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Long Range Electricity Control System for Post-Paid Electricity Meter with Power Line Carrier Communication

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ABSTRAK

Pelanggan yang menunggak tagihan listrik berkali-kali akan diberikan tindakan disiplin oleh penyedia jasa kelistrikan berupa pemutusan aliran listrik. Maka dari itu dibutuhkan sistem pemutusan listrik contactless jarak jauh. Pada penelitian ini dirancang suatu sistem kendali listrik dari jarak jauh dengan menggunakan komunikasi power line carrier (PLC). Realisasi pengujian pada sistem ini telah berhasil pada 3 rumah dalam topologi jalur bus. Proses komunikasi antar muka untuk mengirimkan data perintah kontrol adalah dengan menggunakan aplikasi mobile yang terhubung secara nirkabel ke master device. Proses pengendalian berhasil dilakukan pada electricity meter jenis analog dan digital. Pemutus electricity meter yang disabotase dapat diidentifikasi melalui pembacaan tegangan umpan balik. Delay tersingkat adalah 7.74 detik dengan panjang konduktor 5.9 meter, sedangkan delay terlama adalah 8.16 detik dengan panjang konduktor 310 meter.

Kata kunci*: pemutusan listrik, nirkontak, jarak jauh, pembawa saluran listrik, topologi bus.*

ABSTRACT

Multiple time electricity bill arrears customer will be given disciplinary act by the electrical service provider in form of disconnection of the electricity. The solution to overcome this problem is a long-range contactless electricity disconnection system. This study proposes an electricity control system using power line carrier communication method. Overall results on this system have been successful on three houses in bus line topology. Proposed interface communication process to send a control command data is by using the mobile application via Bluetooth to the master. A sabotaged electricity meter breaker can be identified by means of a feedback voltage reading. The shortest delay is 7.74 seconds with a conductor length of 5.9 meters, while the longest delay is 8.16 seconds with a conductor length of 310 meters.

Keywords*: electricity disconnection, contactless, long-range, power line carrier, bus topology.*

1. INTRODUCTION

Power Line Carrier Communication is a communication system that reiterate current infrastructure which primary purpose is the delivery of AC (50 Hz or 60 Hz) or DC electrical power, considering as data communication purposes **(Prasad et al., 2017)**. With this type of communication system, sending information does not require additional cables or devices, it is only requisite conductor cable that has been installed as a transmission medium **(Varunkumar, 2018)**. So that, each area or household that has electricity installed can use the PLC method. Power line carrier is a system for transmitting information through a conductor which is also used for the transmission of electric power.

In this era, infrastructure of well-known metering is still infancy in term of effectiveness of data exchange and scalability **(Rahayani & Nair, 2021)**. Technical features in building reliable communication infrastructure provision are a primary factor as a concern. Innovation in detecting a monitoring scheme of electrical power during distribution could be one of the features that improve the effectivity of metering. In study of nontechnical losses in electrical power system, an illegal electricity utilization detected as differential amplitude change of narrow band carrier **(Christopher et al., 2014)**.Trough this introduced scheme it shows that used of Power line communication scheme is yet simple and efficient to become the feature of improving the distribution monitoring system.

The implementation of power line carrier communication design can be diverse as the communication method also various. In paper **(Arihutomo et al., 2012)**, the monitoring system using power line communication consists of 1 master and one slave in bus line topology and using simplex communication which is only one way of communication. Data transmission process can successfully receive identically in terms of frequency and duty cycle with the glitch of phase and delay appear in this study. The greater the frequency of the data, the greater the delay. This is probably due to the low response capability of the receiver device. It was corresponding with the previous study **(Varunkumar, 2018)**, it states by using power line communication (PLC) method, electric home automation can be seen as a new approach while data transmission. The other method that also popular for power line communication analyze in several study, in-band full duplex (IBFD)in relay networks **(Canete et al., 2020)**, half duplex decode-and-forward (DF) two-way relay (TWR) **(Ahiadormey et al., 2019a)**, half duplex two-way relay (TWR) **(Ahiadormey et al., 2019b)**, low power half duplex FSK **(Cappelletti & Baschirotto, 2000)**.

