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Andalas Journal of Electrical and Electronic Engineering Technology

ISSN 2777-0079



Development of 220V Overcurrent Relay Protection System Based on Internet of Things

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ARTICLE INFORMATION

Received: June 21, 2023

Revised: January 7, 2024

Accepted : March 19, 2024

Available online: May 22, 2025

KEYWORDS

Relay, PZEM-004T, LCD, NodeMCU ESP8266, Arduino Uno R3

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A B S T R A C T

Electrical protection is essential to keep electrical systems safe. A suitable protection system can create a safe situation in the event of an overcurrent or voltage drop in the power grid. This can be caused by various factors such as usage, short circuits, or other disturbances. An electrical load control system regulates and monitors power consumption to prevent overcurrents and short circuits. The current reading process uses the current sensor and voltage sensor PZEM-004T, and when the set consumption exceeds the consumption, the relay holds the electric load. Also, the LCD is used to display the power consumption, and the keypad is used to enter the power limit. On the other hand, remote monitoring uses NodeMCU ESP8266. Arduino Uno R3 is also a microcontroller that controls the central system. This study aims to create a prototype to monitor, limit, adjust, and control energy consumption to minimize energy consumption. This tool can monitor current and voltage and limit electrical energy consumption if necessary. This research is expected to alleviate the problem of house fires caused by overcurrents.

INTRODUCTION

In everyday life, humans are inseparable from the ever-increasing need for electricity. [1] [2]. Per consumer needs, reliable, stable, efficient, and safe electricity is needed. Overcurrent relays are essential to protect a system from disturbances caused by overcurrents, such as short circuits. [3].

The use of electrical energy [4] is the most widespread among humans. Electrical energy has been implemented in various sectors of human life, including industry, offices, agriculture, trade, and other sectors [5][6]. Almost all of these sectors depend on electrical energy as the primary energy source [7].

The protection system is an arrangement of equipment that is designed to be able to sense [8], measure disturbances and determine the location of disturbances or begin to detect abnormalities in equipment or parts of the electric power system, and immediately automatically open the load breaker to separate the equipment or part of the system that is disturbed, and give a signal in the form of lights, alarms, and so on [8] [9] [10].

Currently, there is the development of electrical energy control and monitoring devices using Internet of Things (IoT) technology [11]. With IoT, users can easily control and monitor both alternative and non-alternative electrical energy systems remotely in real time using the Internet. This allows users who are not near the power system control panel to control and monitor their home electrical system directly [12].

According to the C. Wangetal Journal of Gunawan Hendro Cahyono, raw data collection is accurate and efficient in all IoT activities. But more importantly, it analyzes raw data and transforms it into more valuable information [13]. IoT accessibility can be unlimited as IoT devices are always connected to the internet to be accessed and used anytime, anywhere. An example of his use of IoT in everyday life is a server or device that is always connected to the internet [2] [14].

Previous designs have created an overcurrent relay with an Arduino microcontroller for Internet of Things (IOT) based monitoring that can be monitored with a mobile phone, and have used an ATmega 328 with added reverse time delay characteristics for overcurrent. There was also. The design of the relay was done. An Arduino-based overcurrent relay built on a

miniature 20kV grid. This research developed a 220V overcurrent relay protection system based on IoT. The system helps replace the performance of factory-manufactured mini circuit breakers (MCBs), which can be monitored remotely, as a protection to keep all electronic equipment from being damaged.

METHOD

Relay

A relay is an electrical component that acts as an electronic switch powered by an electric current [15]. Essentially, it consists of a switch lever wrapped in wire, which connects to a nearby iron bar known as a solenoid [16]. When the electromagnet is activated, it generates a magnetic field that pushes the lever to close the switch connections. Conversely, when no current flows through the magnet, the magnetic force dissipates, causing the switch to reopen. Relays feature two main contact configurations: normally open, where the switch is not connected to the reference potential under normal conditions (relay de-energized), and normally closed, where the switch is linked in common when the relay is not activated.

