Designing SMART-PJU Based on LoraWAN for Rural Light System

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Abstract* — In the industrial era 4.0, every industrial tool or equipment and building already uses automation via IoT, especially in public street lighting. Using a SMART-PJU-based LoraWAN system can minimize electrical energy use by using dimmer schedule control and ON/OFF schedule control. Using a dimmer schedule for PJU lights, the energy is set maximum of 10 amperes depending on the dimmer module used. The SMART-PJU has a LoRa module to control and monitor them via a wireless network. This research used the LoRa-EBYTE E32-DTU(915L20) module as the data sender and receiver. LoRa-EBYTE E32-DTU(915L20) with a frequency of 915 MHz to 931 MHz and an RS232/RS485 connector. The furthest distance that can be reached during testing at the Jakarta Global University campus, with a frequency of 922 MHz, is 450 meters, 344 meters, and 215 meters at three different points. The SMART-PJU system can regulate light, ON/OFF control, and ON/OFF schedule and can see the on or off status of the digital output on the Arduino. To ensure the module is on or off. Furthermore, it can monitor electricity usage in the PJU, such as power, voltage, current, power factor, and frequency, via the PZEM-016 sensor. The comparison value using the dimmer schedule at 12 hours is 375.62 Wh without the dimmer, 1085.04 Wh, and the average comparison error value of the PZEM-016 sensor reading with a multimeter is 0.1 current, 0.009 voltage, 0.3 power at each dimmer setting from 20 to 80. All data are obtained and viewed using Node-red software. By using Node-red software, users can control and monitor easily because Node-red uses language and displays that are easy for users to understand.

Keywords— **Design smart PJU berbasis Lora, Lora ebyte E32-DTU(915L20), Arduino Nano, PZEM-016, Node-red.**

I. INTRODUCTION

Public street lighting (PJU) in each area is still a manual or automatic system using timer switches due to the lack of automation in PJU. The electricity used is inefficient, and the use at the PJU will not be monitory. Using smart PJU, electricity usage can be monitored, such as power, voltage, current, power factor, and frequency, using the PZEM-016 sensor. It can be controlled ON/OFF or scheduled ON/OFF, as well as a dimmer schedule to reduce the electrical energy used by the PJU. The smart PJUs are equipped with LoRa communication. Connections often break due to broken cables, or it is challenging to install communication cables due to areas that are difficult to reach using cables. There is a need for wireless communication, such as LoRa. LoRa is wireless communication that can send and receive data via air transmission without cables.

Based on previous research conducted by [1] entitled Design of Smart Lighting and Monitoring Street Light Conditions Based on Wireless Sensor Network Using Lora. [2] entitled Smart Lighting System Using LoRa WAN Technology. [3] entitled Public Street Lighting Monitoring and Control System Using Lora Communication Network Based on Internet of Things (IoT). [4] entitled Automatic Monitoring and Control System for Public Street Lighting Based on Lora Communication. [5] entitled Analysis of Radio Transceivers on Street Lights Using the Ra-02 Module System with a Frequency of 433 MHZ. [6] with the title Public Street Lighting Control System (PJU) Using an Android-Based Internet Network. ([7] titled Implementation of Smart PJUs on Electrical Energy Consumption Efficiency on Jalan Raya Padjadjaran, Bogor City. [8] with the title Automatic PJU Lights. [9] with the title Power Efficiency of Wireless Sensor Network Devices in Algorithm-Based Public Street Lighting (PJU) Leach. [10] with the title Analysis of LoRa Transmission Characteristics in Urban Areas. The previous research above explains that each reference journal created a system for public street lighting for monitoring and manual control or depending on sensors. In the research on intelligent PJUs based on LoRa and Node-red, they can monitor all values on the PZEM-016 sensor and manually control ON/OFF, dimmer, or scheduled via node-red. This research aims to find a solution for energy efficiency and placement of PJUs without the internet or in areas where cable media is impossible for data communication.