Newest study application on a novel cost-effective power line communication system for low bandwidth home automation **(Wanninayake et al., 2021)**. This system consists of control and periodic reporting system on several nodes on star topology with half duplex communication from main controller. Unlike the other design technique **(Xiao et al., 2020)**, it used master and slave architecture on lighting system with also half duplex communication. Those method conclude to be cost effective method as its simple in term of design and minimum circuitry. Many states of the art technology also start to implement this method, such as in-vehicle PLC system **(Zhang et al., 2017)**, deep learning network **(Miao et al., 2021)**, and artificial neural network on IoT **(Kong & Song, 2022)**.

Based on previous works, this study proposes the controlling system using half duplex (two-way) communication in power line information transmission to control a power distribution. There will be more than one assigned slave with one master that can transmit data to cut off or reconnect the electricity to the electricity meter according to the intended address and then receive a feedback signal that serves as information.

2. SYSTEM DESIGN

2.1 System Illustration Diagram

Figure.1 illustrates the devices and communication system used in the system proposed, which consists of:

1. This cloud database functions as a storage for customer data such as the address of termination or connection, the date of arrears or settlement, the date of disconnection or connection and other data. The cloud database is connected to a smartphone via the internet network with the HTTP protocol.
2. The UI on this smartphone functions as a face-to-face officer with the master device, data access, and data logger. The app is connected to the master device via Bluetooth.
3. This master serves as the sender of control command data to the intended slave address. Data is sent by superimposing data on 220V power lines by modulating the data.
4. This slave serves as the recipient of the command to disconnect or connect the electricity meter electricity. The slave will demodulate the data sent by the master and then check whether the data matches the address, if the address is correct then the slave will process the command to cut off the electricity meter electricity and then send feedback data to the master.

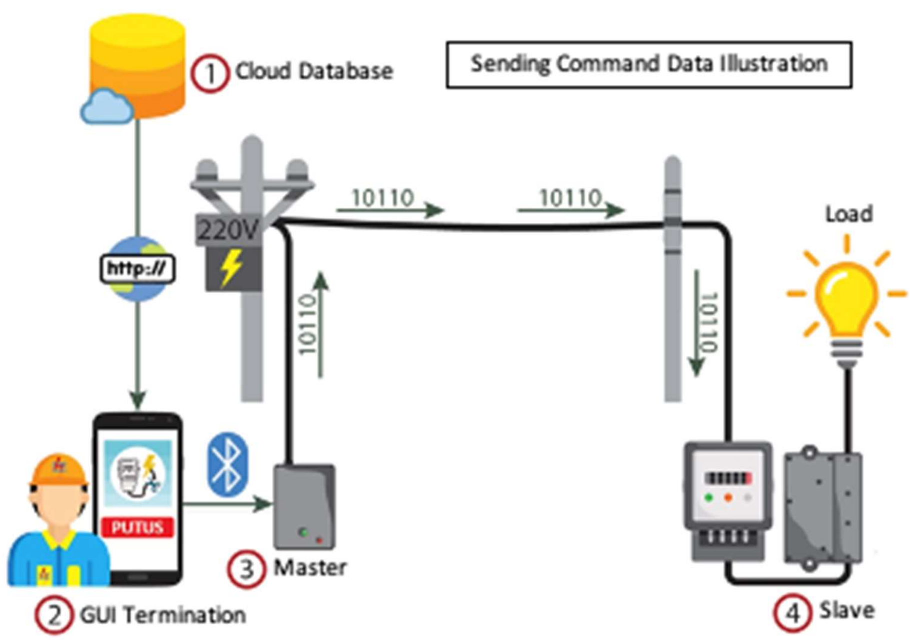


Figure 1. Device and Communication System Illustration

The control process begins with the officer checking the control area data on the application then visiting the 220V low voltage network (JTR) area, then the master device that brought by the officer is connected to the network. After that the officer selects the address of the termination house/object on the application and then press the end or connect button. The UI will notify the officer if the enforcement process is successful.

2.2 System Block Diagram

Proposed system block diagram shows on Figure 2. The tools in this system consist of a Master and a Slave that communicate via a 220V power line. The master consists of a powerline modem (PLM), a microcontroller, a PLM data input/output indicator, a connection indicator, and Bluetooth. PLM functions to modulate and demodulate data on power lines, the microcontroller functions to process data from PLM devices, Bluetooth serves as a communication medium with the Graphic User Interface (GUI) on smartphones, the Bluetooth connection indicator serves as an indication that Bluetooth communication has been connected or not, while the PLM data input/output indicator serves as an indication of PLM data entry or exit to the microcontroller.

