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Arduino-Based Overcurrent Relay Design with Very Inverse Type

Arbain[1], Rizky Aprylianto Susilo[2], Amirul Syadikin Akbar[3], Muhammad Wahyu[4], Muhammad Risky[5]

[1,2,3,4,5] State Polytechnic of Samarinda

ABSTRACT: The protection system is a very important system in the electric power system, because this protection system functions as a safety for electrical equipment from abnormal events or disturbances. In this study ever current relay is used as a protection system, over current relay works based on the current value measured by the PZEM-004T current sensor. The value of the current sensor will be output from the arduino to the relay module, so that the relay will work according to the current limit setting that will be progammed on the UNO arduino as a command to the relay module to break or connect the current in the circuit. The current value and the state of the overcurrent relay will be displayed on the LCD that receives input from the arduino Uno. Very inverse type overcurrent relay (OCR) is one type of OCR that has a longer trip delay time for smaller fault currents and faster at large currents. This allows the system to aperate again faster after a small disturbance. This research aims to design and build dan Arduino-based very inverse type OCR. The system uses PZEM-004T current sensor to detect the current and Arduino Uno microcontroller to process the data and control the relay. The characteristics of the trip delay time of the very inverse type OCR are programmed according to the IEEE C37.122 Standard. With TMS values ranging from 0.01 to 13 seconds. The programme is given setting current value of 2 Amperes and a TMS value of 0.05 seconds. In the test carried out, it was found that the current and trip time were directly proportional to the simulation experiments in ETAP although there was still a slight difference in the tiime difference in current disconnection based on the comparison curve.

KEYWORDS: Arduino, Overcurrent relay, PZEM-004T, Very inverse.

1. INTRODUCTION

Electrical systems are a vital part of modern life, whether for industry, households, or other sectors. The safety and reliability of the electrical system is an important factor to avoid equipment damage and hazards that can be caused. One of the common problems in electrical systems is overcurrent. Overcurrents can occur due to various factors, such as short circuits, overloads, and disturbances in the electrical network. If not controlled, overcurrent can cause damage to electronic equipment, cables, and even fire. An overcurrent relay is a device used to protect electrical systems from overcurrent hazards. This relay will detect and cut off the current flow when the value exceeds the predetermined safe limit. Currently, the safety of the power system has used relays as safety equipment. Overcurrent relays with inverse characteristic curves are very useful for securing disturbances due to overload / overload, because they work with a delay time that depends on the magnitude of the current inversely (inverse time), the greater the current, the smaller the delay time [1]. In solving the problem, the Standart Inverse, Very Inverse and Extremely Inverse curves are used to determine the speed capacity of the relay by setting the incoming current in the Over Current Relay design equipment [2].

Very Inverse type is one of the characteristics of the overcurrent relay trip time which has a faster trip speed compared to other types. In solving the problem, the Very Inverse curve is used to determine the speed capacity of the relay by adjusting the current entering the Over Current Relay design equipment [2].

Safety in electrical circuits has a crucial role in delivering voltage quality to the load, because it is an important part needed to reduce the potential for problems in the electrical system. Overcurrent relays can work with a fast and flexible response in overcoming disturbances and are designed with an Arduino-based electronic circuit [3]. With the application of the Arduino-based Over Current Relay in electrical circuits, it is hoped that as much as possible away from various kinds of problems that can interfere with system reliability. then a very inverse type protection relay is made as a Project Basic Learning (PBL) as learning in the Protection Lab and Microprocessor Lab courses [4].

