ISSN No:-2456-2165

Application of Modbus and Long Range (LoRa) for 3-phase Electricity Monitoring System

Ari Sriyanto Nugroho, Dimas Alvin Faiz
Department of Electrical Engineering
Politeknik Negeri Semarang
Semarang, Indonesia

Abstract:- A system for recording the use of electrical energy is needed to determine the amount of electrical energy that has been used. Industry, households, and electricity supply companies need this recording system for payment matters. The manual recording system uses an analog kWh meter and then the usage is recorded manually. In this study, an automatic recording system was created which was stored in a database. The system created for monitoring 3-phase electricity usage is one of the technologies used to determine the use of electrical energy in a place that can be done anywhere. One way to find out electricity usage is to use a digital kWh meter which stores electricity reading data in registers which will then be read using the RS-485 communication protocol or commonly called Modbus and processed by ESP32 then forwarded to ANTARES using the LoRa communication network (LongRange). The research method used is the waterfall method which consists of observation, planning, design, implementation, and testing. Based on the results of the measurement accuracy test, the system is able to read data on the digital kWh meter exactly the same where the resulting error rate is 0% in voltage, current and power readings. In the LoRa network QoS test, the system has an average delay of 1189.9 ms and an average packet loss of 0.083%.

Keywords:- *Modbus, LoRa, Smart Monitoring, Digital KWh Meter*

I. INTRODUCTION

The rapid development of technology has made more and more electronic devices used for daily needs, one of which is the learning process in the laboratory. A laboratory that continues to be used during teaching and learning activities will result in electricity consumption being increasingly difficult to monitor, especially if there is no person assigned to monitor electricity use in the laboratory or the electrical panel that regulates the network in the laboratory is in a place that is difficult to reach, resulting in the monitoring process and data collection on electricity usage is increasingly inflexible and inefficient.

Based on these problems, an electricity usage monitoring system is needed that utilizes the Internet of Things (IoT) concept so that electricity usage data can be monitored remotely and increase the efficiency of electricity usage data collection. In this case, the Internet of Things (IoT) is involved to help the electrical power monitoring system become a monitoring tool that can be seen anywhere and displays more accurate data [7][8].

This research will create a 3-phase electricity usage monitoring system from a project called IoT-for-Energy. This system will carry out the process of reading the electrical indicators used by the Semarang State Polytechnic Telecommunications Laboratory using a microcontroller and a module which will then be forwarded to an IoT Platform using a LoRa (Long Range) communication network so that data on electricity usage in the laboratory can be monitored anywhere and anytime. This system is expected to increase the flexibility and efficiency of data collection on the use of 3-phase electricity at the Telecommunications Laboratory of the Semarang State Polytechnic.

II. METTHODOLOGY

The method used in this study uses the waterfall method. The waterfall method is a method that describes a systematic and sequential approach (step by step) in software development. The stages with the specification of user requirements then continue through the planning stages, namely planning, modeling, construction, the processes that are carried out should be sequential and interrelated [1] [4] . The description of the method used can be seen in Figure 1.

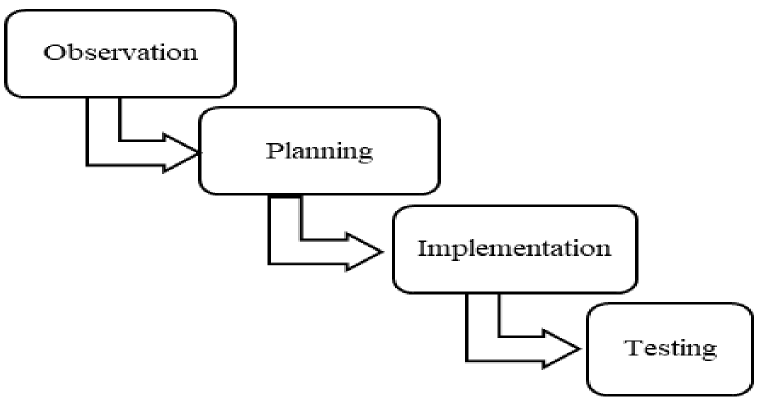

Fig. 1: Research methods

A. Observation

Determine each phase on the MCB (Miniature Circuit Breaker) contained in the electrical panel using a tespen screwdriver. Tespen screwdriver has an indicator light that will light up if the screwdriver is touched with a phase wire. Then determine the position of the LoRa Gateway that will be connected to the system.