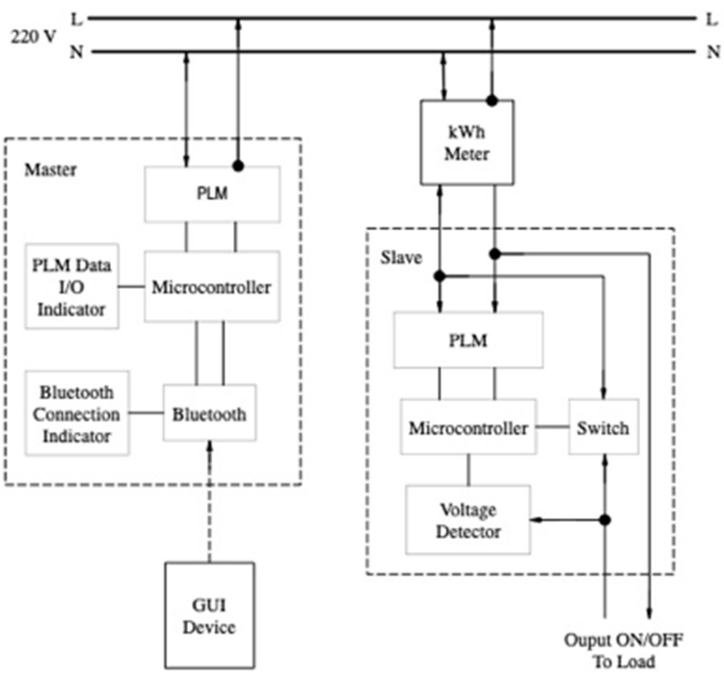


Figure 2. Proposed System Block Diagram

2.3 Master Circuit Design

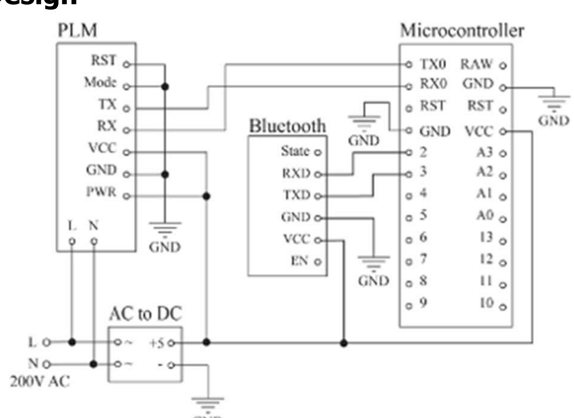


Figure 3. Wiring Diagram of Master Device Hardware

This hardware design serves to connect PLM, microcontroller, and Bluetooth. Figure 3 is a wiring diagram of the hardware master proposed. This design contains the PLM module that connect to the microcontroller along with Bluetooth module. The PLM module works as the translator of the signal that came from the power line to the microcontroller while the communication to deliver the command from the master will go through Bluetooth module to the slave.

2.4 Slave Circuit Design

This hardware design serves to connect the PLM, microcontroller, and circuit breaker. Figure 4 below is a wiring diagram of the slave device hardware to be built.

