State Polytechnic Lake," *PoliGrid*, vol. 4, no. 1, pp. 1–10, Oct 2023, doi: 10.46964/poligrid.v4i1.12.
11. M. I. Ibrahim, R. A. Wijaya, R. A. Susilo, and P. Murdiyat, "Design and construction of differential relays based on Arduino," *PoliGrid*, vol. 5, no. 1, pp. 13–19, Jun 2024, doi: 10.46964/poligrid.v5i1.41.
12. A. H. Hardiansyah, R. S. Hartati, and Y. Divayana, "Electrical Short Circuit Protection by Remotely Cutting the Current of 3 Phasa of Large Load with a Combination of Solid State Relay (SSR) and IoT Nodemcu 8266 Using the Blynk Application in the Sub Panel of the Telkomsel Smart Office Renon Denpasar Building," *Scientific Magazine of Electrical Technology*, vol. 22, no. 1, p. 71, Jun 2023, doi: 10.24843/mite.2023.v22i01.p09.

Cite this Article: Susilo, R.A., Kurniawan, A.H., Ningrum, B.C., Maulana, I., Fatieh, A., Setiawan, W. (2025). Design and Construction of the Standard Inverse and Constant Time Overcurrent Relay Simulator Based on Arduino. International Journal of Current Science Research and Review, 8(11), pp. 5528-5555. DOI: <https://doi.org/10.47191/ijcsrr/V8-i11-12>