Design a Prototype Monitoring System and Data Logging for 3-Phase Electrical Systems

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Abstract. Electrical energy is one of the basic needs in life today, but in its utilization, several problems can cause losses in the electricity system, one of the causes is nontechnical shrinkage that often occurs on the customer's side in the form of electricity theft. Therefore, innovation is carried out using IoT (Internet of Things) to easily check the parameters of electricity magnitude. In this study, a stage of collecting parameters of the amount of electricity was proposed. The electric power observation method uses a voltage sensor (*ZMPT101B*) and a current sensor (SCT-013-000). Arduino Nano microcontrollers are used in measurement systems and the Wemos D1 Mini is used as a link to internet connections over Wi-Fi networks. Measurement data is sent and stored in the MySQL Database in the form of a data logger. The media used is a Website-based GUI. The results showed that remote monitoring using a GUI can be done, where this tool can send parameters of electricity measurement to the GUI a period of every 10 minutes.

Keywords: Monitoring, Internet of things, *ZMPT101B*, SCT-013-000, Data Logger.

1 Introduction

The use of electricity has become one of the primary needs of modern society. This is evidenced by the increasing number of supporting tools for human activities which use electricity as their energy source. However, in the system of the electric power distribution process, there is a condition that causes a decrease in the efficiency of the process of distributing such energy. One of them is the theft of electrical energy by certain individuals. The problem of theft of Electrical energy is not easy to handle due to limited oversight of equipment that is owned by the customer. Here's the case of data theft of electrical energy in Batam city in the areas of Bengkong in 2013 and Nongsa in 2018. The majority of electrical violations occur in the residential and commercial sectors, where the mode of theft is to meet directly on the terminal [1].

Violations are divided into four groups, namely, a violation of group one (PI) is a violation that affects the power limit but does not affect the measurement of power. Violation group two (PII) is a violation that affects power measurement but does not affect the power limit. Group

ICAE 2022, October 05, Batam, Indonesia

DOI 10.4108/eai.5-10-2022.2327860

three violations (PIII) are an influencing offense, power limits, and power measurement. Violation group four (PIV) is a violation that is committed by non-customers who use electric power without valid rights [2]. Several studies have been conducted related to the measurement of electrical power, including in the journal "AC Power Meter Design for Home Electrical Appliances," which was designed by Nattachart Tamkittikhun, Thitinan Tantidham, and Puwadech Intakot. The journal is designed to monitor the use of power used in every electrical appliance in a residential house. The microcontroller used is the Arduino Mega 2560 using the Pascal method [3]. Andi Hanif's "Electrical Energy Theft Monitoring System" is another related study. The study was designed to monitor the theft of electrical power. The microcontroller used is the AT-mega 16 [4]. Muhammad Ilham Siregar designed a microcontroller power usage monitoring tool using Wemos D1 Mini in his research entitled "Control of sockets and monitoring of electrical power use using Android" [5].

Bryan Thaylen Sitorus designs monitoring tools for the use of microcontroller power using Arduino Nano in his research entitled "Design and Build an Equipped Socket Power Meter Measurement." [6]. Florus Herman Somari designed a data logger tool using the equipment. The electric microcontrollers used are the Arduino Nano and Wemos D1 Mini in his research entitled "Electronic Equipment Data Logger System Android-based." [7]. Hanif Ibadurrahman designed a monitoring system tool using current. The microcontroller used is Nodemcu. In his research titled "Portable Electric Current Monitoring System Using SCT-013-000 and Nodemcu Microcontroller for Operation Center Room" [8].

Lucky Agazi Subagyo and Bambang Suprianto designed a 3-phase unbalanced current monitoring system tool, the microcontroller used is Arduino Uno, in their research entitled "Arduino Uno-Based 3-Phase Unbalanced Current Monitoring System" [9]. Nasution A, Putra R, and Madona E designed the monitoring system tool 3-phase power-based microcontroller in their research entitled "Design and Build a Microcontroller-Based 3-Phase Power Monitoring Tool that can be read online at the Padang State Polytechnic Microprocessor Laboratory" [10]. And also, another research related to electric current monitoring entitled "Design and Build a Microcontroller-Based Current and Voltage Monitoring Tool with SMS Gateway" was designed by Afrizal Fitriandi, Endah Komalasari, and Herri Gusmedi [11].

One of the solutions offered to monitor the theft that occurs in the field is by comparing the use of electrical power consumption by customers with data on the amount of electricity delivered by the substation. Therefore, research was conducted in the form of stages to detect the theft of electrical energy in the form of data collection of voltage, current, power, consumption energy, and cost of using electricity. It is expected that the creation of this system can help analyze the theft of electrical energy. Looking at the problem, the researcher will create a tool that can monitor data on voltage, current, active power, power factors, energy consumption, and the cost of using electricity. The data will be displayed on the Liquid Crystal Display (LCD), sent over the internet network and stored on the database, and later displayed on the Graphical User Interface (GUI) based website.

2 Method

2.1 The Hardware and Software System Design Element

This section will explain the creation of our systems, namely the design of system diagram blocks, the design of electrical design, the design of mechanical design, and the design of system flowcharts. The following are the parts of our system design:

A. Diagram Block Design System

Design a prototype monitoring system and data logging for a 3-phase electrical system designed by measuring how much the voltage, current, active power, and power factor, and calculating energy consumption, which is also the cost of using electricity, as well as the duration of time on electronic equipment in specific time intervals. Current sensors and voltage sensors will measure how much current and voltage electronic equipment needs at the time it turns on. In the data logger subsystem, there is a place for storing *MySQL* and *LCD* databases for a display of the magnitude of the current and voltage when measured.

