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Design of digital kWh-Meter to Top-Up the electric pulses by automatically using Relay Module Based on SMS and arduino uno

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Abstract

This study aims to design a digital kWh-meter prototype to top-up the electricity pulse by automatically using relay modules based on Short Message Service (SMS) and Arduino Uno. The utilization of 12 relay modules to substitute the keypad input function in the digital kWh meter is our basic idea in this study. The method we used to replace the keypad input function with the relay module is based on the integration between the circuit path in the keypad board and the relay module as an electric switch that can activate when the relay gets a trigger from the Arduino Uno. In this study, when the user wants to top up the electric pulse, the user will send the voucher number to the GSM SIM900A module via SMS, then it will be processed to the Arduino Uno. Then Arduino Uno will trigger the relay to be activated so that it can automatically fill the voucher number to the digital kWh-meter. This study result is the success of relay modules can substitute the function of keypad input to fill the voucher pulse number to the digital kWh-meter through SMS with the successful voucher number filling up to 98%. The usefulness of the relay module to change the keypad input function on the digital kWh meter is our original idea for this study.

Keywords: Digital kWh-Meter; Relay Module; Arduino Uno.

Introduction

Electricity is a basic need that can support all everyday human activities. Humans cannot do much without electricity because all the devices and technology today require electricity as a voltage source. PLN (State Electricity Company) has provided electricity usage services to the public to meet this electricity demand with a postpaid and prepaid system. In the postpaid system, consumers who use electricity can use electricity first and then pay for electricity usage services to PLN. This postpaid system is also commonly referred to as a conventional system and uses an analog kWh meter as a benchmark for consumer electricity consumption. In contrast to the prepaid system, currently, PLN has implemented a prepaid system for people who wish to use electricity usage services and uses a digital kWh-meter as a benchmark for the amount of electricity usage that consumers will use. In the prepaid system, the consumer must first purchase the number of kWh of electricity in the form of pulses, and then fill it into the digital kWh-meter according to the serial number of the token that has been purchased by the consumer [1].

The use of digital kWh meters by PLN (State Electricity Company) for the community at this time has attracted a lot of attention from researchers. These researchers want to develop it so that the digital kWh meter can be used more easily and efficiently by the public. K.Purnama and T.Rahajoeningroem have designed a Short Message Service (SMS)-based prepaid kWh-meter monitoring system using the AVR ATMega16 microcontroller. The built-in kWh meter can inform consumers when the electric pulse is running out and can top up the electrical pulse by utilizing the SMS service [2]. Ridho et al. have designed an automatic pulse top-up device on a single-phase prepaid digital kWh-meter using Arduino microcontroller-based Android. 3]. the model for topping-up a kWh-meter electric pulse with a smart card has been studied by Siregar et al. In this study, the researchers used smart cards as an alternative that can be used when consumers want to top up digital electricity kWh [4]. The top up of electricity token pulses using SMS has been designed by Sudimanto. In the system built, researchers have used Wavecom to send and receive SMS to consumers and use Arduino Uno as the data processing center [5]. The design of a

residential electric pulse monitoring tool with Arduino Uno-based voice input has been applied by Prameswari. In this study, researchers have used sound sensors to monitor the remaining digital kWh-meter electric pulses [6]. A pulse top up system on prepaid kWh meters using a mobile phone has been developed by A. Mulyana et al., researchers have utilized the SMS gateway module SIM900 and Arduino Uno to top up credits on prepaid kWh meters [7].

In previous studies, several researchers only provided kWh electricity information through SMS notifications. The drawback of previous research was that there was no automatic token-filling system. So in this study, researchers developed a prototype system for topping up the digital kWh-meter pulses automatically using a relay module based on an SMS gateway and Arduino Uno. The relay module in this study is used as a substitute for keypad input to enter an electric pulse voucher code. On digital kWh-meters that exist today, when consumers want to enter an electricity token voucher code, the user must press the keypad on the digital kWh-meter and then enter the voucher code into the digital kWh-meter system. After that, the pulse will enter the digital kWh meter, and consumers can use electricity services. The technique of topping up the voucher code with the keypad can be developed using a relay input so that the existing digital kWh meters can be topped up automatically without pressing the keypad manually. In the digital kWh-meter keypad input system, there is a data path that can enter data in the form of numbers when the keypad is pressed. This keypad can be replaced with a relay as a trigger for data input. It can be controlled automatically using Arduino Uno when you want to top up an electric pulse. The researchers' basic idea is to develop a digital kWh meter to make it easier for consumers to top up electricity pulses remotely using SMS services.