Protection relays play a crucial role in identifying problems in real time by measuring or comparing various electrical parameters such as current, voltage, frequency, power, and phase angle, depending on the type and size of the relay. When a fault is detected, these relays send an instruction or signal to activate a circuit breaker, effectively safeguarding the system. Their key responsibilities include sensing, measuring, comparing, and quickly pinpointing vulnerable elements within the system to minimize further damage from equipment malfunctions. Additionally, protection relays help reduce the impact of interference on unaffected systems, preventing the propagation of issues. Most importantly, they provide safety for humans by protecting them from the dangers associated with electrical energy.

Essentially, protective relays must perform as promised in rapid timeframes. So no harm done [17]. Figure 1 shows the 1-channel relay module.



Figure 1. The Modul relay of the one channel

Arduino Uno R3

The Arduino Uno R3 is a microcontroller development board based on the ATmega328P microprocessor. The Arduino Uno features 14 digital input/output pins (or I/O, 14 of which can be used as PWM outputs), a 16MHz crystal (pins A0-A5), and a 16MHz crystal (pins A0-A5). The USB connector, socket, ICSP header, and reset button use six standard input pins. That alone provides sufficient support for the Arduino Uno R3 microcontroller circuit [18]. The specs are shown in Figure 2.

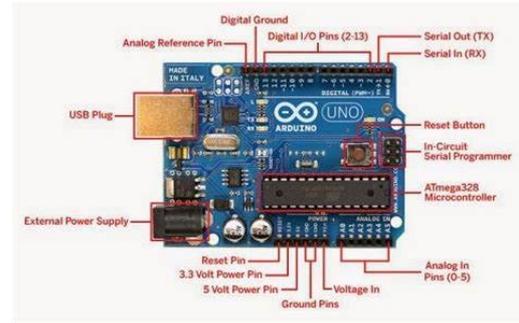


Figure 2. The Arduino Uno R3

Current and Voltage Sensors PZEM-004T

Voltage, current, power, frequency, energy, and power factor are all measured by the PZEM-004T active electronic module [19]. With all of these features, the PZEM-004T module is perfect for power measuring and testing projects in electrical networks such as homes and buildings [20].



Figure 3. Current and Voltage Sensors PZEM-004T

Liquid Crystal Display (LCD)

The LCD shield is built for Arduino-compatible boards, providing a user-friendly interface for creating menus and selecting from current sensor readings. A 1602-character LCD with a blue backlight powers the LCD Shield.



Figure 4. Liquid Crystal Display (LCD)

The LCDs the output of sensor readings from the microcontroller in the form of values, text, and menus. In this case, the creator utilizes a 2x16 LCD, which features a 16-character by 2-line arrangement, each character formed by pixels. This LCD module offers several features, including two 16-character lines, a programmable character generator, and the capability to store 192 characters. Additionally, it can be addressed in four- and eight-bit modes, and it comes equipped with a built-in backlight.

ESP8266 NodeMCU version 12E

NodeMCU is an open-source Internet of Things platform and development kit [21]. The NodeMCU comprises system-style hardware on Espressif Systems' ESP8266 chip, which is the primary source of its ESP8266, particularly the ESP-12 and ESP-12E series. NodeMCU is a regular ESP8266 board with a micro USB programming and power port. Aside from that, the

NodeMCU has push buttons for reset and flashing. Initially, programming the ESP8266 was time-consuming because it required additional wiring knowledge and a USB-to-serial module to download the application [22].



Figure 5: ESP8266 NodeMCU 12E

Internet of Things (IoT)

The mechanics of the Internet of Things (IoT) are grounded in argument programming, whereby argument instructions facilitate interactions among connected machines without the necessity for human intervention or remote coordination. [23].

Before conducting a literature review and formulating the problem statement, a decision was made to develop an overcurrent relay design system utilizing Arduino technology and a comprehensive IoT framework [24].