B. Planning

The research was conducted at the Telecommunications Laboratory of the Semarang State Polytechnic with a load of 50 Watt for each phase and a distance between the RFM95 module and the LoRa Gateway as far as ~140 meters which will be shown in Figure 2. The devices and modules used in this study are shown in table 1.

No.	Name	Amount
1	kWh meter digital	1 piece
2	ESP32 DevKit V1	1 piece
3	Module XY-017	1 piece
4	Module RFM95	1 piece
5	Load 50 Watt	3 piece
6	Wire	Sufficiently

Table 1: Device and module requirements

Fig. 2: Distance between LoRa Gateway and modul RFM95

The parameters used in this study include voltage, current, power, and total energy use. The XY-017 module will use the Modbus communication protocol to retrieve electricity usage data from the digital kWh meter which is still in the form of registers in hexadecimal number format and then forward the data to the ESP32 DevKit V1 using the UART (Universal Asynchronous Receiver Transmitter) communication protocol [2]. The data will be processed on the ESP32 DevKit V1 which has been programmed using the Arduino IDE software and turned into a decimal number and forwarded to the RFM95 module using the SPI (Serial Peripheral Interface) communication protocol. The RFM95 module will send the processed data to the LoRa Gateway using the LoRa communication network [5]. After the process of sending data using the LoRa communication network, the LoRa Gateway will use the HTTP (Hypertext Transfer Protocol) communication protocol to forward the data to ANTARES. The data displayed on ANTARES will be compared with the data displayed by the digital kWh meter. This is done to determine the accuracy of the readings made by the system. Figure 3 is a system block diagram.

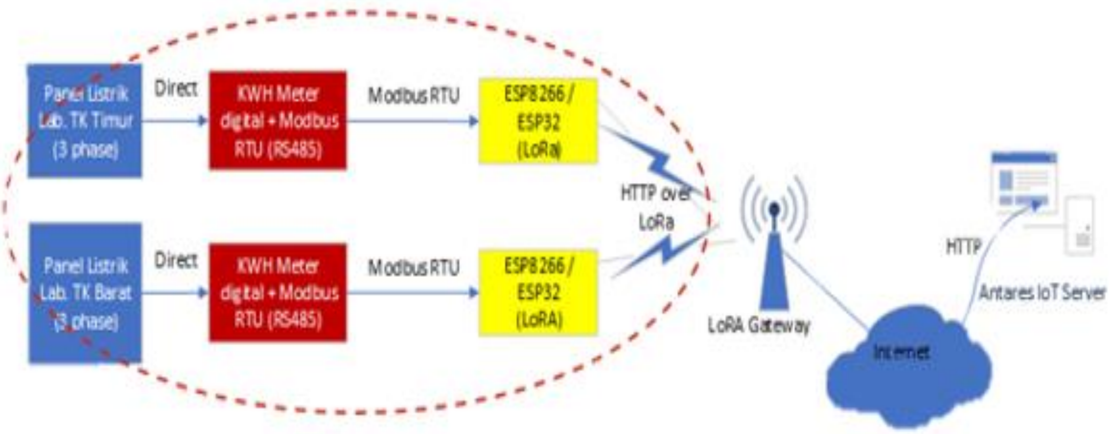

Fig. 3: System block diagram

ISSN No:-2456-2165

C. Implementation

The system is combined by connecting the pins on the devices and modules as follows:

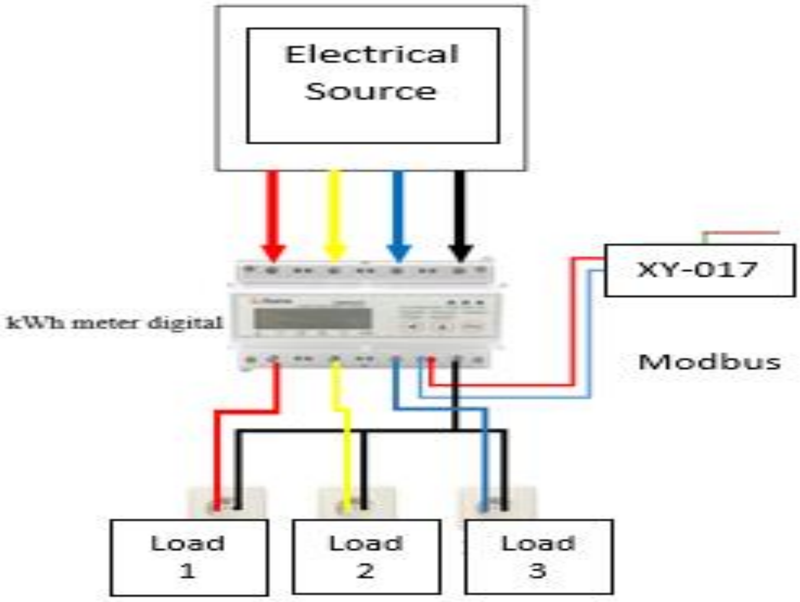

Fig. 4: Module XY-017 and kWh meter digital wiring

Figure 4 shows the electrical panel, digital kWh meter, and the connected XY-017 module. The electrical panel output line is connected to the input port on the digital kWh meter using 4 wires. The red wire is for the R phase, the yellow wire is for the S phase, the blue wire is for the T phase, and the black wire is for the neutral. Tshe output port on the digital kWh meter will be connected to 3 outlets according to the phase. The modbus output port on the digital kWh meter will be connected to the XY-017 module with the configuration port 15 connected to pin B- and port 16 connected to pin A+.

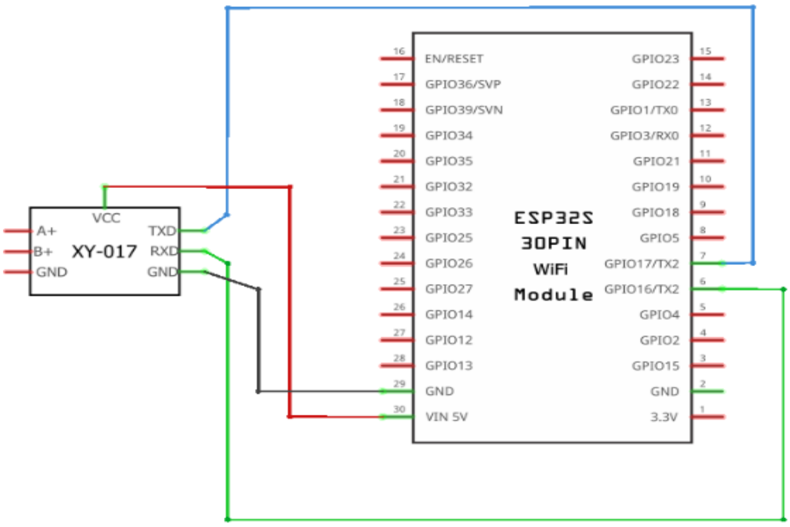

Fig. 5: Module XY-017 and ESP32 DevKit V1 wiring

Figure 5 shows the XY-017 module connected to ESP32DevKit V1 with the VCC pin configuration connected to VIN 5V, the TXD pin connected to RX2, the RXD pin connected to TX2, and the GND pin connected to GND [6].