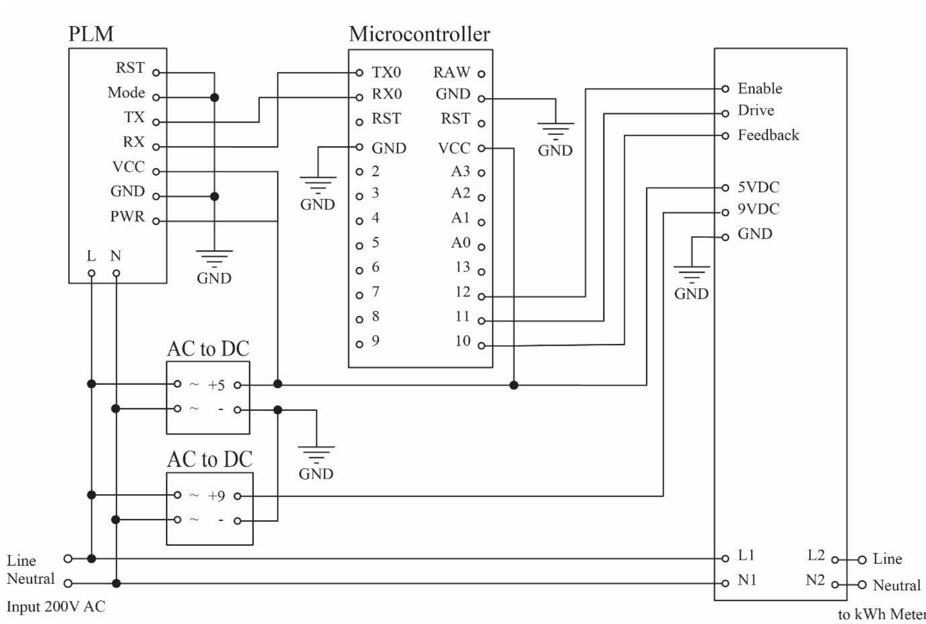


Figure 4. Wiring Diagram of Slave Device Hardware

The breaker on this hardware is built from an optocoupler latching relay circuit as a breaker and a voltage detector as feedback. Figure 5 shows the circuit breaker which will works to cut and reconnect the electricity towards the user.

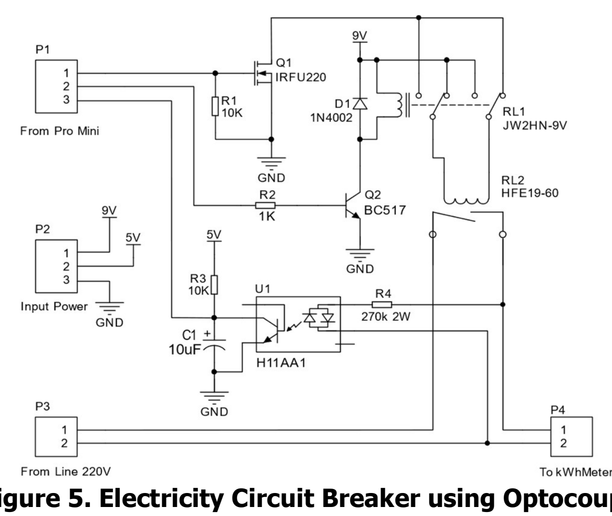


Figure 5. Electricity Circuit Breaker using Optocoupler

2.5 Master Software Flowchart

Figure 6 shows the flow chart of an algorithm design for how the master hardware works for the electricity meter control data sending system. The whole process including the parsing data, transferring information and feedback of the system was defined on this flowchart.