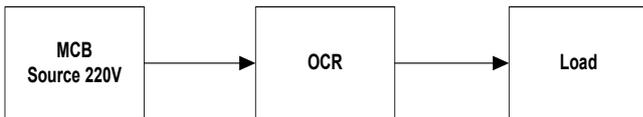


Figure 6. Overcurrent relay block diagram for the complete system

Figure 6 presents the operational methodology, commencing with a 220V Miniature Circuit Breaker (MCB) source and installing an Overcurrent Relay (OCR) tool for demonstration purposes. Once powered, the OCR tool facilitates the operation of the MCB. The flowchart additionally illustrates the functioning of a single-phase overcurrent relay protection system.

Figure 7 visualizes the IoT-based 220V single-phase overcurrent relay safety system operation. The sequence begins with device initialization and progresses once an Android device connects to the NodeMCU ESP8266. The PZEM-004T sensor measures current and voltage, featuring an integrated current transformer (CT). The resultant output is digital, displayed on an LCD screen, and communicated to the Blynk application, which facilitates remote monitoring in alignment with IoT applications. The relay will open the circuit if the current surpasses the predefined limit. This mechanism is essential for safeguarding electronic components against potential damage due to overcurrent or short circuits.

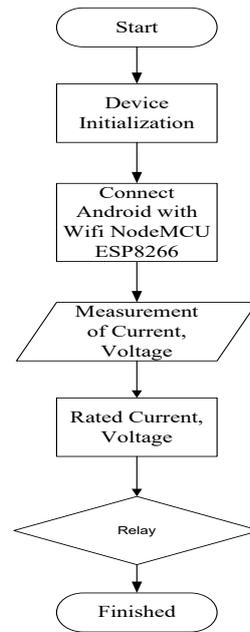


Figure 7. Overall flowchart of the operation of a single-phase overcurrent relay protection system.

RESULTS AND DISCUSSION

Result of Mechanical Realization

The design and construction of the manufactured overcurrent relay hardware include specific functions that can be tailored to suit various applications. The following overview of the overcurrent relay design highlights these functionalities.



Figure 8. Complete System Realization

The picture features an LCD panel with a 16x2 format for menu display and settings. Accompanying the display is a 4x4 keyboard matrix for user input and a reset button allowing system restart. The entire setup operates using a PLN 220-volt power supply, and it includes a PZEM-004T socket that serves as a current and voltage sensor for load output. This combination of components facilitates an interactive and functional system.

Figure 8 shows the overcurrent relay design model constructed to be nearly identical to the Mini Circuit Breaker (MCB) model in terms of normally open (NO) and normally closed contact relays (NC) and their component content. Indicates (NC). The MCB is simply a mechanical device with no indication of overload current levels as it passes through the MCB device, and no adjustments or amperage settings are required.

Comparison results of prototype tools with Tang Ampere and AVO

Data analysis was performed at six different loads in the research, and testing was conducted for current and voltage sensors, as shown in Table 1 below. A current clamp was used to measure the current, allowing for calculating the real-time error associated with the sensor readings.

Table 1. Current sensor test results (I)

No.	Load	Output Sensor (I)	Tang ampere	Error %
1.	Rice cooker	1,74 A	1,59 A	0,09
2.	45watt lamp	0,22 A	0,17 A	0,29
3.	Fan	0,18 A	0,12 A	0,05
4.	Iron	1,33 A	1,19 A	0,11
5.	Water Dispenser	1,59 A	1,43 A	0,11
6.	Laptop	0,27 A	0,19 A	0,42
7.	Solder	0,17 A	0,11 A	0,54
Error Rate%				0.23 %

The test results of the current sensor reading analysis are in Table 1. The error or tool (error) result averages 0.23% at various current loads.