ISSN No:-2456-2165

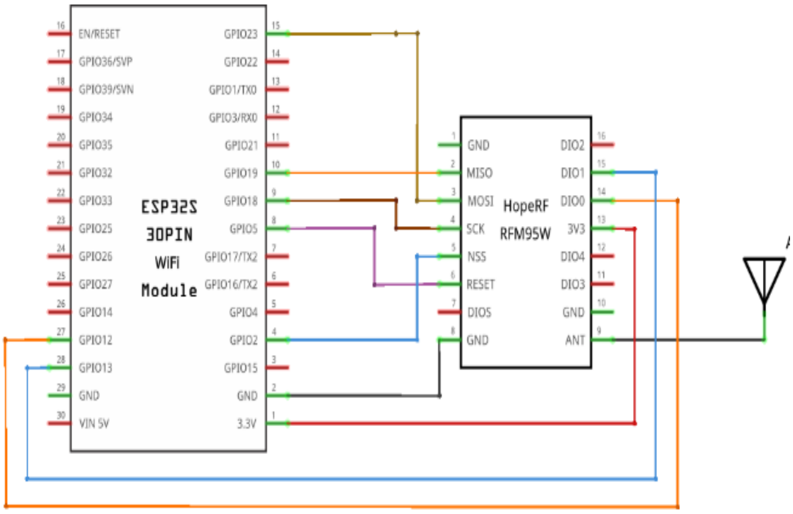

Fig. 6: ESP32 DevKit V1 and module RFM95 wiring

Figure 6 shows the ESP32 DevKit V1 connected to the RFM95 module with 3.3V pin configuration connected to pin 3V3, the GND pin connected to the GND pin, the GPIO2 pin connected to the NSS pin, the GPIO5 pin connected to the RESET pin, the GPIO12 pin connected to DIO0, the GPIO13 pin. connected to DIO1, pin GPIO18 connected to pin SCK, pin GPIO19 connected to pin MISO, pin GPIO 23 connected to pin MOSI, and pin ANT connected to antenna.

III. RESULT AND DISCUSSION

Tests are carried out to determine the measurement accuracy of the monitoring system and network quality of the system that has been created. The measurements taken are the accuracy of parameter reading, delay, and packet loss.

A. Voltage Test

In this test, the readings in the form of AC voltage from a digital kWh meter will be compared with the readings made by the system. The testing process will use a load in the form of a PC in an idle condition that uses 50 watts of power in each phase. The results of the voltage test are shown in table 2.

Digital kWh meter reading (V)			**System reading (V)**		
Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3
233,97	234,23	233,01	233,97	234,23	233,01
234,08	234,29	233,01	234,08	234,29	233,01
234,10	234,36	233,00	234,10	234,36	233
234,09	234,43	233,07	234,09	234,43	233,07
234,09	234,32	233,04	234,09	234,32	233,04
233,99	234,38	233,08	233,99	234,38	233,08
234,09	234,40	233,13	234,09	234,4	233,13
234,02	234,27	233,12	234,02	234,27	233,12
234,03	234,21	233,10	234,03	234,21	233,1
234,05	234,17	233,11	234,05	234,17	233,11

Table 2: Voltage test

B. Current Test

In this test, the results of the readings in the form of AC electric current from a digital kWh meter will be compared with the readings made by the system. The testing process will use a load in the form of a PC in an idle condition that uses 50 watts of power in each phase. Current test results are shown in table 3.