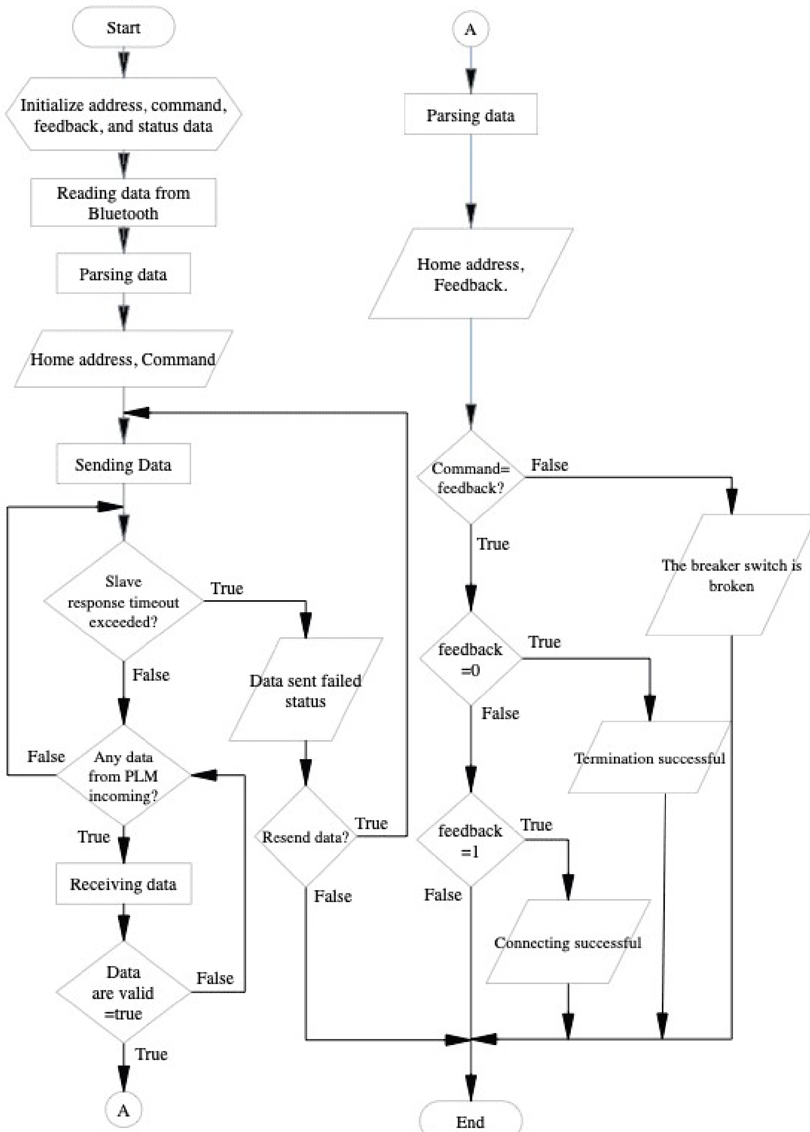


Figure 6. Flowchart of Master Device

2.6 Slave Software Flowchart

This flow chart is an algorithm design for how the master hardware works for the electricity meter control data sending system. Figure 7 shows the working design of the slave that work along with the Master device that operate by the operator to execute the command that received from master device. This device will also give the feedback to the master as the answer of the command status that execute by the breaker on the slave.

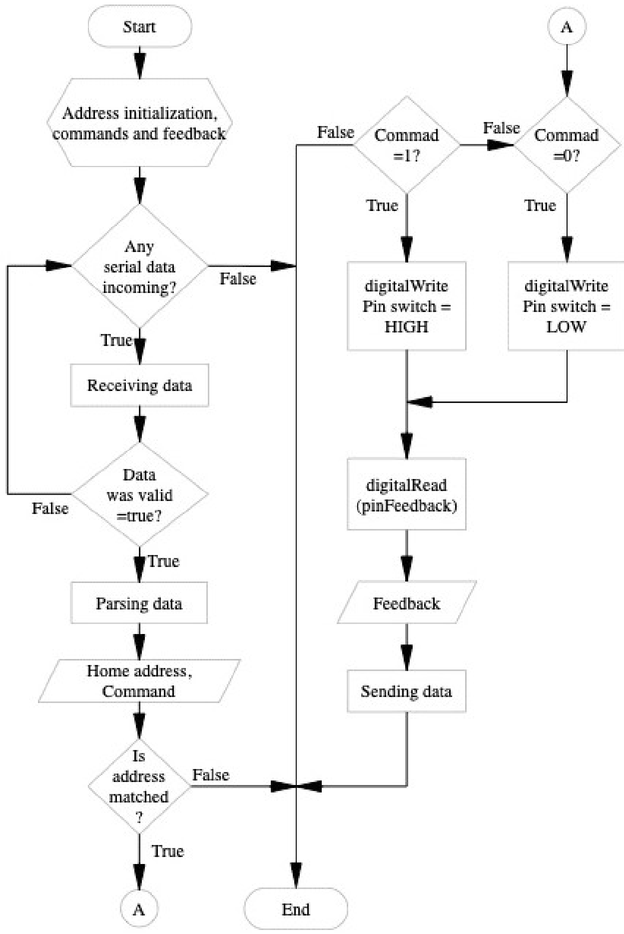


Figure 7. Slave Flowchart

3. RESULT AND DISCUSSION

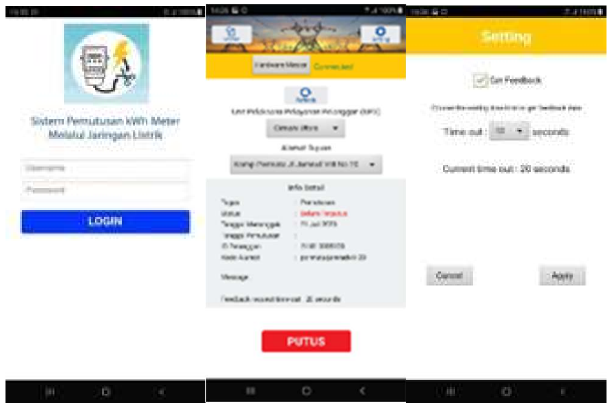
3.1 Hardware Realization

The master hardware is in the form of a box with dimensions of 125 x 85 x 52 mm to make it easy to grip and carry, while the mechanical breaker is in the form of a box that can be mounted or can be attached to the wall near the electricity meter. Figure 8 shows the realization of the hardware for master and slave control on this study.