Tool Test Results

This IoT-based 220V single-phase overcurrent protection system testing using seven kinds of loads is used to test this current sensor, namely, Fan, Fan, 45Watt Lamp, Laptop, Iron, Rice cooker, dispenser, with a current drive capacity of 1-4 amperes below:

Table 2. The results of the 3-load overcurrent relay test

No	Load	Current	Volt	Information	Trip
1	Fan	0,16 A	220 Volt	Stable and normal load	No
2	Fan + Laptop	0,22 A	220 Volt	Stable and normal load	No
3	Fan + Laptop + Iron	1,32 A	215 Volt /trip	Over Current	Yes

Iset: 1 A

Table 3. The results of the 4-load overcurrent relay test

No	Load	Current	Volt	Information	Trip
1	Fan	0,16 A	220 Volt	Stable and normal load	No
2	Fan + Fan	0,28 A	220 Volt	Stable and normal load	No
3	Fan + Fan + 45watt Lamp	0,48 A	218 Volt	Stable and normal load	No
4	Fan + Fan + 45watt Lamp + Rice cooker	2,16 A	210 Volt/Trip	Over Current	Yes

Iset: 2 A

Table 4. The results of the 4-load overcurrent relay test

No	Load	Current	Volt	Information	Trip
1	Fan	0,16 A	220 Volt	Stable and normal load	No
2	Fan + 45watt Lamp	0,34 A	218 Volt	Stable and normal load	No
3	Fan + 45watt Lamp + Iron	1,59 A	215 Volt	Stable and normal load	No
4	Fan + 45watt Lamp + Iron + Dispenser	3,05 A	212 Volt/Trip	Over Current	Yes

Iset 3 A

Table 5. The results of the 5-load overcurrent relay test

No	Load	Current	Volt	Information	Trip
1	Fan	0,16 A	220 Volt	Stable and normal load	No
2	Fan + 45-watt Lamp	0,34 A	219 Volt	Stable and normal load	No
3	Fan + 45 watt Lamp + Iron	1,59 A	216 Volt	Stable and normal load	No
4	Fan + 45 watt Lamp + Iron + Dispenser	3,05 A	212 Volt	Stable and normal load	No
5	Fan + 45 watt Lamp + Iron + Dispenser + Rice cooker	4,57 A	198 Volt /Trip	Over Current	Yes

Iset 4 A

DISCUSSION

Based on the test results in Tables 2 to 5, the Single Phase 220V Overcurrent Relay Protection System based on IoT demonstrates flexibility and reliability in managing electrical current. The system allows users to set the trip current limit (Iset) from 1A to 4A using a keypad. In Table 2, with an Iset of 1A, the relay activates and cuts off the power when the current reaches 1.32A. Similarly, in Table 3, with an Iset of 2A, the system detects an overload and trips when the current reaches 2.16A. In Tables 4 and 5, the system maintains stability even as the load increases to 3.05A (Iset 3A) and trips when the load reaches 4.57A (Iset 4A). These results demonstrate that the system accurately responds to overload conditions based on the preset current limit.

One of the key advantages of this system is its ability to be monitored in real time via an Android device connected to the

system using IoT technology (NodeMCU module) [25]. Users can easily oversee the hardware's power flow and system status remotely. Additionally, the system is equipped with a keypad for setting the current limit, allowing users to adjust the trip threshold as needed. When a trip occurs due to an overload, the system prevents the device from shutting down completely, and users can reset the system by pressing the reset button. This provides convenience and flexibility for users to manage the protection system without requiring complex manual intervention [26].

Overall, the tests highlight that the Single Phase 220V Overcurrent Relay Protection System based on IoT is highly effective in protecting electrical devices from damage due to overloads [27]. The system not only ensures electrical safety but also offers efficiency and ease of operation. With features such as adjustable trip settings, real-time power flow monitoring, and a quick reset function, this device is an ideal solution for both household and small industrial applications [28]. Its combination of accurate protection, user-friendly controls, and IoT integration makes it a highly relevant innovation in today's digital era [29].