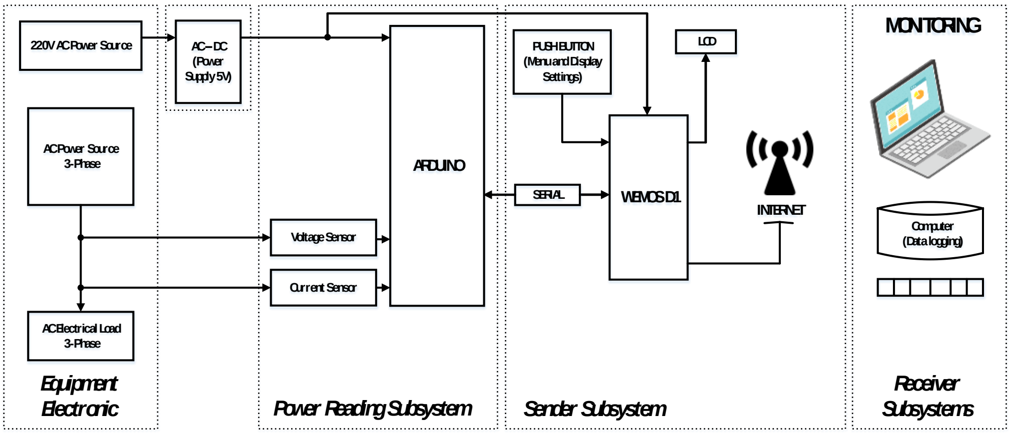

Fig. 1. The diagram block system

B. Electrical Design System

This section will explain electrical designs created using Autodesk EAGLE 9.6.2. The electrical design consists of the microcontroller Arduino Nano connected to the microcontroller Wemos D1 Mini with serial communication, the connector circuit voltage sensor (*ZMPT101B*), and circuit current sensor support (SCT-013-000) in the form of a resistor and capacitors on the Arduino analog pins. The supporting circuit serves so that the current sensor can be connected, and the error of the reading of the current value can be minimized as much as possible, so it is necessary to calculate the value of the burden resistor. The electrical design system can be seen in Figures 2 and 3.

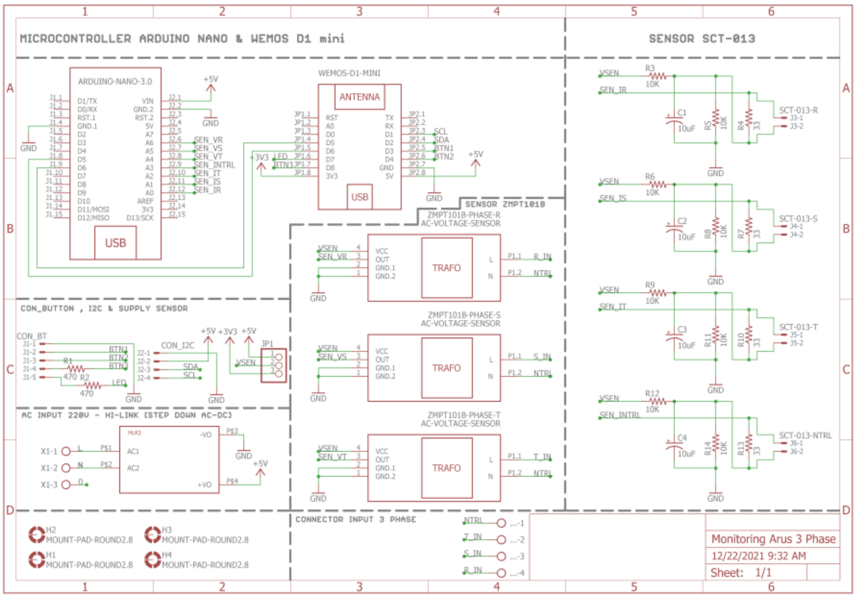

Fig. 2. Electrical design system

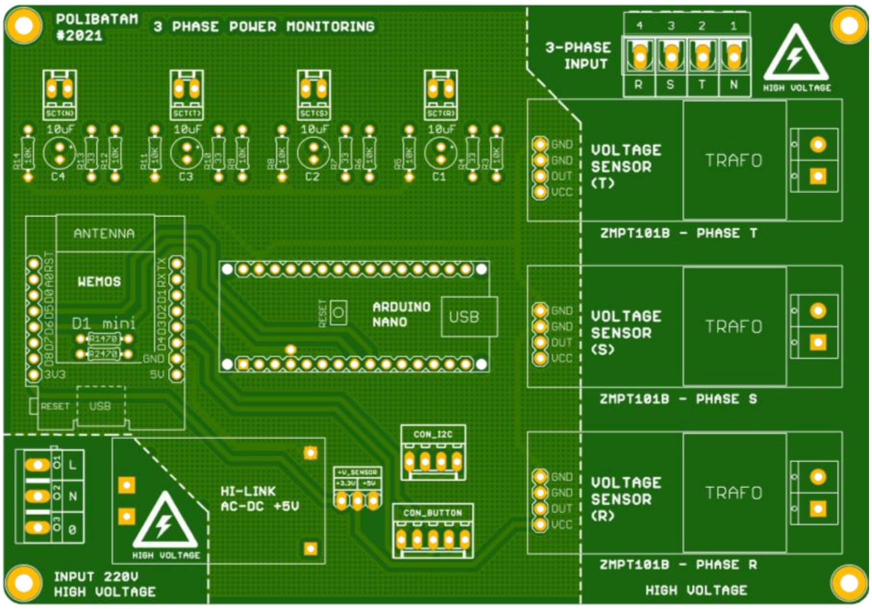

Fig. 3. Design of printed circuit boards (PCB)

C. Electrical Design System

This section will describe the mechanical design created using SolidWorks software. The description of the mechanical design can be seen in table I.