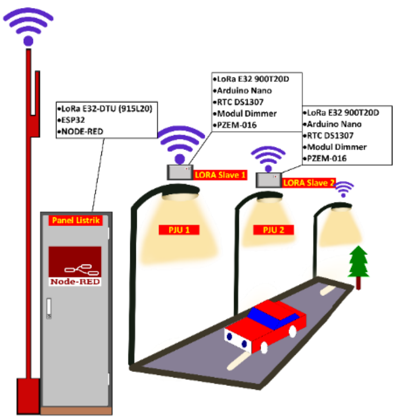

Fig.1. LoRa Network for Public Street Lighting

II. METHODS

LoRa Communication, or Long Range communication, is a wireless communication system for IoT that offers long-distance and low-power communication. LoRa is efficient in power usage due to its asynchronous communication model. LoRa communication is a new technology in Indonesia that has not yet been maximized for the future. This innovation can be helpful in densely populated metropolitan cities. The location makes it challenging to use cable media. As well as areas still

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lacking centralized control and monitoring of public street lighting.

Several methodologies exist in making LoRa-based smart PJUs, including tool design, manufacturing, and testing. Several tools and sensors exist in the LoRa master or secondary module.

1. Arduino nano is a slave controller for public street lighting to function as an ON/OFF control, dimmer control, and PZEM-016 sensor monitor.
2. ESP32 is a master controller that functions as a communication data converter from Modbus RTU to Modbus TCP/IP.
3. Dimmer module, PZEM-016, RTC DS1307, max485.

This paper making a flowchart explains or describes the smart-PJU system to make it easier for programmers to read the system flow, as in the fig.2.

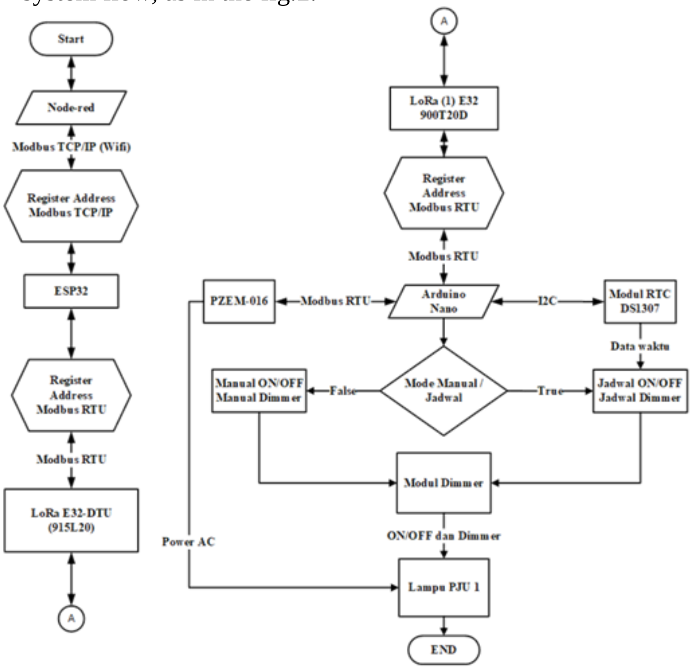

Fig.2. Flow chart Transmitter and receiver

Node-red will send and receive data via Modbus TCP-IP sent by LoRa and will display all the parameters that will be viewed or controlled, such as controlling lights on or off, light dimmers and seeing light energy usage such as power, voltage, current, power factor and frequency. Node-red will write and request Modbus RS485 RTU data to the Arduino Nano and PZEM-016 and send via LoRa. LoRa Is a receiver and transfers Modbus RS485 RTU data via a wireless network. As a Modbus RS485 RTU receiver, Arduino Nano will control the lights on or off. The dimmer read the PZEM-016 sensor and transferred it to LoRa via Modbus RS485 RTU. The PZEM-016 sensor will read power, voltage, current, power factor, and frequency. The information will sent by the Arduino nano via Modbus RTU and bypass to Node-red via the Modbus RS485 RTU protocol too.