CONCLUSIONS

The results obtained from designing the overall hardware configuration, programming the system, implementing internet networks, and conducting data collection, testing, and analysis for the Single Phase 220V Overcurrent Relay Protection System based on the Internet of Things (IoT) lead to several conclusions. Firstly, the overcurrent monitoring protection system is configured using a 4x4 keypad, and protection is managed by a relay module channel programmed with Arduino, which limits the current setting; if the current exceeds the Iset threshold, the relay activates to send an on/off command to the contactor. Secondly, this overcurrent relay protection system utilizes the NodeMCU Module (Wi-Fi module), allowing it to leverage IoT capabilities during development, enabling remote monitoring in real-time via an Android device connected to a web server (Blynk).

REFERENCES

[1] N. Tesla, *The problem of increasing human energy*. A Distant Mirror, 2019.

[2] R. Putri, D. Pratama, A. Hasibuan, M. A. Muthalib, and N. S. Nurfebruary, "Evaluation of Technical Shrinkage of Express Extension PL 03 and LW 09 at PLN Lhoksukon Using ETAP Software," *Int. J. Eng. Sci. Inf. Technol.*, vol. 3, no. 2, pp. 88–96, 2023.

[3] T. Iot, D. A. N. Arduino, S. Proteksi, and E. Fasa, "Prosiding SNST ke-10 Tahun 2019 Fakultas Teknik Universitas Wahid Hasyim 1," pp. 1–6, 2019.

[4] E. Syahputra, Z. Pelawi, and A. Hasibuan, "Analisis Stabilitas Sistem Tenaga Listrik Menggunakan Berbasis Matlab," *Sisfo J. Ilm. Sist. Inf.*, vol. 2, no. 2, 2018.

[5] A. Hasibuan, K. Kartika, S. Mahfudz, and M. Daud, "Network Reconfiguration of 20 kV Sample Connection Substance LG-04 Lhokseumawe City Using Digsilent Power Factory Software Simulation 15.1," *Int. J. Adv. Data Inf. Syst.*, vol. 3, no. 1, pp. 20–29, 2022.

[6] H. Arnawan, I. Muzamir, I. Y. Mohd, R. A. R. Siti, and S. Hadi, "Evaluation of 20 kV Distribution Network Losses In Radial Distribution Systems Due to Distributed Generation Penetration," in *Journal of*

Physics: Conference Series, 2021, p. 12085.

[7] Y. Setiyawan, "No 主観的健康感を中心とした在宅高齢者における健康関連指標に関する共分散構造分析Title," pp. 1–14, 2017.

[8] S. Hardi, Y. Tarigan, H. Zulkarnaen, and A. Hasibuan, "Influence of Artificial Pollutants on Disc Insulators under Dry and Wet Conditions on Leakage Current and Flashover Voltage," in *2019 3rd International Conference on Electrical, Telecommunication and Computer Engineering (ELTICOM)*, 2019, pp. 174–178.

[9] R. Ismail, A. Hasibuan, E. S. Nasution, S. Hardi, and I. M. A. N. Arnartha, "Comparative analysis of differential relay settings in Langsa substation transformer to avoid protection failure," in *2020 4rd International Conference on Electrical, Telecommunication and Computer Engineering (ELTICOM)*, 2020, pp. 52–56.

[10] R. Sudjoko and H. Hartono, "Rancang Bangun Sistem Proteksi Generator Sinkron 3 Fasa Terhadap Arus Beban lebih dan Drop Tegangan Berbasis Mikrokontroler Arduino," *J. Penelit.*, vol. 3, no. 2, pp. 25–36, 2018, doi: 10.46491/jp.v3e2.32.25-36.

[11] A. Hasibuan, R. Rosdiana, and D. S. Tambunan, "Design and Development of An Automatic Door Gate Based on Internet of Things Using Arduino Uno," *Bull. Comput. Sci. Electr. Eng.*, vol. 2, no. 1, pp. 17–27, 2021.

[12] B. Kurniawan and A. Lomi, "MEMONITOR ENERGI LISTRIK BERBASIS INTERNET OF THINGS (IoT)," pp. 1–8, 2020.