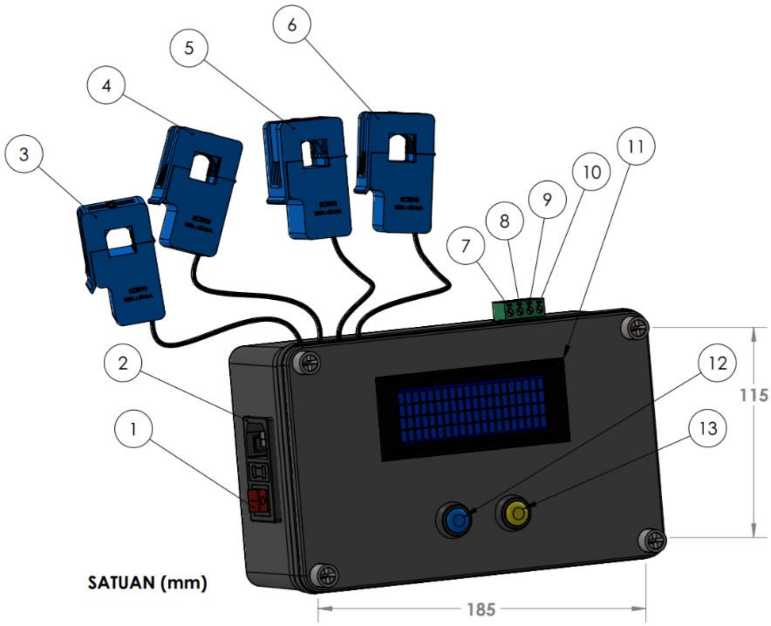

Fig. 4. The mechanical design system

Table 1. Description of the mechanical design

No	Description of the mechanical design	
	Information	***Function***
1	Power On/Off Button	On/Off system
2	AC Electrical Power Connector	Electrical connecting
3	Sensor SCT-013-000 – L1	Phase L1 current measurement
4	Sensor SCT-013-000 – L2	Phase L2 current measurement
5	Sensor SCT-013-000 – L3	Phase L3 current measurement
6	Sensor SCT-013-000 – N	Phase N current measurement
7	Terminal Sensor ZMPT – L1	Phase L1 voltage measurement
8	Terminal Sensor ZMPT – L2	Phase L2 voltage measurement
9	Terminal Sensor ZMPT – L3	Phase L3 voltage measurement
10	Terminal Block - N	Terminal neutral
11	LCD 20X4	Displaying measurements
12	Pushbutton Blue	Tool settings menu
13	Pushbutton Yellow	Change the display

D. Flowchart Design System

This section will describe the flowchart of the system. First, the microcontroller initializes the initial value by reading the voltage and current. In addition, there are several subprocesses: data processing of voltage, current, power, power factor, and calculation of energy consumption. There is also a data transmission sub-process where the Arduino microcontroller communicates with the Wemos D1 Mini microcontroller, sending serial data in the form of parameters of the amount of electricity from reading the reading power by calculating the amount of current, voltage, active power, and power factor obtained from the results of energy consumption and the cost of electricity used. The next process is the sub-process of sending data and storing data in the database as data logging. The last sub-process is website-based data monitoring.

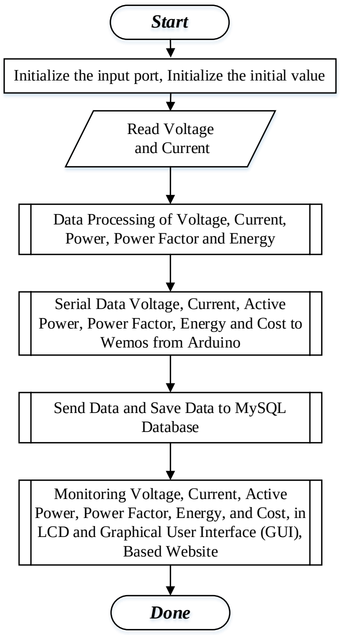

Fig. 5. The flowchart of our system

Figure 6 is a sub-process of data processing of voltage, current, power, power factor, and energy. The voltage is detected and calculated, then the RMS value of the sensor is searched, the same as the current value is searched for the RMS value of the current. After this process, the power will be calculated by the formula ($W=V.I.t$) and calculated the value of kWh.

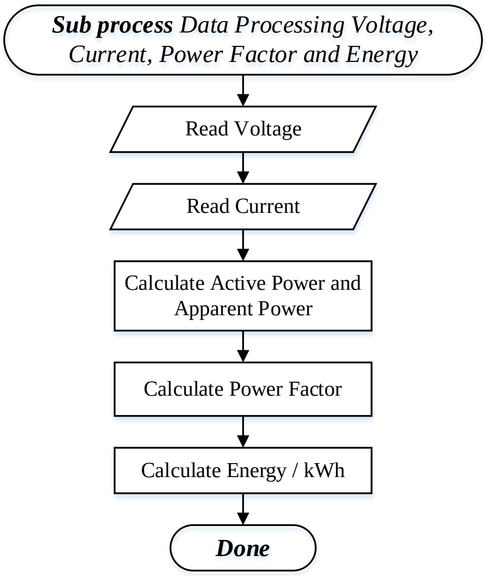

Fig. 6. The data processing sub-processing flowchart

Figure 7 is a sub-process of receiving data from the Arduino using serial communication. Because the data received has several different parts of data, the data must be parsed or separated to divide the corresponding data into several parts, namely voltage data, current, active power, power factor, energy consumption, and electricity usage cost data.