Method

A.   System Architecture Design

The design of the digital kWh-meter pulse top up prototype is built from three core parts, including input, process, and output. The input of this system is a 20-digit voucher code in SMS format, which is sent from the mobile phone to the SIM900A GSM module, after which Arduino Uno will process the SMS data received by the GSM module to control the 12-channel relay module, which functions as output. The relay in this study is used to replace the existing keypad function on the digital kWh meter. Therefore, the format of the SMS voucher code sent from a mobile phone can be entered into the digital kWh-meter based on the input from the relay trigger, which Arduino Uno controls. **Figure 1** is the architectural design built in this study.

Figure 1. System architecture design

Based on **Figure 1**, it can be seen that the 12-channel relay module is used to enter the voucher code into the digital kWh-meter, which is sent from the cellphone in the form of SMS to the SIM900A GSM module which Arduino Uno controls. On the digital kWh-meter keypad circuit, a data line is used to enter electricity token data. When the keypad is pressed, it will trigger the data lines to be connected, and the data will be entered and read by the electricity token in a number format. In this study, the function of the digital kWh-meter keypad will be replaced by a relay as a trigger on the data path to enter data into the digital kWh-meter.

B.   Hardware Design
  1.   Relay

A relay is an electronic component that functions as an electronic switch that can work when it gets an electric current voltage trigger [8]. In general, relays are used as switches to connect large and small currents to control the on and off of electronic devices. The use of relays as automatic switches that can turn on and off electronic devices that are controlled remotely has been implemented by Jalil [9]. In this study, researchers have used relays to turn on and turn off household electronic devices, namely room heaters, lights, fans, and air conditioning. In this study, a

relay as an electronic switch will be developed to trigger a voltage current to enter numerical data on a digital KWh-meter as a substitute for a digital KWh-meter keypad. Based on **Figure 2** is a picture of the relay module used in this study.

Figure 2. Relay module

2. GSM SIM900A

The GSM SIM900A module is a GSM/GPRS module that can be used to receive and send SMS which can be controlled using a microcontroller, Arduino, Raspberry Pi and other control devices. GSM SIM900A can communicate with control devices using a serial data communication system and can work at a power voltage of 5 Volts DC [10].

3. Arduino Uno

Arduino Uno is a microcontroller board based on the ATMega328 microcontroller, which has 6 analog pins, 14 digital I/O pins, and pins that function as output voltage pins of 5 Volt DC, 3.3 Volt DC, GND, RX/TX, PWM, and AREF. Arduino Uno can be active and work with an input voltage between 7 to 12 Volts DC. The application of Arduino Uno as a control data processing center has been applied by many researchers, such as for water level detection systems in hydroponic growing media [11], controlling electronic devices [12], and for Internet of Things (IoT) based control [13].

4. Prototype kWh-meter Digital

A digital kWh-meter is a measurement tool that can measure the amount of electrical energy consumption or the amount of power consumption in a unit of time and works based on a program designed by the microprocessor contained in a digital kWh-meter device [14]. In general, digital kWh meters are used in the society as prepaid kWh meters. If electricity services are used from PLN, the public must top up the digital kWh-meter and then be able to use electricity services from PLN [15]. When an electricity consumer wants to enter a token pulse into the digital kWh-meter, the consumer must enter a unique 20-digit code into the digital kWh-meter by pressing the keypad on the kWh-meter. After that, the unique code can be entered and read by the system on the kWh-meter and can activate electricity services according to the nominal electricity pulses purchased by consumers. In this study, researchers have designed a digital kWh-meter prototype that focuses on the work system of the digital kWh-meter keypad. When the keypad is pressed, it will provide a trigger to enter data in the form of numbers into the control system on the kWh- digital meters. **Figure 3** is a digital KWh-meter prototype built in this study.

Figure 3. Digital kWh-meter prototype

C.   Software Design

In building control software using the Arduino Uno, tools are needed in the form of a text editor that can be used to type programs for the Arduino. Furthermore, the programming language used to control the Arduino Uno microcontroller is the C programming language [16]. In designing Arduino control software, a program algorithm must be applied to a program, so Arduino can execute the program according to the tasks assigned to Arduino Uno to control a device. **Figure 4** is a flowchart of the software design built in this study.
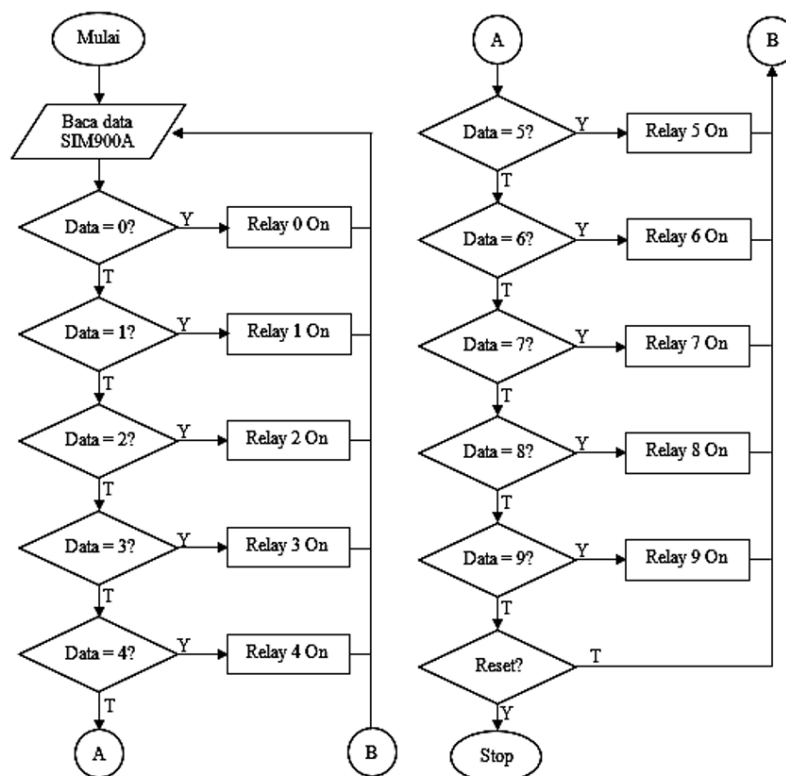