The wiring of this paper can be seen in Fig. 3, which explains the paper's working.

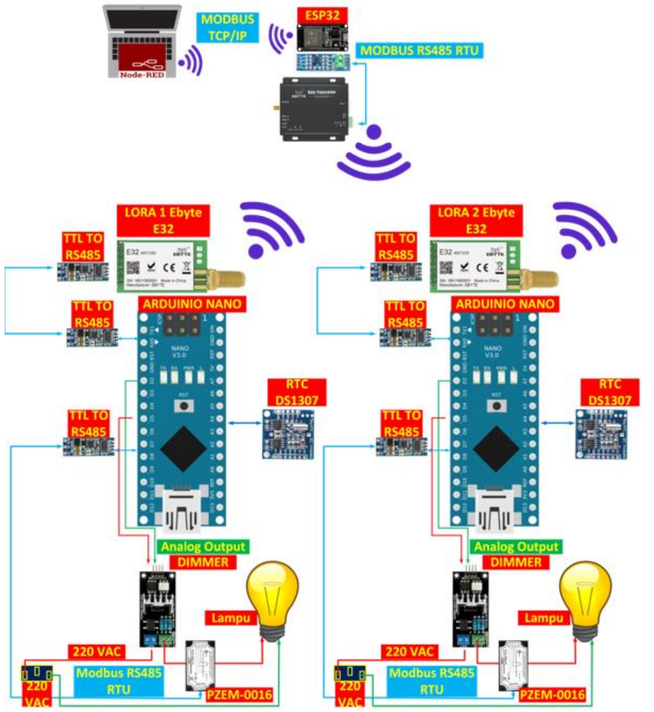

Fig.3. Schematic Wiring of LoRa-based Smart PJU

A schematic diagram of the Smart-PJU on the laptop (Node-red) will send a Modbus RTU data request and forward it to the LoRa Master. The LoRa Master will forward data to LoRa 1 and 2. LoRa 1 and 2 will forward the data sent by the LoRa Master to the Arduino Nano. The Arduino Nano will receive data, which will process according to commands from Node-red, such as ON/OFF control and dimmer control. After the Arduino nano, the Modbus data is forwarded back to the PZEM-016 sensor, which will then send Modbus data to the Node-red, such as power, voltage, current, power factor, and frequency.

The tools and materials used in making Smart PJU are LoRa (915L20)[11], LoRa E32-900T20D[12], Arduino Nano[13], PZEM-016[14], RTC DS1307[15], AC Light Dimmer Module[16], LED Lamp, ESP32[17]. The software used in making the Smart-PJUs is FLprog[18], Arduino IDE, and RF Setting LoRa.

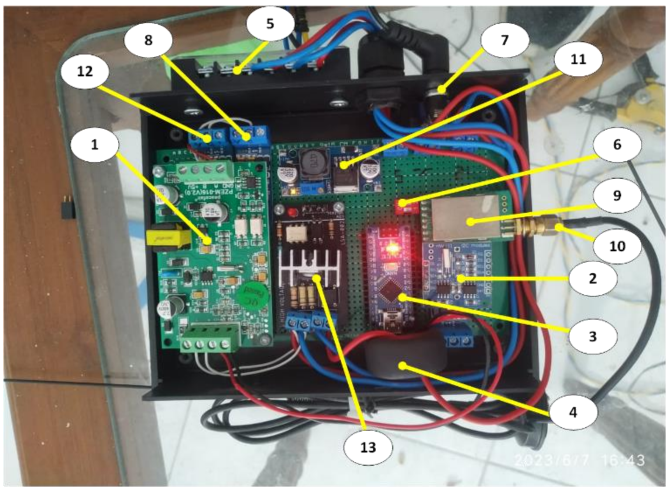

Fig.4. LoRa Master Wiring Diagram

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Explanation of the LoRa Master module, namely (Fig.4).
1. LoRa antenna.
2. LoRa E32-DTU module is equipped with two communications, RS232 and RS485. The smart PJU uses RS485 communication.
3. Power and RS485 terminals.
4. ESP32 is used as a TCP-IP Modbus master
5. Access Point or Client mode.
6. MAX485 is a serial to RS485 converter.
7. Stepdown to reduce the voltage from 12 VDC to 5 DC.