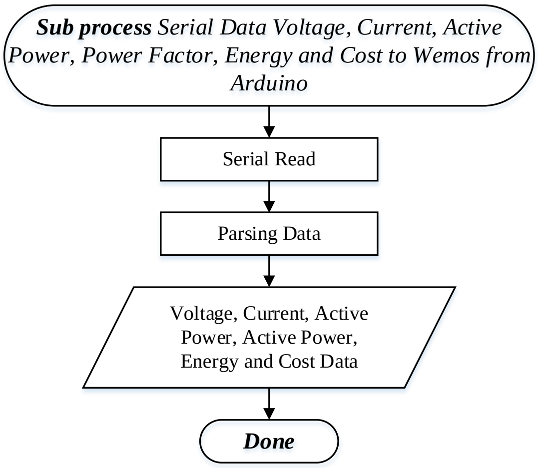

Fig. 7. The serial data sub-processing flowchart

Figure 8 is a sub-process of sending data and saving data to a MySQL database. In this sub-process, the transmission and storage of data on voltage, current, active power, power factor, energy consumption, and the cost of using electricity to the database by the microcontroller.

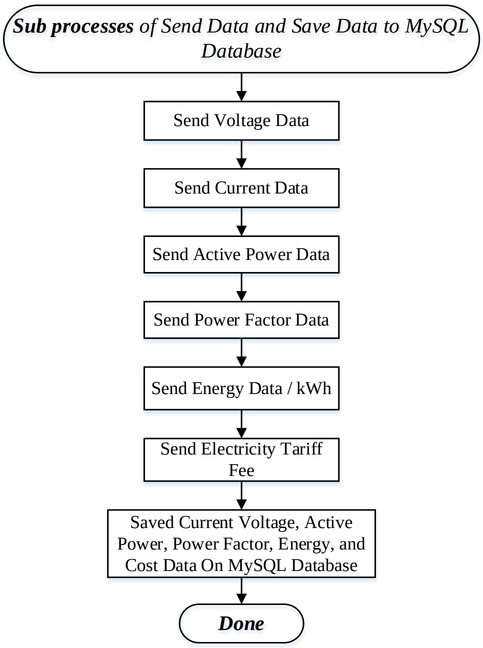

Fig. 8. The flowchart sub-processing sends data and saves it to the database.

Figure 9 is a sub-process of monitoring data in a website-based GUI. After the data on voltage, current, active power, power factor, energy consumption, and electricity usage costs are stored in the database, the next process is that the GUI will take the last data from the database, and then the data will be displayed in a website-based GUI on the condition that there is an internet connection.

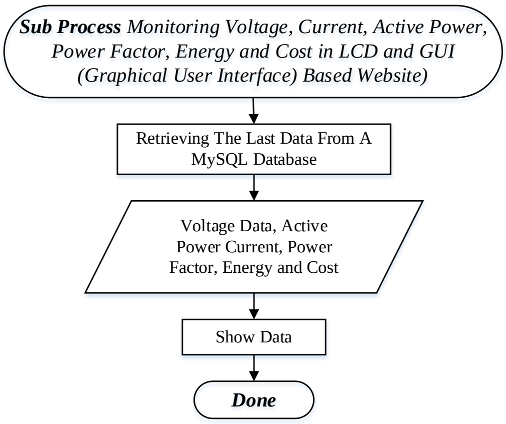

Fig. 9. The flowchart sub-processing of monitoring data

3 Experimental Results

The data recording and monitoring system that has been created includes three sub-systems, among other things, power reading sub-systems, sending sub-systems, and receiver sub-systems. Following that, the voltage, current, active power, power factor, energy consumption, and electricity cost are all monitored. The test was carried out in the W7 Laboratory room of the Batam State Polytechnic on a 3-phase panel with an ac load and a 3-phase dummy load, namely resistive and inductive loads. Figure 10 below shows the application of a data logger monitoring device on a 3-phase electricity supply.

Fig. 10. The implementation of a data logging monitoring system

A. *ZMPT101B* Voltage Sensor Calibration

The linearity test of the voltage sensor is carried out by measuring the output and input voltage of the sensor by taking a sample voltage measurement of 0 to 220V using a calibrated digital multimeter, then comparing the results of the measurement of the output voltage and the input voltage of the voltage sensor. The linearity test of the voltage sensor aims to find out whether the voltage sensor used is good or not. If the output is linear with the input, then the voltage sensor is good to use.

Table 2. Calibration Results Of *ZMPT101B* Voltage Sensor

No	Calibration results of *ZMPT101B* voltage sensor	
	V supply (V)	*Vout Sensor (V)*
1	2.27	0.04
2	9.8	0.12
3	20	0.15
4	30.2	0.26
5	40	0.28

No	Calibration results of *ZMPT101B* voltage sensor	
	V supply (V)	***Vout Sensor (V)***
6	50.1	0.36
7	60.5	0.48
8	69.9	0.62
9	80	0.81
10	90.2	0.97
11	99.9	1.17
12	110	1.30
13	120	1.43
14	130	1.58
15	140	1.71
16	149.3	1.85
17	159.4	1.99
18	170	2.08
19	180	2.22
20	90	2.34
21	200	2.4
22	210	2.45
23	220	2.5

The linear regression method is used to prove whether the data in Table II is linear or not. Using Microsoft Excel, one can obtain a linear regression formula, the correlation coefficient R2, as well as its graph. In the linearity test of this voltage sensor, the variable to be sought for the degree of linearity is the input voltage against the output voltage of the *ZMPT101B* sensor.