Figure 8. Master (left) and Slave (right) Hardware Device Realization

3.2 Software Realization

Software or GUI that can be installed on any kind of android base mobile phone was made to easily setup the setting and command that will be sent by the master to the slave. This mobile application can easily access the database of the costumer that already assign for this system. Each customer also represents the number of the slave attach in the communication line.



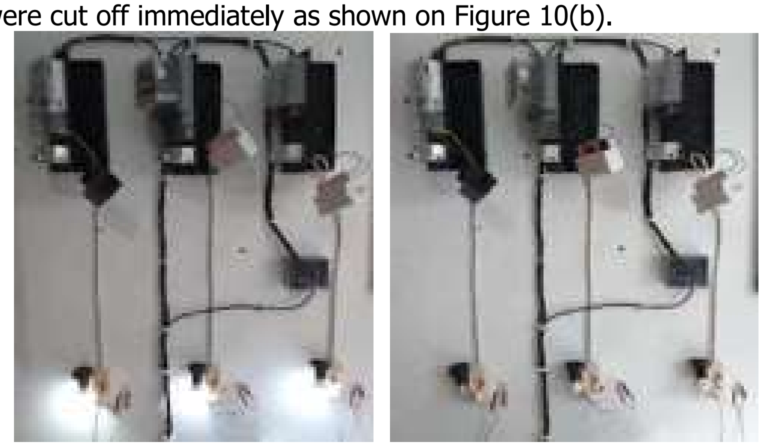
(a) (b) (c)

Figure 9. Software GUI (a) Login Feature, (b) Main Window, and (c) Setting Window.

The results of this software design are the realization of UI design on smartphones and cloud databases. Figure 9 shows the results of the UI design consist of a login page, the main page for selecting the destination address and disconnecting or connecting, and the settings page for setting the time limit for waiting for feedback and enabling or disabling receiving feedback.

3.3 Disconnection Test on Analog and Digital Electricity Meter Type

This test is carried out by attaching a breaker (slave) just right after the analog and digital electricity meters. Figure 10(a) shows that on the left side is the previous condition before disconnection command was sent to these electricity meters both analog and digital type provided. Three lamps were all on indicating the electricity still flowing through the meter. After the disconnecting command was received by the modulator all the electricity on these three meters were cut off immediately as shown on Figure 10(b).



(a) (b)

Figure 10. Disconnection Test on Analog and Digital Electricity Meter, (a) Before Disconnection (b) After Disconnection

3.4 Testing of Termination Delay on Conductor Length

Table 1 and Figure 11 shows the delay data of this system deliver the packet of command data two ways in half duplex communication. The test is carried out by connecting the master and slave (breaker) using conductors of varying lengths.

We measure it by getting attention on the sending/receiving data indicator and the sound of relay then we start the stopwatch when the sending/receiving data indicator is toggling and then we stop the stopwatch when the relay has sounded or switched. Based on datasheet QK-130F (PLM), when PLM is receiving data smaller than 253 bytes it might be inserted by noisy data. It was Approved by Figure 5. When data in buffer to small, it will be inserted by noisy data, and we used parsing method to separate information and noisy data. Even we just need 24 bytes (0permata-jamrudviii-20|0) and we have separated it; however, the receiver will be busy to read the whole data in buffer 253 bytes. So, the conclusion is the buffer always has 253 bytes on it.

Table 1 Disconnecting Delay Data According to Conductor Length

Length of Conductor (m)	Breaker 1 Time (s)	Breaker 2 Time (s)	Breaker 3 Time (s)
310	8,16	7,88	7,8
271,9	8,12	7,86	7,79
251,4	7,9	7,77	7,77
224,4	7,84	7,76	7,74
179,3	7,82	7,75	7,71
144,3	7,8	7,71	7,7
66,6	7,76	7,74	7,66
5,9	7,74	7,72	7,65