No	Digital kWh meter reading (A)			System reading (A)		
	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3
1	0,38	0,45	0,48	0,38	0,45	0,48
2	0,37	0,55	0,50	0,37	0,55	0,5
3	0,38	0,47	0,50	0,38	0,47	0,5
4	0,38	0,47	0,50	0,38	0,47	0,5
5	0,38	0,47	0,50	0,38	0,47	0,5
6	0,38	0,46	0,50	0,38	0,46	0,5
7	0,38	0,44	0,48	0,38	0,44	0,48
8	0,38	0,54	0,48	0,38	0,54	0,48
9	0,38	0,54	0,48	0,38	0,54	0,48
10	0,38	0,54	0,48	0,38	0,54	0,48

Table 3: Current test

C. Power Test

In this test, the results of readings in the form of AC power from a digital kWh meter will be compared with the readings made by the system. The testing process will use a load in the form of a PC in an idle condition that uses 50 watts of power in each phase. The power test results are shown in table 4.

No	Digital kWh meter reading (kW)			System reading (kW)		
	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3
1	0,05	0,06	0,06	0,05	0,06	0,06
2	0,05	0,07	0,07	0,05	0,07	0,07
3	0,05	0,06	0,07	0,05	0,06	0,07
4	0,05	0,06	0,06	0,05	0,06	0,06
5	0,05	0,06	0,07	0,05	0,06	0,07
6	0,05	0,06	0,07	0,05	0,06	0,07
7	0,05	0,05	0,06	0,05	0,05	0,06
8	0,05	0,07	0,06	0,05	0,07	0,06
9	0,05	0,06	0,06	0,05	0,06	0,06
10	0,05	0,06	0,06	0,05	0,06	0,06

Table 4: Power Test

D. Energy Total Test

In this test, the readings in the form of total AC electrical energy from a digital kWh meter will be compared with the readings made by the system. The testing process will use a load in the form of a PC in an idle condition that uses 50 watts of power in each phase. The digital kWh meter is capable of reading the amount of total energy in units of kWh (kilo-watt hour) with an accuracy of one digit after a comma. This results in the sensitivity of the test being drastically reduced compared to the previous three tests which had a level of accuracy of two digits after the comma. This test will focus on the total energy changes that occur during the testing process, because the total amount of energy stored by the digital kWh meter cannot be erased. The total energy test results are shown in table 5.

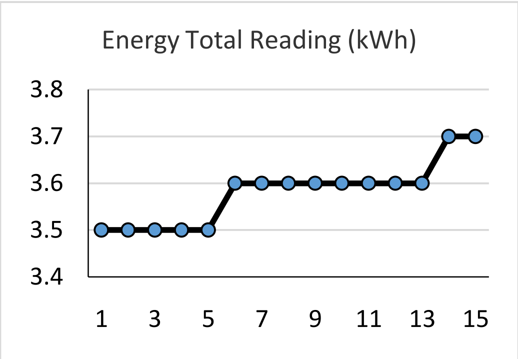

Fig. 7: Energy Total Reading

Time	Power (kW)	*Energy* (kWh)
18:03:46	0.17	3.5
18:07:47	0.17	3.5
18:11:48	0.16	3.5
18:15:49	0.16	3.5
18:19:50	0.17	3.5
18:23:51	0.16	3.6
18:27:52	0.17	3.6
18:31:53	0.17	3.6
18:35:54	0.17	3.6
18:39:55	0.16	3.6
18:43:56	0.16	3.7
18:47:57	0.17	3.7
18:51:58	0.16	3.7
18:55:59	0.16	3.7
19:00:00	0.17	3.7

Table 5: Energy Total Test

Through the data above, it is known that the data was taken for 56 minutes 14 seconds or 3374 seconds, the total energy obtained during the test time was ~0.2 kWh (~3.7 kWh – ~3.5kWh), and the average power used was 0.165 kW. With the power and time data that has been obtained, the energy change can be calculated using the energy formula. The following energy formula is used along with the results of the calculation of the energy changes obtained:

$$\text{Energy(kWh)} = \text{power (kW)} \times \frac{\text{time(s)}}{3600}$$

Then it can be calculated:

$$\text{Energi(kWh)} = 0{,}165 \times \frac{3374}{3600} = 0{,}1549 \text{ kWh}$$

Energy changes in the test data results are as follows:

$$Energy\ Change\ (kWh) = latest\ energy\ data - first\ energy\ data$$

$$Energy\ Change\ \text{(kWh)} = 3{,}7 - 3{,}5 = 0{,}2 \text{ kWh}$$

Energy(kWh)=power (kW)×(time(s))/3600
Then it can be calculated:
Energi(kWh)=0,165×3374/3600=0,1549 kWh
Energy changes in the test data results are as follows:
Energy Change (kWh)=latest energy data-first energy data
Energy Change (kWh)=3,7-3,5=0,2 kWh