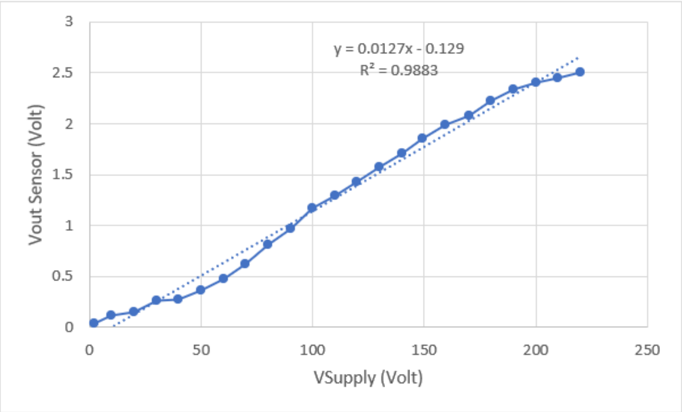

Fig. 11. The comparison of power supply to sensor output voltage

Figure 11 is a form of a straight-line equation. The following is the straight-line equation that has been obtained, namely y = 0.0127x – 0.129, and the value of R2, or the correlation value for the voltage sensor, is 0.9883. Then the equation is used for the calibration formula of the voltage sensor.

B. Current Sensor *SCT-013-000* Calibration

This section will describe the library "EmonLib_3PH.h" used. This library serves to obtain the current data and requires calibration values in the current reading program. The calibration value is obtained based on the voltage changer circuit or load resistor in Figure 2. To calculate the value of the burden resistor, there are several steps as follows:

- Specifically, the maximum current to be measured, in this study, namely the SCT-013-000 series sensor, has a current measurement range from 0A to 100A. so that the value of 100A is used as the maximum current
- By converting RMS maximum current to peak current, by associating it then formulated as follows:

$$I\ (measured) = \sqrt{2}\ x\ I\ RMS\ (current)$$

$$I\ (measured) = 1{,}414\ x\ 100 = 141{,}4A \quad (1)$$

- It is known that for the SCT-013-000 series sensors, the number of windings is 2000. Because the current value of the sensor output is greatly influenced by the number of windings of the sensor, it can be formulated:

$$I\ (sensor) = (I\ (measured))/(nb\_turns)$$

$$I\ (sensor) = 141{,}4A/2000 = 0{,}0707A \quad (2)$$

- To increase the resolution of the measurement, the voltage crossing the burden resistor at peak current must be equal to half of the reference voltage of the microcontroller, or (AREF/2), then formulated as follows:

$$R\ (ideal\ burden) = ((V\ (Ref))/2)/(I(sensor))$$

$$R\ (ideal\ burden) = (5V/2)/0{,}0707A = 35{,}4\ \Omega \quad (3)$$

There is no resistor value with a size of 35.4 Ω. It is replaced with a value that is close to 33 *Ω*. To calibrate the SCT-013-000 sensor, it is necessary to calibrate the sensor parameters. To calculate the calibration value can be formulated as follows:

$$Calibration\ Value = (I\ measured)/I(sensor)/R(burden)$$

$$Calibration\ Value = (141{,}4A/0{,}0707A/33\Omega) = 60{,}607 \quad (4)$$

C. Voltage Sensor *ZMPT101B* Testing

Voltage sensor testing is carried out by measuring the voltage in each phase L1, L2, and L3, which is changed from a voltage of 22.15V to 22.05V using the *ZMPT101B* sensor and digital multimeter, then comparing the measurement results of the sensors with the measurement results using a calibrated digital multimeter. After testing, the test result data is obtained as follows:

Table 3. Test Results Of The Phase L1 Voltage Sensor

No	Test results of the phase L1 voltage sensor			
	Observed voltage (V)			
	V supply	*Sanwa Digital Multimeter (CD731a)*	*Sensor ZMPT101B*	***Error (%)***
1	22.15	22.15	22.16	0.05 %
2	44.1	44.1	44.13	0.07 %
3	66.5	66.5	66.12	0.57 %
4	88.5	88.5	88.56	0.07 %
5	110.2	110.2	110.3	0.09 %
6	132.2	132.2	132.3	0.07 %
7	154.2	154.2	154.65	0.29 %
8	176.3	176.3	176.4	0.06 %
9	198.6	198.6	199.11	0.26 %
10	220.5	220.5	220.7	0.09 %
Average error (%)				0.46 %

Table 4. Test Results Of The Phase L2 Voltage Sensor

No	Test results of the phase L2 voltage sensor			
	Observed voltage (V)			
	V supply	*Sanwa Digital Multimeter (CD731a)*	*Sensor ZMPT101B*	***Error (%)***
1	22.15	22.15	22.19	0.18 %
2	44.1	44.1	44.15	0.11 %
3	66.5	66.5	66.58	0.12 %
4	88.5	88.5	88.61	0.12 %
5	110.2	110.2	110.31	0.10 %
6	132.2	132.2	132.29	0.07 %
7	154.2	154.2	154.45	0.16 %
8	176.3	176.3	176.58	0.16 %

No	**Test results of the phase L2 voltage sensor**			
	V supply	***Observed voltage (V)***		***Error (%)***
9	198.6	198.6	198.71	0.06 %
10	220.5	220.5	220.65	0.07 %
Average error (%)				1.15 %