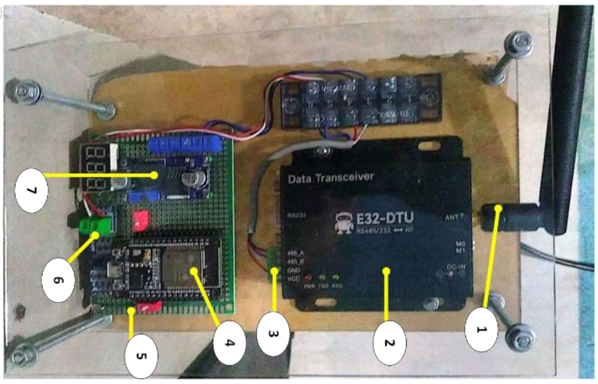

Fig.5. LoRa Slave Wiring Diagram

Based on Fig.5 in the LoRa Slave Wiring Diagram. There are several components needed to make a LoRa-based smart PJU. Among them are as follows:
1. The PZEM-016 module reads Volt, Current, Energy, Power, Frequency, and Power Factor.
2. DS1307 RTC module provides time data via the SPI protocol as a return for schedule control settings.
3. Arduino nano is a master control, which can control ON/OFF, dimmer, and read clock data on the RTC DS1307 module.
4. Current Transformer, namely the sensor from the PZEM-016 module for reading amperes on PJU units.
5. Terminals for AC power input and output cable connections.
6. Dipswitch is used for mode on the LoRa module.
7. Power input 5-12 VDC for microcontroller power.
8. TTL to RS485 as a data protocol converter from serial to RS485 Modbus for Arduino Nano to PZEM-016.
9. LoRa e32 is used as a medium for receiving and transferring data via air transmission.
10. LoRa db12 antenna.
11. Stepdown is used to reduce the voltage from 12 VDC to 5 VDC.
12. TTL to RS485 as a data protocol converter from serial to Modbus RS485 LoRa to Arduino nano.
13. Dimmer module as ON/OFF control and brightness control for PJU lights and ON/OFF control.

III. RESULTS AND DISCUSSION

From the research results above, smart PJU works well and correctly. PJU can be controlled manually ON/OFF and automatically from a laptop or computer on the Node-red dashboard and can be scheduled according to what is set by the user. The ON/OFF status can work according to the digital output conditions on the Arduino Nano. If the digital output condition is ON, the dashboard's ON/OFF status display will be ON and vice versa. On schedule, the dimmer control works properly. Namely, when 18:00, the light works at 60. Meanwhile, at 20:00, the light works at 80. At 03:00, the light works at 60%. At 06:00, the lights work at 0%. On the PZEM-016 sensor, every power parameter, voltage, current, power factor, and frequency parameter can be read on the Node-red dashboard.

Power Consumption Analysis

TABLE 1 POWER ANALYSIS USING THE PZEM-016 SENSOR

Input Dimmer	Delay Microsecond	Current (A)	Voltage (V)	Power (W)
0	9000	0	222	0
10	8100	0	222	0
20	7200	0,028	222	2,85
30	6300	0,073	222	7,7
40	5400	0,096	222	13,8
50	4500	0,11	222	21,8
60	3600	0,13	222	26,4
70	2700	0,141	222	29,2
80	1800	0,142	222	29,7