Figure 4. Software design flowchart

Results and Discussion

The results of this study are the design and construction of a digital kWh-meter prototype that can top up electricity pulses automatically using a relay module based on an electricity token number sent from a mobile phone

in the form of an SMS to the SIM900A GSM module. **Figure 5** is the result of the design and prototype of the digital kWh-meter tool built in this study.
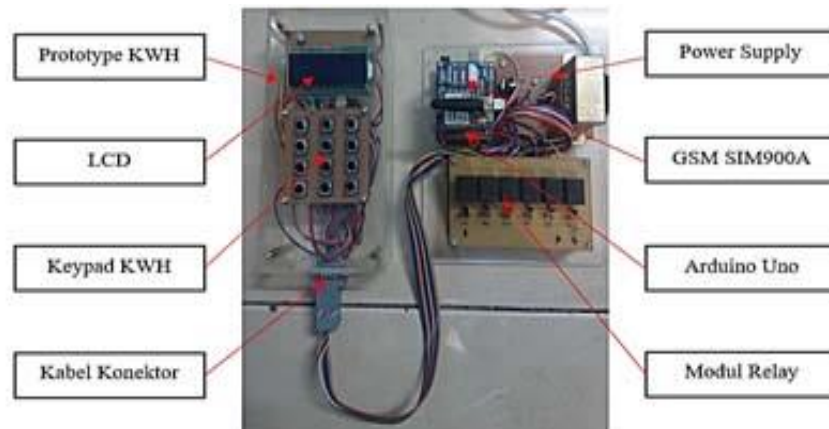

Figure 5. The design results of the digital kWh-meter prototype

Based on the information in **Figure 5**, it can be seen that the design results of the digital kWh-meter prototype consist of several parts, including the digital kWh-meter prototype, LCD, keypad, connector cable, power supply, SIM900A GSM module, Arduino Uno, and relay module. The digital kWh-meter prototype in this study is a device that looks similar to a digital kWh-meter, where the prototype focuses on the keypad to enter numerical data into the digital kWh-meter microcontroller system. When the keypad is pressed, the data is in the form of numbers. It will enter and be read by the microcontroller. The function of the LCD on this prototype is to display data on the number of token electric pulses entered into the microcontroller system when the keypad is pressed or the relay is working. The function of the keypad on this prototype is as a device used to enter electricity token pulse numbers into the microcontroller system when the keypad is pressed. Furthermore, the function of the connector cable is to act as a liaison between the keypad on the digital kWh-meter prototype device and the relay circuit.

The power supply in this study is a resource used to provide electric current to each component, which are 5 Volts DC and 12 Volts DC. The function of the SIM900A GSM module is as a device that is used to receive electricity token pulse data in the form of SMS sent from a cell phone and then sends the data to Arduino Uno for processing. In this study, the function of the Arduino Uno is as a data processing centre, where the Arduino Uno will process the SMS data received by the SIM900A GSM module. Then, it instructs the relay to turn on and off to enter the electricity token number data into the digital kWh meter. Furthermore, the relay function in this study is a device used to enter data in the form of numbers into a digital kWh-meter which acts as a substitute for a digital kWh-meter keypad input. In a digital kWh meter, when the keypad is pressed, it will trigger the data path on the keypad circuit to enter numeric data into the microcontroller system. Therefore, in this study, the keypad function was replaced with a relay as a trigger to enter numerical data into the digital kWh-meter microcontroller. **Figure 6** is a series of keypads on a digital kWh-meter with a built prototype tool.