Table 5. Test Results Of The Phase L3 Voltage Sensor

No	**Test results of the phase L3 voltage sensor**			
	V supply	***Observed voltage (V)***		***Error (%)***
		Sanwa Digital Multimeter (CD731a)	*Sensor ZMPT101B*	
1	22.15	22.15	22.17	0.09 %
2	44.1	44.1	44.12	0.05 %
3	66.5	66.5	66.61	0.17 %
4	88.5	88.5	88.62	0.14 %
5	110.2	110.2	110.31	0.10 %
6	132.2	132.2	132.31	0.08 %
7	154.2	154.2	155.07	0.56 %
8	176.3	176.3	176.36	0.03 %
9	198.6	198.6	199.01	0.21 %
10	220.5	220.52	220.65	0.01 %
		Average error (%)		1.43 %

Using the formula from equations 9 and 10, it can be concluded that the percent error value is taken from the value taken from the *ZMPT101B* sensor. The percentage of error is obtained with the formula:

% Error = (Measuring Instruments - Sensor Measurement)/ (Measuring Instruments) x 100 %

Average Error = (Σ% Error)/n x 100 %

Test measurements with the *ZMPT101B* sensor and a digital multimeter the error percentage value in the voltage sensor test in the L1 phase were 0.46%, in the L2 sensor 1.15%, and in the L3 sensor 1.43%. Then an average error value of 1.013% is obtained. Differences in sensor readings from all sensors can be caused by internal as well as external factors. Internal factors are derived from the unequal characteristics of each component. External factors derived from the incoming reference source voltage in each sensor are not the same.

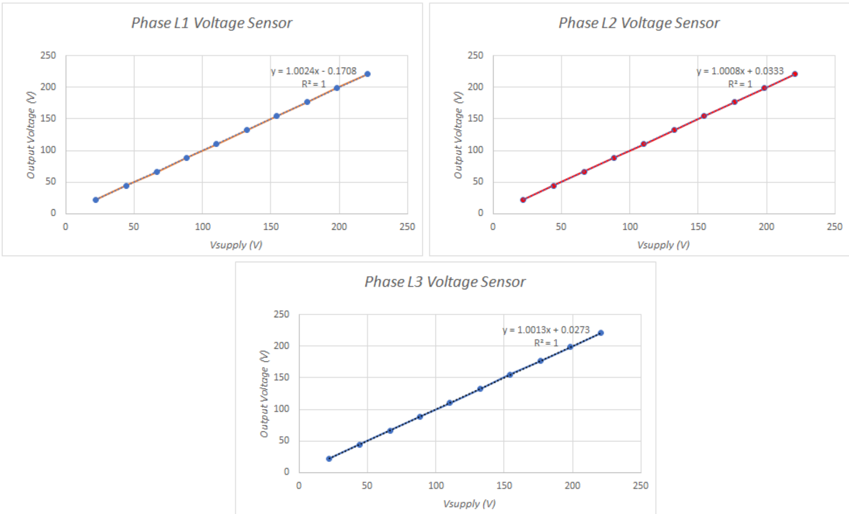

Fig. 12. *ZMPT101B* sensor test result graph

Figure 12 is a test graph of voltage sensors made in each phase L1, L2, and L3. From the graph, the difference in measurements between voltage sensors is quite small when compared to measurements using a calibrated digital multimeter measuring instrument. From the test results of the voltage sensor, it can be concluded that the sensor was successful and well-used for the monitoring system in this study.

D. *SCT-013-000* Current Sensor Testing

The testing of the current sensor is carried out by measuring the current in each phase L1, L2, and L3 by being given a changing electrical load using an *SCT-013-00* sensor and calibrated ampere pliers, then comparing the sensor measurement results with the measurement results using calibrated ampere pliers. changed the electrical load value by using resistive, inductive, and capacitive loads After testing, the current sensor obtained the test result data as follows:

Table 6. Test Results Of The Phase L1 Current Sensor

No	***Loads***	***Observed current (A)*** Clamp Meter (KT87N)	Sensor *SCT 013-000*	***Error (%)***
		Test results of the phase L1 current sensor		
1	No Load	0.00	0.01	0.00 %
2	Solder AK- 9039 (40W/220V)	0.12	0.12	0.00 %
3	Fan (45W/220V)	0.12	0.12	0.00 %
4	LED (14W/220-240V)	0.12	0.12	0.00 %
5	Iron (350W/220V)	1.30	1.30	0.00 %
6	Rice Cooker (400w/220)	1.55	1.54	0.65 %

No	Test results of the phase L1 current sensor		
	Loads	***Observed current (A)***	***Error (%)***
Average error (%)			0.65 %

Table 7. Test Results Of The Phase L2 Current Sensor

No	Test results of the phase L2 current sensor			
	Loads	***Observed current (A)***		***Error (%)***
		*Clamp Meter (*KT87N*)*	Sensor *SCT 013-000*	
1	No Load	0.00	0.01	0.00 %
2	Solder AK- 9039 (40W/220V)	0.12	0.12	0.00 %
3	Fan (45W/220V)	0.12	0.12	0.00 %
4	LED (14W/220-240V)	0.12	0.12	0.00 %
5	Iron (350W/220V)	1.30	1.30	0.00 %
6	Rice Cooker (400w/220)	1.55	1.54	0.65 %
	Average error (%)			0.65 %

Table 8. Test Results Of The Phase L3 Current Sensor

No	Test results of the phase L3 current sensor			
	Loads	***Observed current (A)***		***Error (%)***
		*Clamp Meter (*KT87N*)*	Sensor *SCT 013-000*	
1	No Load	0.00	0.01	0.00 %
2	Solder AK- 9039 (40W/220V)	0.12	0.12	0.00 %
3	Fan (45W/220V)	0.12	0.12	0.00 %
4	LED (14W/220-240V)	0.12	0.12	0.00 %
5	Iron (350W/220V)	1.30	1.29	0.77 %
6	Rice Cooker (400w/220)	1.55	1.53	1.29 %
Average error (%)				2.06 %

There is a difference in measurement results between the results of the sensor and the clamp meter. On the L1 sensor, the percentage error value is 0.65%, as on the L2 sensor and the L3 sensor, it is 2.06%, and the average error value in each phase is 1.12%.