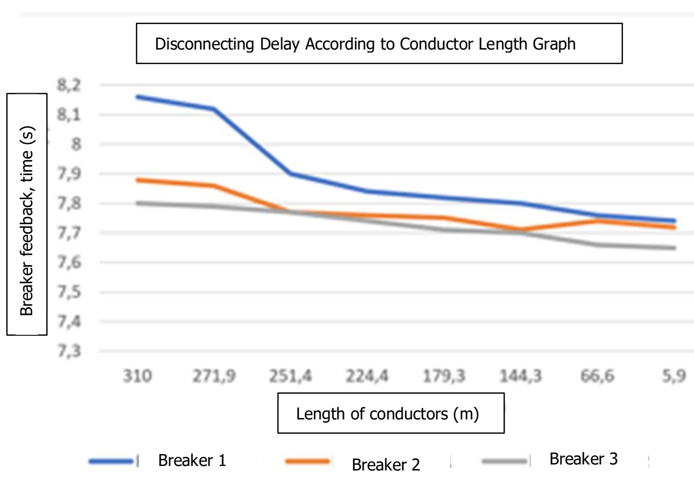


Figure 11. Disconnecting Delay Data with Half Duplex Communication

Delay or latency has the definition of the time it takes a data packet to travel from source to destination **(Wibisana, 2013)** The delay can be found by dividing the packet length (between first and last packet(s)) divided by (packets). Based on the termination delay test on the length of the conductor, it shows that the longer the conductor used, the greater the termination delay.

Delay affects the quality of service (QoS), in term of causes a packet to take longer to reach its destination. ITU-T G.114 recommends delay not greater than 150ms for various applications to categorized as great with index of 4 **(Cahyadi et al., 2013)**. In this proposed system all the command and feedback data have 24bytes per packet. From equation number 1 this test giving the result of average delay (latency) of the longest conductors about 7,9467s.

$$Average\ Delay = Total\ Delay\ /\ Total\ Packet\ Received \quad (1)$$

To find out the Transmission Speed of proposed system the formula number 2 giving the information of Transmission Speed of breaker 1 at 310meter conductance length about 2,9411millisecond. By using the transposition, we got the result that based on ITU-T G.114 standard the proposed system can be categorized as great in quality of system (QoS).

$$Transmission\ Speed = Length\ of\ Packet\ /\ Transmission\ Delay \quad (2)$$

3.5 Overall Test

The overall testing of the tool is carried out by disconnecting, connecting, and disconnecting the sabotaged breaker respectively in the certain duration. The data line uses an electricity company or provider cable that goes through four houses with the same 1 conductor. The numbering of the four houses is 19, 20, 21, and 22 (grey, yellow, blue, and green color of house respectively). The length of the conductor from house to house is unknown because it is very difficult to measure the distance from the main transformer to the nearest installed house, but the distance from house to house is 21 m for the distance from house No.19 to No.19. 20.7 m for the distance from house No.20 to No.21, 7 m for the distance from house No.21 to No.22, so the total distance from No.19 to No.22 is 35 m. The master device with a cable length of 286.3 m has been connected to the electrical installation of house No.19 and for the rest of the house we varied the installed meter between the analog and the digital one to shows that this study will works on every type of meter installed on user houses.

The three breaker devices are installed in No.20, No.21, and No.22 housings. For the installation of the breaker device, it is not possible to install it directly on the electricity meter because it can interfere with the homeowner, so that the breaker of master and slave device is installed in line with the home meter installation as the test shown on Figure 12. The breaker output is connected to a lamp to simulate the consumer load on each breaker or meter, so the successful process of command can be evaluated from this lamp as an indicator. The installation illustration provides on Figure 12. The length of conductor was designed according to real distance between houses.