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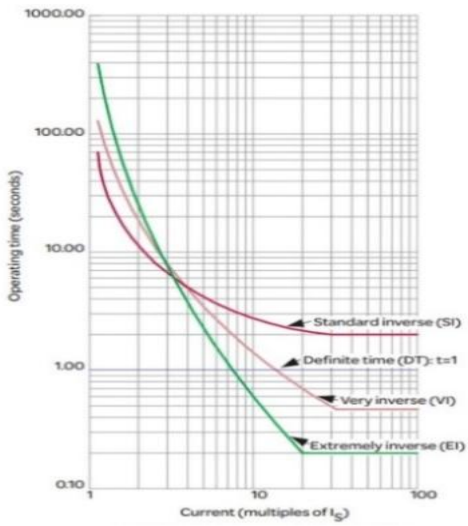

Figure 1: Inverse Overcurrent Relay Characteristic Curve

2. LITERATURE STUDY

A. Previous Research

There are several references used in the process of designing this Arduino Microcontroller Based Overcurrent Protection Relay. This research is a development of previous research conducted by Galang Nazhrullah and Aria Kharisma (2023) Arduino Microcontroller Overcurrent Protection Relay. Samarinda State Polytechnic [4]. Wijaya, Prawira Kusuma (2022) Design of an Arduino-based Overcurrent Protection Relay. Final thesis, ITN Malang [5]. Amrulloh, Amrizal Karim (2018) Design of an Overcurrent Relay prototype with Arduino- based Inverse Characteristics at the Electrical Power System Laboratory. Bachelor thesis, Universitas Brawijaya [6]. Aceng Daud Department of Energy Conversion Engineering, Bandung State Polytechnic Design of overload current and short circuit protection module [7]. Salim, Nur (2018) Design of Prototype Over Current Protection Device Using Arduino Control. Thesis, ITN Malang [8].

B. Protection System Rules

Planning a protection system, then to get a good protection system the following requirements are needed:

1) Sensitive

A protection relay is tasked with securing a device or a certain part of an electric power system, a device or part of the system that is included in its security range. To minimise the time needed to disconnect the disturbed part of the healthy system, the protection relay must have a high speed. security and must be sensitive enough to detect the disturbance with a minimum stimulus and if necessary only mentripkan power breaker (PMT) to separate the disturbed part of the system, while the healthy part of the system in this case should not be open.

2) Selective

Selectivity of the protection relay is a quality of selection accuracy in providing security. The open part of a system due to a disturbance must be as small as possible, so that the disconnected area becomes smaller. The protection relay will only work during abnormal conditions or disturbances that occur in its security area and will not work under normal conditions or in a disturbance that occurs outside its security area.

3) Quick

The faster the protection relay works, not only can it minimise the possibility of the consequences of the fault, but it can minimise the possibility of the spread of the consequences caused by the fault.

4) Reliable

Under normal circumstances or a system that has never been disturbed the protection relay does not work for months maybe years, but the protection relay when needed must and can definitely work, because if the relay fails to work it can cause more damage to the secured equipment or result in the operation of another relay so that the area experiences a wider blackout. To maintain its reliability, the protection relay must be tested periodically.

5) Economical
With the smallest cost, it is expected that the protection relay has the greatest security capability.

6) Simple
Protection relay devices are required to have a simple and flexible form [9].

C. Arduino Uno

Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (6 of which can be used as PWM outputs), 6 analogue inputs, a 16 MHz Crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. Arduino Uno contains everything needed to support a microcontroller, it is easy to connect it to a computer with a USB cable or supply it with an AC to DC adapter or use a battery to start it [10].

Figure 2. Arduino Uno [11]

Table 1: Arduino Uno Pins

No. Pin	Type	Description
0-13	Digital I/O	Digital input/output port 0 to 13
A 0-A 5	Analogue I/O	Analogue input channel 0 to 5
Vin	PWR	Supply Voltage
GND	PWR	Supply Ground
+5V	Output	+5V output (from on-board regulator)
+3.3V	Output	+3.3V output
SCL & SDA	Output	Output to 12C
Reset	Input	Reset (active low)
Aref	Input	ADC Reference

Each digital pin on the Arduino Uno board can be used as an input or output. By using the pinMode(), and digitalRead() functions. These pins operate at a voltage of 5 volts [8][9].