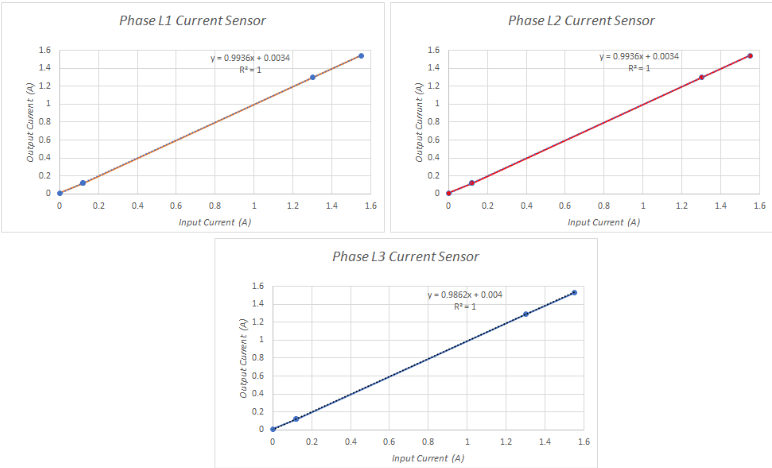

Fig. 13. *SCT-013-000* sensor test result graph

Figure 13 is a test graph of a current sensor that is in each phase of L1, L2, and L3. From the graph, the difference in measurements between current sensors is quite small when compared to measurements using the existing Ampere Plier measuring instrument. From the results of current sensor testing, it can be concluded that the sensor was successful and well-used for the monitoring system in this study.

E. Voltage, Current, and Power Reading System Testing

After conducting the voltage and current sensor tests, the next test performs a test of the current and power voltage readings. Testing was carried out to find out that this system worked well. The test is carried out to find out and compare the measurement results against the calibrated measuring instrument. This test was carried out in phase L1, with varying electrical loads applied. I obtained the data of the test results as follows:

Table 9. Power Test Results

	Power test results				
	V (Volt)	***I (Amp)***	***P (W)***	***PF***	***Loads***
Measuring Instruments	2013	1.36	289	1	
Measuring System	213.64	1.36	290.55	0.98	Iron (350/220V)
Error %	0.30 %	0.00 %	0.54 %	2.00 %	
Measuring Instruments	226	0.09	8.41	0.29	
Measuring System	226.24	0.08	7.76	0.27	LED (14W/220-240)
Error %	0.11 %	11.11 %	7.73 %	6.90 %	
Measuring Instruments	223	0.13	28.99	0.71	Fan (45W/220V)

	Power test results				
	V (Volt)	*I (Amp)*	*P (W)*	*PF*	*Loads*
Measuring System	223.17	0.13	27.5	0.7	
Error %	0.08 %	0.00 %	5.14 %	1.41 %	

F. Testing saves data to the *MySQL* database

In this test, data storage with a period of once every 10 minutes was carried out on the database. Figure 14 shows the view when sending to a MySQL database. The data displayed on the database table is a view that will be sent to the GUI. When the tool is not connected to the internet, the database does not experience an update process, but when the tool is connected to the internet, it can be seen that the data in the database undergoes an update process.

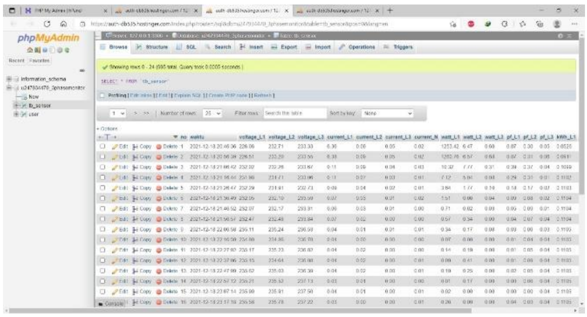

Fig. 14. Data test results on the database *MySQL*

G. Data transmission testing to a *Web-based* GUI

The process of sending data on AC electrical parameters using an internet connection is obtained from a *Wi-Fi* network connected to the Wemos microcontroller. The first sending process is done by sending data to the *MySQL* database, and then the GUI retrieves the data from the database once every 10 minutes. Figure 15 shows a sketch of a PHP program for the process of calling data. It can be seen that the refresh variable is used to call the data.

```
<!-- Memanggil data Grafik Voltage -->
<script type="text/javascript">
    var refresh = setInterval(function(){
     $('#responsecontainer1').load('data-voltage.php');
     $('#responsecontainer2').load('data-current.php');
     $('#responsecontainer3').load('data-daya.php');
     $('#responsecontainer4').load('data-powerfactor.php');
     $('#responsecontainer5').load('data-energy.php');

     $('#cekVoltage1').load('cekVoltage1.php');
     $('#cekVoltage2').load('cekVoltage2.php');
     $('#cekVoltage3').load('cekVoltage3.php');

     $('#cekCurrent1').load('cekCurrent1.php');
     $('#cekCurrent2').load('cekCurrent2.php');
     $('#cekCurrent3').load('cekCurrent3.php');
     $('#cekCurrentN').load('cekCurrentN.php');

     $('#cekDaya1').load('cekDaya1.php');
     $('#cekDaya2').load('cekDaya2.php');
     $('#cekDaya3').load('cekDaya3.php');

     $('#cekPF1').load('cekPF1.php');
     $('#cekPF2').load('cekPF2.php');
     $('#cekPF3').load('cekPF3.php');

     $('#cekEnergy1').load('cekEnergy1.php');
     $('#cekEnergy2').load('cekEnergy2.php');
     $('#cekEnergy3').load('cekEnergy3.php');
  }, 10000) ;
</script>
```