TABLE 2 POWER ANALYSIS USING A MULTIMETER

Input Dimmer	Current (A)	Voltage (V)	Power (W)
0	0	220	0
10	0	220	0
20	0,021	220	4,62
30	0,054	220	11,88
40	0,08	220	17,6
50	0,105	220	23,1
60	0,123	220	27,06
70	0,133	220	29,26
80	0,137	220	30,14

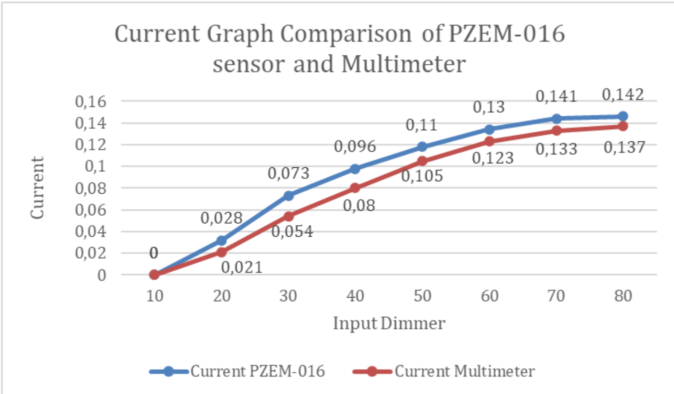

Fig.6 Current Chart Comparison

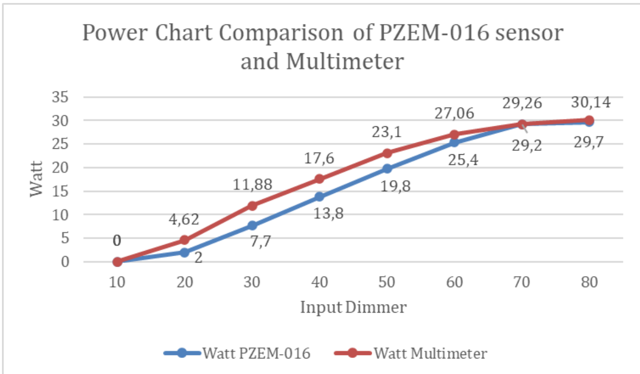

Fig.7 Power Chart Comparison

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Based on the readings in Table 1 and Table 2, there are no significant differences in current, voltage, and power. The value produced by the PJU lamp based on the set dimmer size has the same value graph and is in the same direction. This looks at Fig.6, the current chart comparison, and Fig.7, the power chart comparison. The dimmer will only work if there is an input of 20. The power value produced by the lights on the PJU shows a relatively close value. Based on node-red web readings, this value corresponds to the PZEM016 sensor value. The dimmer values 0 and 10 do not respond well to PZEM-016 and direct measurements using a multimeter.

Based on the reading error percentage value, the value is in the error range of more than 10% but does not reach 20%. This reading value is still said to be valid because the value that causes the error appears to be significant when reading the value of 3 digits after the comma, such as the dimmer input values of 20, 30, and 40, which are visible in contrast to the dimmer input values of 50, 60, 70 and 80.

TABLE 3. ERROR % VALUE ON THE PZEM-016 SENSOR

Input Dimmer	Error Current (A) %	Error Voltage (V) %	Error Power (W) %
20	33,333	0,909	62,105
30	35,185	0,909	54,286
40	20,000	0,909	27,536
50	4,762	0,909	5,963
60	5,691	0,909	2,500
70	6,015	0,909	0,205
80	3,650	0,909	1,481
Average error	12,071	0,909	17,120

IV. CONCLUSIONS

The following are several essential things that can be concluded from research on LoRa and node-red-based smart PJUs.

1. Lights can be controlled manually ON/OFF, manual dimmer, ON/OFF schedule, dimmer schedule, and PZEM-016 sensor monitoring such as power, voltage, current, power factor, and frequency via the node-red dashboard.
2. The error percentage is above 10% when the dimmer is set at 20, 30, and 40. Moreover, when the dimmer is set at 50, 60, 70, and 80, the error value is immediately reduced to less than 10% compared with the reading value.

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