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D. PZEM-004T Sensor

The PZEM-004T sensor is an electronic sensor module that has the function of measuring current, voltage, frequency, power, energy, and also power factor and this sensor is also equipped with an integrated CT [12].

Figure 3. PZEM-004T Sensor Module

The PZEM-004T board has dimensions of 3.1 × 7.4 centimetres. The PZEM-004T material is wrapped using a 3mm diameter current transformer coil that can be used for optimal current detection of 100A. The wiring of this module has 2 parts, namely from the voltage and current input connected wiring, as well as the information transmission wiring. Based on the needs, this module has a TTL pin board to support information transmission communication between hardware. The detailed explanation of the PZEM-004T module specifications can be seen in the following table.

Table 2: Pzem-004t Sensor Specifications

NO	Specifications	Description
1	Input voltage	5V DC
2	Output voltage	80 – 260V
3	Maximum current	10A
4	Power	2 – 3kW
5	Power factor	0 – 1
6	Frequency	45Hz – 65Hz

E. 1 Channel Relay Module

Rele is part of an electrical power protection system in the form of a switch that is operated semi-automatically. Rele is an electromechanical component that has 2 main parts, namely an electromagnet in the form of a coil and mechanics in the form of a set of switch contacts. The relay uses electromagnetic principles to move the switch contacts so that with a small electric current it can deliver electricity that has a higher voltage [13].

The relay consists of 3 main parts, namely coil, coil and contact. Contact also consists of NC (Normally Closed) which is the switch of the relay in a normal state (the relay is not under voltage) connected to the common and NO (Normally Open) which is the switch of the relay in a normal state (the relay is not under voltage) not connected to the common [14].

Figure 4. 1 Channel Relay Module

F. 16x2 I2C LCD (Liquid Crystal Display)

Electronic display is one of the electronic components that functions to display numbers, letters or other symbols. LCD (Liquid Crystal Display) is one of the commonly used electronic displays. LCD is made with CMOS logic that works by not producing light but reflecting the surrounding light to the front-lit or transmitting light from the backlit The number of characters that can be displayed by an LCD depends on its specifications (Revolution Education Ltd. 2016) [16].

Figure 5. 16x2 I2C LCD

G. Push Button

Push Button is an electrical panel component that functions as a triger switch to connect or disconnect the flow of electricity. Push Button works when the component is pressed and changes the N/O contact to N/C or vice versa is momentary. Momentary is a pulze when the value is I and when released the value is 0, the value is not locked [17].

Figure 6. Push Button

H. Buzzer

Buzzer is an electronic component that functions to convert electrical vibrations into sound vibrations. Basically the working principle of the buzzer is almost the same as the loud speaker, so the buzzer also consists of a coil attached to the diaphragm and then the coil is electrified so that it becomes an electromagnet, the coil will be pulled in or out, depending on the direction of the current and the polarity of the magnet, because the coil is mounted on the diaphragm, each coil movement will move the diaphragm back and forth so that it makes the air vibrate which will produce sound. Buzzers are commonly used as an indicator that the process has been completed or an error occurs in a device (alarm) [18].

Figure 7. Buzzer [19]

I. Calculation of Protection Relay Working Time

Overcurrent relay with inverse time characteristics is this relay works with operating time inversely proportional to the amount of current measured by the relay. This relay has working characteristics that are influenced by time and current The greater the fault

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current, the faster the relay will operate, and vice versa, the smaller the fault current, the longer the relay operation delay time will be. The relationship between current and time is shown by the following equation:

$$TMS = \frac{(\frac{I}{Is})^{\alpha} - 1}{\beta}$$

$$t = \beta \frac{TMS}{(\frac{I}{Is})^{\alpha} - 1}$$

Description:
TMS = Time Multiplier Setting
I = Disturbance Current (A)
Is = Setting Current (A)
T = Relay Trip Time (s)
Standar inverse characteristics according to IEC 60255, Large characteristics on alpha and beta factors in the following table.