Figure 6. Left: Original digital kWh-meter keypad assembly; Centre: Keypad kWh-meter prototype circuit; Right: Digital kWh-meter keypad data path

Figure 6 shows that in the keypad series, there is a data line that functions as data input when the keypad is pressed. This research aims to connect the data line to the relay module device, where the keypad function as a

trigger to enter numeric data will be replaced by the relay module. The following is a connection table between the digital kWh-meter keypad, the relay module and the Arduino Uno pins used to control this study.

Table 1. Connections between the digital kWh-meter keypad and the Arduino Uno relay module and pins.

Keypad KWH	Modul Relay	Pin Arduino Uno
1	1	0
2	2	1
3	3	2
4	4	3
5	5	4
6	6	5
7	7	6
8	8	7
9	9	8
0	10	9
#	11	10
*	12	11

Based on the information from **Table 1**, it can be seen that the data for each digital kWh-meter keypad will be replaced by a relay module. Therefore, the number of relay modules used to replace the keypad function is 12 channels of the relay module, where each relay channel represents one keypad of kWh- digital meters. Furthermore, each relay module channel will be controlled by one pin from Arduino Uno to trigger the relay to turn on and off when entering the electricity token pulse data into the digital kWh meter. Researchers have conducted a trial of sending electricity token pulse data as many as 20 digit numbers in the form of SMS from a mobile phone to a digital kWh-meter prototype. The following is a system test table.

Table 2. Test results for prototype devices and systems

Data Tokens	Price	Electricity Amount	Results
8546-2649-5641-4375-6335	Rp 20,000	13.2 kWh	Succeed
9087-2648-5612-7792-4169	Rp 50,000	33.1 kWh	Succeed
7095-2754-7214-1359-8453	Rp 100,000	66.2 kWh	Succeed
5641-8163-2965-9163-5417	Rp 250,000	132.3 kWh	Succeed
6431-5576-4874-3286-9126	Rp 500,000	328.9 kWh	Succeed
5167-4382-1496-5587-6942	Rp 1.,000,000	659.7 kWh	Succeed

Table 2 shows the results of testing the device by entering the electricity token voucher code sent from the mobile phone to the digital kWh meter device. Based on these results, the electricity token was sent successfully and can run well in topping up in the voucher code. In topping up the electricity token, the user sends a voucher code to the GSM SIM900A module, after which Arduino Uno reads the SMS code received by GSM SIM900A in the form of a voucher code. Next, Arduino instructs the relay to top up the voucher code automatically. In this study, the relay functions as a substitute for keypad input on the digital kWh meter prototype. When the relay has finished entering the voucher code on the digital kWh-meter electricity token, the next step is for Arduino to instruct GSM SIM900A to send an SMS in the form of notification information that topping up the credit has been successful. In this study, we tested the accuracy of topping up the electricity tokens 50 times, of which 1 trial was inaccurate due to the poor quality of the GSM network. We have calculated the accuracy of the system in successfully topping up the voucher code using the following **Formula 1**:

$$\text{Accuracy} = \frac{\text{Voucher code total successfully topped-up}}{\text{Total voucher code successfully sent}} \times 100\% \qquad (1)$$

Based on the results of the trials we have carried out, the system we have built successfully topped up the electricity token vouchers with a success accuracy of up to 98%. We obtained those results based on the calculation of the total voucher codes that have been successfully entered into electricity tokens, which are 49 trials divided by the total code vouchers that have been successfully sent are 50 trials, then multiplied by 100%. Furthermore, Figure 7 below is a display of information on sending the voucher code and the results of the information if the relay has successfully topped up the digital kWh-meter electricity token.

Figure 7. Display of topping up the digital kWh-meter electricity tokens

In **Figure 7**, it can be seen that the results of toping up the digital kWh-meter electricity token sent by the user in the form of a voucher code to Arduino have been successfully sent to be forwarded to the relay in the process of topping up the electricity token automatically. The reply information from GSM SIM900A is in the form of an SMS notification that the top up electricity token has been successful.

Conclusion

The design of a digital kWh-meter to top up the electric pulse prototype using a relay module based on an SMS gateway and Arduino Uno has been successfully applied in this study. The relay function as an electronic switch can be used and developed to replace the existing keypad function on the digital kWh-meter prototype when the device receives electrical pulse token data sent from a cell phone to the SIM900A GSM module in SMS format. A trigger circuit in the digital kWh-meter keypad is used to enter electricity token credit data. In this study, the trigger circuit is connected to the relay module to replace the keypad function when entering electricity token pulse data into the digital kWh meter. The test results of the system being built are that the relay module device has succeeded in entering token pulse data into the digital kWh-meter prototype with a success rate of up to 98%. Furthermore, success is obtained from the total voucher codes that have been successfully topped up into electricity tokens divided by the total voucher codes that have been successfully sent. The success to top up the electricity token that we built dramatically affects the GSM network's quality when sending customers' SMS messages to the SIM900A GSM module.

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