[13] N. Mairittha, T. Mairittha, and S. Inoue, "On-device deep learning inference for efficient activity data collection," *Sensors*, vol. 19, no. 15, p. 3434, 2019.

[14] S. Greengard, *The internet of things*. MIT press, 2021.

[15] A. Andriana, Z. Zuklarnain, and H. Bachaqi, "Sistem kWh Meter Digital Menggunakan Modul PZEM-004T," *J. Tiarsie*, vol. 16, no. 1, pp. 29–34, 2019.

[16] M. Y. Aditya, "Rancang Bangun Alat Penguji Relay 220 Vac Portable Pada Cubicle Panel Unit 6 PLTA TES," *J. Tek. Elektro Rafflesia*, vol. 1, no. 1, pp. 23–29, 2021.

[17] Y. Tjandi and S. Kasim, "Electric Control Equipment Based on Arduino Relay," in *Journal of Physics: Conference Series*, 2019, p. 12028.

[18] A. Hasibuan, A. Qodri, M. Isa, and others, "Temperature Monitoring System using Arduino Uno and Smartphone Application," *Bull. Comput. Sci. Electr. Eng.*, vol. 2, no. 2, 2021.

[19] K. A. Yasa, I. M. Purbhawa, I. M. S. Yasa, I. W. Teresna, A. Nugroho, and S. Winardi, "IoT-based Electrical Power Recording using ESP32 and PZEM-004T Microcontrollers," *J. Comput. Sci. Technol. Stud.*, vol. 5, no. 4, pp. 62–68, 2023.

[20] A. A. P. Hasibuan, T. Syahputra, D. Setiawan, and J. Halim, "Aplikasi Pemberian Pakan Serta Kekurangan Air Kolam Ikan Cupang Berbasis Nodemcu," *J. MESIL (Mesin Elektro Sipil)/Journal MESIL (Machine Electro Civil)*, vol. 2, no. 2, pp. 69–74, 2021.

[21] Y. S. Parihar and others, "Internet of things and nodemcu," *J. Emerg. Technol. Innov. Res.*, vol. 6, no. 6, p. 1085, 2019.

[22] U. Dutta, N. Khurana, and others, *The Internet of Things Using NODEMCU*. Blue Rose Publishers, 2021.

[23] A. Bintoro, B. Badriana, I. F. Rahman, and A. S. Suli, "PENERAPAN CAHAYA BUATAN PADA RUANGAN KELAS MENGGUNAKAN RASPBERRY PI," *J. Energi Elektr.*, vol. 9, no. 2, pp. 18–23, 2020.

[24] M. Daud, M. Y. Zulfikar, A. Hasibuan, and M. Isa, "Prototype of Automatic Watering and Fertilizing System for Oil Palm Seeds Based on Internet of Things," *Andalas J. Electr. Electron. Eng. Technol.*, vol. 3, no. 1,

- pp. 1–9, 2023.
- [25] A. Lezcano Sirre, “IoT environmental monitoring system using Arduino and NODE MCU ESP8266,” Universitat Politècnica de Catalunya, 2024.
- [26] P. M. Anderson, C. F. Henville, R. Rifaat, B. Johnson, and S. Meliopoulos, *Power system protection*. John Wiley & Sons, 2022.
- [27] A. A. K. Majhi and S. Mohanty, “A Comprehensive Review on Internet of Things Applications in Power Systems,” *IEEE Internet Things J.*, 2024.
- [28] Y. Perwej, K. Haq, F. Parwej, M. Mumdouh, and M. Hassan, “The internet of things (IoT) and its application domains,” *Int. J. Comput. Appl.*, vol. 975, no. 8887, p. 182, 2019.
- [29] S. Nižetić, P. Šolić, D. L.-I. Gonzalez-De, L. Patrono, and others, “Internet of Things (IoT): Opportunities, issues and challenges towards a smart and sustainable future,” *J. Clean. Prod.*, vol. 274, p. 122877, 2020.