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

3. RESEARCH METHODS
A. Time and Location

The time used for this PBL work was 4 months or 14 lecture meetings, which were held from February 2024 to May 2024 which was carried out at the Electrical Engineering Microcontroller Laboratory of Samarinda State Polytechnic.

B. Types of Data and Data Sources

In PBL work is divided into three stages, namely planning, workmanship and testing, the data sources used during planning and workmanship are obtained from scientific journals, books, official arduino websites, related research reports, and also datasheets of the equipment used and also use software such as ETAP and Proteus to simulate the tools to be worked on. At the time of testing the data was taken directly from the results of testing the overcurrent relay in the samarinda state polytechnic laboratory.

C. System Overview

An overview of the system that will be designed in the Arduino Microcontroller-Based Overcurrent Protection Relay PBL can be seen in Figure 8. The microcontroller system gets a voltage supply from a 5V adapter.

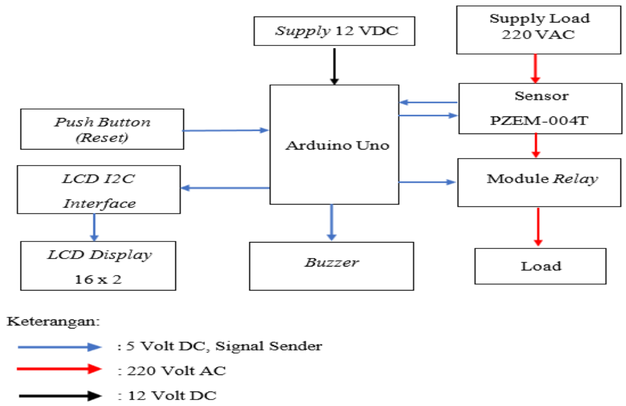

Figure 7. Block Diagram

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D. Equipment and Materials

Table 3. shows the equipment and materials used to make and means in making overcurrent protection relays:

Table 3: Equipment And Materials

Tools	Materials
Drill	Arduino
Grinding	PZEM-004T Sensor
Solder	Relay
Laptop	Buzzer
Variable Resistor	16x2 LCD
100W Incandescent Lamp	PCB Board
Ampere Meter	Push Button
Crocodile Clips	Cable
	Sekun
	Tin
	Acrylic

E. Over Current Relay (OCR) System Flowchart

In Figure 8. Shows the Flowchart of the over current relay system

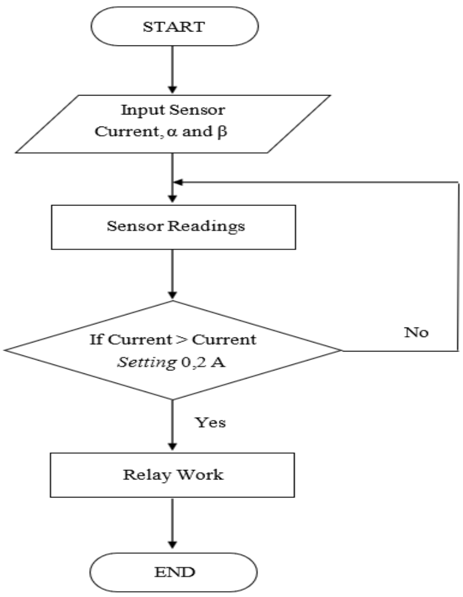

Figure 8. Over Current Relay System Flowchart

From the flowchart in Figure 8. Can facilitate the process of understanding how the relay works which can be described as follows.

1. The process begins
2. The system enters data for the need to calculate the working time of the relay
3. The sensor reads the current in the circuit
4. If the current value read by the sensor exceeds the setting current value then the process will continue to the next process if not fulfilled then the system returns to process 3

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5. The relay will act and the process ends

4. RESULT AND DISCUSSION

The method includes designing tools, making tools, and testing tools by simulating the tools and loads available in the Protection Lab and Microprocessor Lab [20].