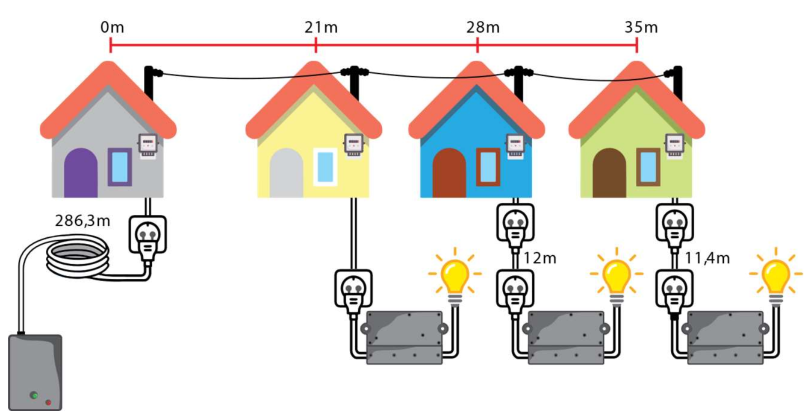
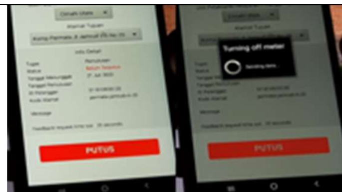
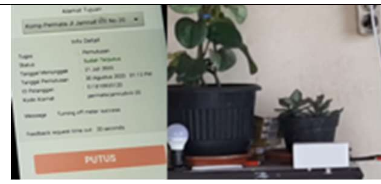
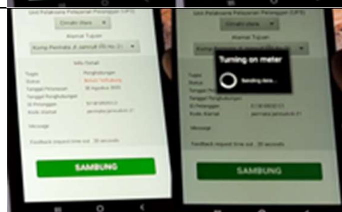
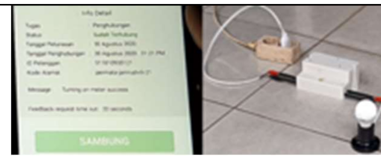
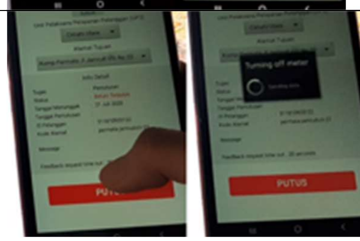
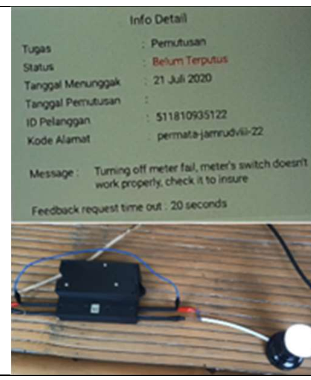


Figure 12. Installation of Master and Slave Device Illustration

Table 2 Disconnect and Connection Test and Result

Type of Test	Interface and Setting on GUI	Result	Status
Power disconnection at address No.20			Success
Power connection at address no.21			Success
Sabotaged power disconnection at address No.22			Not Success

Power disconnection test at home address No.20 start by opening the apps and choose the address to process the command of disconnection through the UI. The UI will give a successful termination message if the master has received the appropriate feedback. The results of this experiment indicate that the disconnection has been successful, the UI has displayed "Turning off meter success" and the breaker has successfully disconnected the load. As well as previous test, the power connection process at home address No.21 starts the process of connecting through the UI. Then, UI will give a successful linking message if the master has received the appropriate feedback. The results of this experiment indicate that the connection has been successful, the UI has displayed "Turning on meter success" and the breaker has successfully connected the load indicate also by the lamp that turning "ON" automatically.

Another test has done to prove that this system will not work if the system was sabotage by the customer. This disconnection test is carried out by sabotaging the breaker device by attaching a jumper cable from input to output so that the breaker will not be able to disconnect electricity to the load. At the Table 2 it shows the real test condition on power cut sabotaged process. The result shows the disconnection process through the UI was successfully set by the user or operator of GUI. The UI will give a message there is a problem with the breaker if the master has received inappropriate feedback. The results in this experiment show that there is a problem with the breaker, the UI has displayed "Turning off meter fail, meter's switch doesn't work properly, check it to insure" and the load remains electrified.

4. CONCLUSSION

In this research, we breakdown the possible solution from the proposed communication technology that we developed. Hereafter, we aim is to create a system with the specific topology, electronic devices system to provide the fit communication process with less circuitry yet effective to send and receive the command on Power Line Communication (PLC). Substantially, this study can be effectively overcome ethe main problem. By the end of this study, we can state that the control officers do not need to disconnect or connect the electricity power cable directly by using our system because of all the communication is combined the wireless and in-line of installed communication. It shows the connection can be done from a distance with a measured conductor length of 310 meters so that there will be no direct contact with the customer or more with delay compensation respectively. The results of the measurement of the termination delay on the length of the conductor are directly proportional, the longer the conductor used, the greater the termination delay time. However, the sabotaged electricity meter breaker can be identified through the feedback voltage reading easily in this system. By the comparation observation, the slave device can be used on digital or analog electricity meter types. This study prove that more than one communication system can be done to communicate several devices to receive and send a command, there is also a big possibility to stream the data to make a monitoring system. Because of the slave devices are built identically each other and only do the specific action we assume the anomaly behaviors can be detect in instance. The issue of sabotage detection that not yet solved in this research will be addressed in the next study. Still and all, regardless all the unsolved problem due to the limitation of the system designed this proposed system is on the frontline of implemented system of power line communication.

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