From the calculation of the test data that has been done, it can be seen that the difference in the data from the test results with manual calculations is 0.05 kWh. This is due to the rounding of P and Etotal data on the digital kWh meter which makes the calculation accuracy decrease. Figure 7 shows the graphic of Energy Total Reading.

E. LoRa Network QoS Testing

At this stage, the quality of service for sending data from the system to ANTARES will be described. The test results will discuss the delay and packet loss in the system that has been created.

F. Delay Test

In the delay test, a test will be carried out to determine the delay that occurs when the system is in the process of sending data and ANTARES receives data. This test is carried out at the Telecommunications Laboratory using the help of a timer application that has an accuracy level of up to milliseconds (ms). This is because ESP32 DevKit V1 and ANTARES only have the accuracy of sending and receiving data in second (s). The results of the delay test are shown in table 6. Figure 8 shows the delay testing result.

ISSN No:-2456-2165

No	Package Sent Time	Package Received Time	*Delay* (*ms*)
1	13:45:33	13:45:34	1041
2	13:45:36	13:45:37	774
3	13:45:39	13:45:40	881
4	13:45:42	13:45:43	947
5	13:45:45	13:45:47	2176
6	13:45:48	13:45:49	1039
7	13:45:51	13:45:52	969
8	13:45:54	13:45:55	857
9	13:45:57	13:45:58	1105
10	13:46:00	13:45:02	2110
Delay Average			1189,9

Table 6: Delay Testing

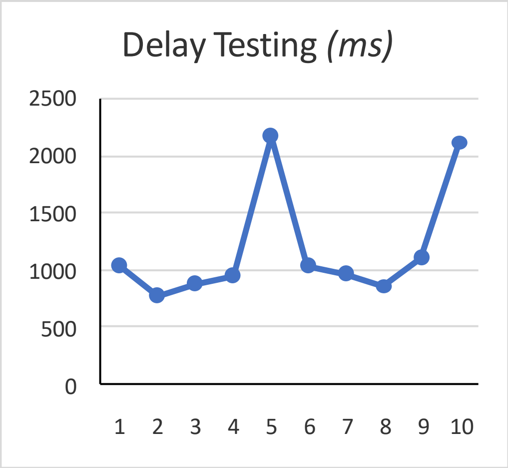

Fig. 8: Delay Testing

The delay test was carried out 10 times using the help of a timer application to improve comparison accuracy. This delay is a delay that occurs when the system processes data transmission to ANTARES using the LoRa network.

From the above test it can be seen that:

- The average time required by the system to display data on ANTARES using the LoRa network is 1189.9 ms
- The delay in the 5th and 10th data which was higher than the other data occurred due to the possibility of LoRa network interference in the telecommunications laboratory area at that time.
- The results of the delay test can be categorized as bad.

G. Packet Loss Test

In the packet loss test, a test will be carried out to determine the amount of monitoring data that failed to be sent to ANTARES. This test will connect the system located in the Telecommunications Laboratory with the LoRa Gateway which is located on the top of the tower next to the C school building which is ~140 m away. The testing process is carried out for 60 minutes by sending data every 3 seconds. The packet loss test results are shown in table 7. Figure 9 shiws the packet loss testing.