A. Design and Build

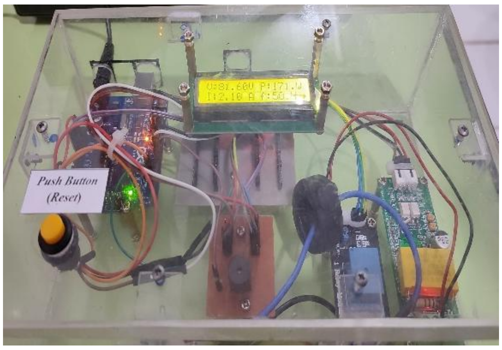

Figure 10. Physical form the tool

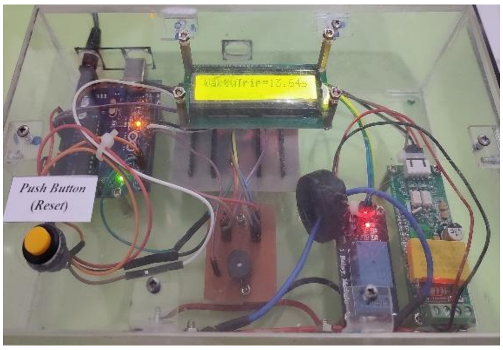

Figure 11. Testing the current sensor

B. Testing Result

The following is the test result data:

Table 4: Current Protection Relay Testing

No.	Current (Ampere)	Trip Time (Seconds)	Trip Time in ETAP (Seconds)
1	2,01	135	135
2	2,02	67,5	67
3	2,03	45	45
4	2,04	33,75	33
5	2,05	27	27
6	2,06	22,5	22
7	2,07	19,29	19
8	2,08	16,87	16
9	2,09	15	15
10	2,10	13,5	13
11	2,11	12,27	12,4

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12	2,12	11,25	11
13	2,13	10,38	10,4
14	2,14	9,64	9,1
15	2,15	9	8,56
16	2,16	8,44	8,37
17	2,17	7,94	7,30
18	2,18	7,5	7
19	2,19	7,11	6,89
20	2,20	6,75	6,67
21	2,21	6,43	6,45
22	2,22	6,14	6,31
23	2,23	5,87	5,87
24	2,24	5,62	5,55
25	2,25	5,4	5,30
26	2,26	5,19	5,14
27	2,27	5	5
28	2,28	4,82	4,89
29	2,29	4,66	4,70
30	2,30	4,5	4,55
31	2,31	4,35	4,37
32	2,32	4,22	4,11
33	2,33	4,09	4
34	2,34	3,97	3.92
35	2,35	3,86	3,83
36	2,36	3,75	3,79
37	2,37	3,65	3,73
38	2,38	3,55	3,67
39	2,39	3,46	3,62
40	2,40	3,37	3,58
41	2,41	3,29	3,55
42	2,42	3,21	3,50
43	2,43	3,14	3,44
44	2,44	3,07	3,27
45	2,45	3	3,14
46	2,46	2,93	3
47	2,47	2,87	2,97
48	2,48	2,81	2,94
49	2,49	2,76	2,91
50	2,50	2,7	2,88
51	2,51	2,65	2,82
52	2,52	2,6	2,80
53	2,53	2,55	2,76
54	2,54	2,5	2,70
55	2,55	2,45	2,68
56	2,56	2,41	2,62

57	2,57	2,37	2,6
56	2,58	2,33	2,57
58	2,59	2,29	2,55
59	2,60	2,25	2,30
60	2,7	1,93	2
61	2,8	1,69	1,78
62	2,9	1,5	1,53
63	3	1,35	1,48
64	3,5	0,9	1
65	4	0,68	0,745
66	4,5	0,54	0,606
67	5	0,45	0,502
68	5,5	0,39	0,432
69	6	0,34	0,374
70	6,5	0,3	0,337
71	7	0,27	0,3
72	7,5	0,25	0,274
73	8	0,22	0,25
74	8,5	0,21	0,233
75	9	0,19	0,217