Fig. 15. Data test results on the database *MySQL*

H. Website Monitoring Implementation

The implementation of website monitoring begins with the creation of hosting and domains. The hosting used is a type of premium hosting from http://hostinger.co.id hosting service provider. while the domain address used is http://3phasemonitor.tech.

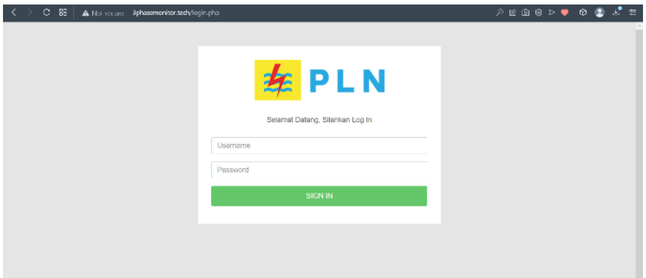

Fig. 16. Log in page

On the login page, the admin enters the username and password that have previously been registered with the system. Then press "sign-in" to enter the system. The design of the login interface can be seen in Figure 16.

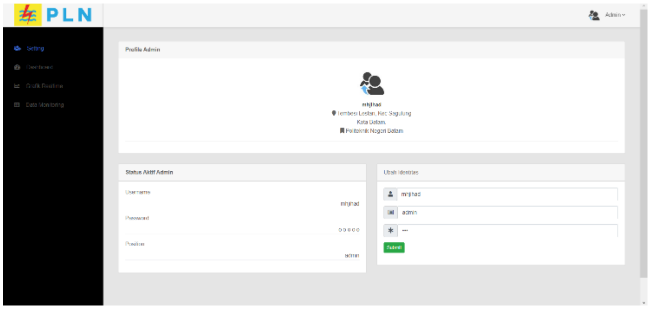

Fig. 17. Home page

If the admin correctly enters the username and password, then the admin can access the menus on this website as shown in Figure 17. On the website, there are several monitoring menus to make it easier to monitor load conditions, including monitoring dashboard views, real-time graph displays, and monitoring table data displays.

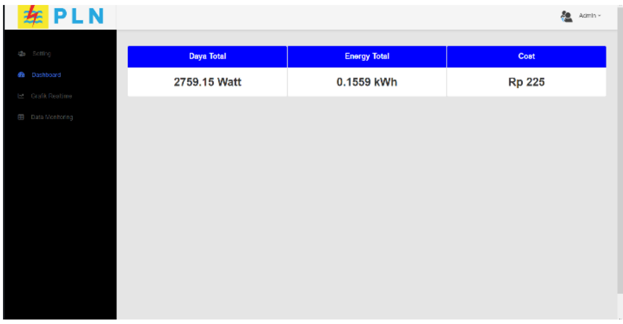

Fig. 18. Dashboard monitoring

In Figure 18, there are three displays, namely, a real-time display of the total power of each phase, L1, L2, and L3, the total energy, and the cost of using electricity.

Fig. 19. Monitoring chart

In Figure 19, there are five load monitoring chart displays in each L1, L2, and L3, including a voltage and current graph display of each phase, an active power graph, a power factor graph, and an energy consumption graph.

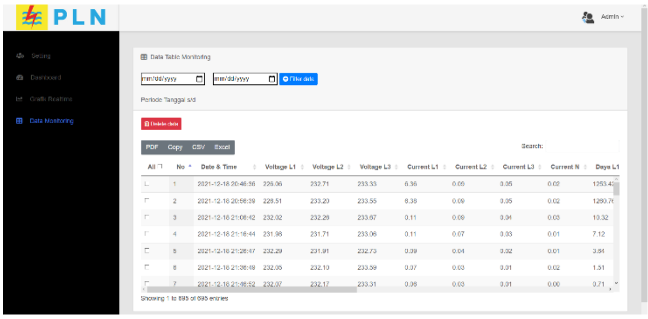

Fig. 20. Monitoring data

Figure 20 shows the display of electrical parameter monitoring data that has been successfully sent to the website display. In the monitoring data display, there are several features, including being able to download monitoring data by filtering data according to the desired date and selecting a data logger with PDF, COPY, CSV, and EXCEL extensions. The amount of electricity consumption that occurs is increasing over a certain period.

4 Conclusion

Based on the results of testing and data collection on the design system prototype of the monitoring system and data logger on the 3-phase electrical system, The following conclusions can be drawn:

- The microcontroller Wemos D1 Mini is proven to be capable of sending electrical parameter data packets to the MySQL database server *via* an internet connection.

- The test results show that remote monitoring using a GUI integrated with the database can be carried out, where this tool can send parameters for measuring the amount of electrical voltage, current, active power, and power factor as well as calculations of energy consumption and electricity usage costs to the GUI with a period of once every 10 minutes and can display measurable electrical power parameters in the measurement system.

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