No	**Minutes**	**Packet Sent**	**Paket Received**	***Packet Loss* (%)**
1	6th	120	120	0
2	12nd	120	120	0
3	18th	120	120	0
4	24th	120	120	0
5	30th	120	120	0
6	36th	120	120	0
7	42nd	120	119	0,83
8	48th	120	120	0
9	54th	120	120	0
10	60th	120	120	0
Packet Loss Average				0,083

Table 7: Packet Loss Testing

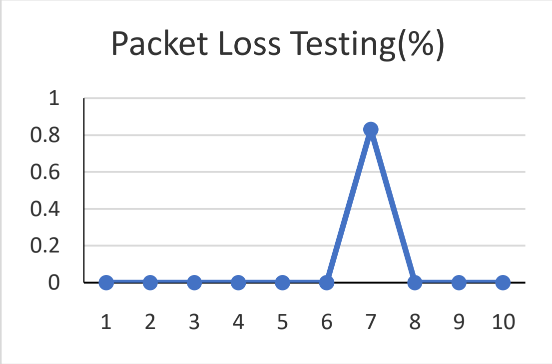

Fig. 9: Packet Loss Testing

Packet loss testing was carried out for 60 minutes with a total of 1200 data sent to ANTARES. In the above test it can be seen that:

- The use of the LoRa network in the 3-phase electricity usage monitoring system is very effective, it can be seen from the 1200 data sent, only 1 data is lost.
- Very low packet loss due to the location of the LoRa gateway which is only ~140 meters from the LoRa device
- The average loss that occurs in the system is only 0.083% so that the system can be categorized as very good.

IV. CONCLUSION

From the results of the design, testing, and discussion of the research entitled "Application of Modbus and LoRa for a 3-Phase Electricity Monitoring System" it can be concluded as follows:

- Based on the test results of the total energy reading using a load of 50 W in each phase, the average electricity usage monitored is 0.15 kWh.
- Based on Quality of Services Testing for LoRa network communication, the results were poor on the delay test with an average of 1189.9 ms, while for packet loss testing the results were very good with an average of 0.089%.

REFERENCES

[1.] Candra Eko Sakti; Primananda, Rakhmadhany, G. B. P. (2020). Implementation of Long Range Based Communication Interface In Iot Middleware To Support Network Interoperability. Journal of Information Technology and Computer Science Development, 4(Vol 4 No 1 (2020)), 65–73.

[2.] Gadre, D. V., Gupta, S., Gadre, D. V., & Gupta, S. (2018). Universal Asynchronous Receiver and Transmitter (UART). Getting Started with Tiva ARM Cortex M4 Microcontrollers, 8, 151–167.

[3.] Kurniawan, A., Syauqy, D., & Prasetio, B. H. (2017). Development of an Electrical Monitoring System in a Room Using NodeMCU and MQTT. Journal of Information Technology and Computer Science Development (J-PTIIK) Universitas Brawijaya, 1(6), 486–491.

[4.] Pressman, R.S., 2015. Software Engineering: A Practitioner Approach Book I. Yogyakarta: Andi

[5.] Qamara, Z., Elektro, F. T., Telkom, U., & Meter, P. (2018). Implementation of the Modbus Protocol on the Spm 91 Power Meter for the Implementation of Household Electric Power Monitoring Implementation of Modbus on the Spm 91 Power Meter for Employment Monitoring Power Household Monitoring. 5(3), 6179–6186.

[6.] Saptadi, A. H. (2017). Multifunction Single Logic Gate Emulation Using Atmega8a Microcontroller. Electrical Media, 10(2), 20–25.

[7.] Tukadi, Widodo, W., Ruswiensari, M., & Qomar, A. (2018). Realtime Monitoring of Electric Power Usage Based on the Internet of Things. National Seminar on Applied Science and Technology VII 2019, 581–586.

[8.] Utomo, T. P. (2019). Potential Implementation of Internet of Things (IoT) for Libraries. Indonesian Islamic University Library Bulletin, 2(1), 1–18.