C. Research Analysis

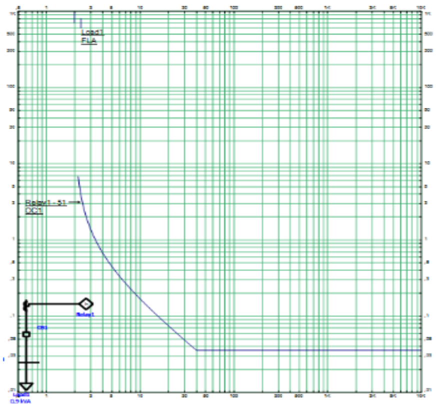

Figure 12. Simulation Curve in ETAP Software

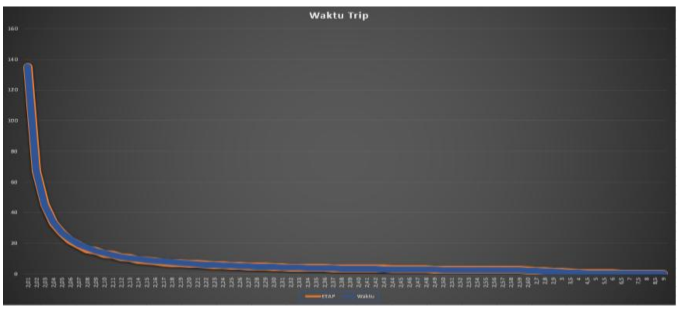

Figure 13. Device Test Result Curve

Analysis:

The analysis carried out aims to compare the simulation results and test results of the over current relay (OCR) theory with the characteristics of the relay trip time with Standard Very Invers so that it is able to work quickly and precisely. That is, it has a longer trip delay time for smaller fault currents and faster at large currents.

The results of the analysis on the test data that in the first experiment at a falling current of 2.01 Amperes with a trip time of 135 seconds with a second experiment at a falling current of 2.02 Amperes with a trip time of 67.5 seconds. There is a very large time difference in the disconnection time and in the last experiment the falling current is getting bigger, which is 9 Amperes with a trip time of 0.19 seconds in the simulation carried out that it is in accordance with the theory although there is still a slight difference in the time difference in current disconnection. graphical form of the test results of the working time characteristics of the over current relay (OCR) [21]. In the simulation experiment above, it can be seen that the curve in the ETAP software is directly proportional to the test result curve between the disconnection time and the current.

5. CONCLUSIONS AND SUGGESTIONS

A. Conclusion

From the Project Based Learning on the design of an Arduino-based Very Inverse Overcurrent Protection Relay in the Protection Systems Laboratory, conclusions can be drawn:

1. PZEM-004T functions as a current sensor that can detect the electric current passing through a line or cable, and then activate the protection relay to cut off the electricity if the current exceeds a predetermined limit.
2. Based on the test data, it has a longer trip delay time for smaller fault currents, namely at a current of 2.01 Amperes, the trip time is 135 seconds and the trip delay time is faster at a larger current, namely at a current of 9 Amperes, the trip time is 0.19 seconds. The test data has fulfilled the characteristics of the very inverse time type.
3. Based on the test data, it is found that the disconnection of the load against the overcurrent is in accordance with the characteristics of the very inverse type, although there is still a slight difference in the time distance in the current disconnection.
4. Based on the results of testing this tool works well in protecting overcurrent but to get an ideal protection relay requires several trials and calculations in order to get good Overcurrent Protection relay results in accordance with the rules of the Electrical Protection System.

B. Suggestion

Here are some suggestions that can be given as a research development of this tool.

1. Comparing the characteristics of Very Invers Time with other inverse characteristics
2. Stability and Realibity during testing whether the tool can operate consistenly without failure
3. Response of the device system to variations in current and other conditions

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