International Journal of Computer Applications Technology and Research
Volume 9–Issue 09, 277-282, 2020, ISSN:-2319–8656

Implementation of Web-based kWh (Kilowatt-hour) Meter System for Student Accommodation Room

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Abstract: Currently student accommodations are very common to be found around campus areas. Student accommodations generally utilize PLN (National Electricity Company) as their source of electricity. However, most student accommodations use single kWh meter system to accommodate all rooms in a unit. This results in difficulty in determining the appropriate billing for each room's energy consumption. This research aims to build a prototype of kWh meter for single use which enables the property owner to bill each room's electricity consumption appropriately. This prototype utilizes the web as the media to display the total energy consumption from each of the student's room. This research designed a prototype of kWh meter which can be used to measure electricity consumption of three rooms, upon which prepaid billing system is applied. This allows consumption of energy to not exceed the amount of money paid with billing system designed to meet with the standard of PLN. The kWh meter device installed in each room is equipped with LCD which displays information about consumption of electricity. This information is then uploaded to the website so that user can access the information easily. Student as the accommodation user or occupant can also purchase electricity token credit to the property owner through the website. The prototype of kWh meter system using token has already been tested to accommodate moderate electricity use (electricity consumption allocated for rice cooker and ironing machine). From the trial test, the average measurement error value obtained was 0,004 kWh for a 1 kWh usage load change. This system automatically cuts off current when the energy used has exceeded the credit limit purchased.

Keywords: Electricity energy, kWh meter, Token system, Current sensor, Student accommodation room

1. INTRODUCTION

kWh meter is a measurement unit used to measure the consumption of electricity energy used by electronic utilities during certain period of time [1] [2]. This measurement unit is commonly used by the National Electricity Company to measure the electricity consumption in each month [3] [4]. There are two types of kWh meter systems used by the National Electricity Company to measure their consumer's electricity consumption, namely the analogue kWh meter (the mechanical electricity consumption measurement unit) and the digital kWh meter (the electronic electricity consumption measurement unit) [5]. The digital kWh meter is also known as token-based kWh meter system where payment is made before usage (prepaid service). The benefit of this system is that it allows the consumer to consume electricity energy by the amount of money paid before use. The system has been implemented by the National Electricity Company, but many of their customers have not yet utilized this system. Specifically, there are many student accommodation units that are still using the postpaid service, paying their bills based on the energy consumption billing system as shown by the older version of kWh meter [6] [7]. The National Electricity Company has implemented a policy that requires each house to be equipped with a single kWh meter system. If a building is using more than one kWh meter systems, the billing will be determined based on the contract. This situation can cause problem for student accommodation owners or landlords because this means that they would have to make all occupants in their unit to pay equal amount of money per month. There are also other student accommodation owners who charge their accommodation user based on the types of electronic devices they use [6]. These approaches are still considered unfair because accommodation occupants are not given exact price for the amount of electricity they have used. It is assumed that although some users possess similar electronic devices, such as television, computer, laptop, rice cooker, and such, the frequency and duration of usage might differ from one occupant to another.

Apart from inability to ensure a fair billing system for every student accommodation occupant, the older version of kWh meter has another drawback; occupants are unable to control their electricity consumption, resulting in a huge end-of-month electricity bill. The difficulty in controlling energy consumption becomes a problem for student accommodation occupants because they do not have access to their electricity consumption and therefore some might gain profit while others might be at lost [8] [9] [10] [11].

Considering the problems above, a token-based kWh meter system is necessary, especially in a student accommodation unit, so that the occupant's bill can be adjusted to their consumption. In this research, a kWh meter system is designed to accommodate three student accommodation rooms. It is also able to display electricity

consumption information as well as the remaining credit left. Control of the kWh meter is carried out by an Arduino micro-controller which automatically cuts off the electric current flowing into the room when the number of available token credit is insufficient [12]. The reading of the kWh meter system is displayed in an LCD to allow easier monitoring [13]. The data is uploaded to the website so that occupants can monitor their energy consumption anywhere they wish. The website is also used as the media to do transaction for token credit payment between occupants and an administrator or the student accommodation owner. Using this system, it is expected that the electricity consumption can be curved by each occupant so that they can consume electricity wisely.

2. RELATED WORKS

A wireless kWh meter with network technology is designed to eliminate human intervention in power management. Customers must pay bills on time; otherwise, the power connection will be cut off automatically from a remote server. It displays billing information via the LCD and data sent to the server by ARM7 based hardware via the GSM Module [14] [15]. This system provides efficient meter reading, avoids billing errors, and reduces maintenance costs [16]

An electronic kWh is developed as a power load management system using ARM-7 and GPRS micro-controllers for communication. This system consists of a kWh electronic meter, an intelligent management terminal(IMT), and a management center. This system can complete remote meter reading and power load management via GPRS wireless communication network [16] [17]. The most important features of this system are increasing the level of automation in power load management and reducing energy consumption reading errors [14].

kWh meter with a smart card is used to calculate prepaid electricity usage [18] [19]. The hardware and application design developed to detect how much energy is used and stored as a basis for usage history will help users know whether their energy usage is efficient, normal, or wasteful. The information system is used as a validation which provides information about electricity usage and as a determinant for saving energy [20] [21] [22}.

3. SYSTEM DESIGN

3.1 Hardware Design

The block diagram below (Figure 1) shows the design of the system made. Figure 1 shows 3 kWh meter devices. Each kWh meter device is equipped with LCD display. In 1st Room, Arduino Uno board is used as the controlling system of all rooms. Apart from controlling the communication with the kWh meter devices in 2nd and 3rd Room which are controlled by Arduino Nano board, this board is also equipped with Ethernet shield, which communicates with server via router. The measurement reading of current moving into each room is not only displayed in the LCD as current load consumed, but also uploaded to the web which will then be measured and adjusted with the token credit paid. When the token credit has reached the limit, indicating that the electricity consumption has reached its limit, the processor within the board sends instruction to cut off the current flowing into the room.

The designing of the hardware for each room is explained in details as follow.

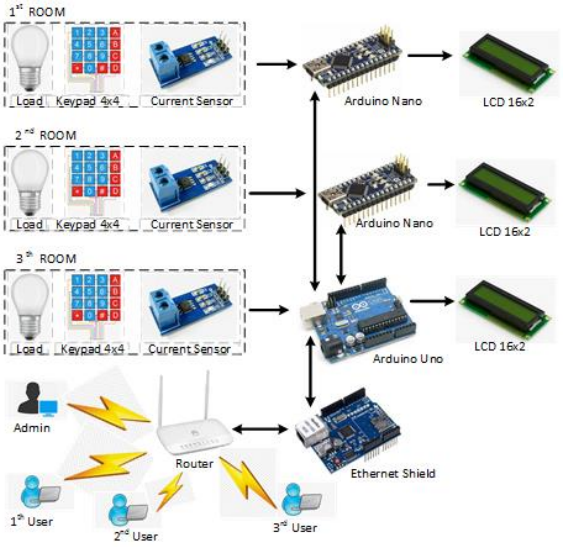

Figure 1. Block Diagram of Token-based kWh Meter System

a. The design of kWh meter hardware for 1st Room

For the 1st Room, the hardware is designed to be able to communicate with another hardware in the 2nd Room and can also upload the reading of electricity use to the web. Therefore, the hardware is equipped with Arduino Uno as the central control and Ethernet shield to communicate with the router in order to connect with server. Figure 2 shows the design of kWh meter device for the 1st Room.

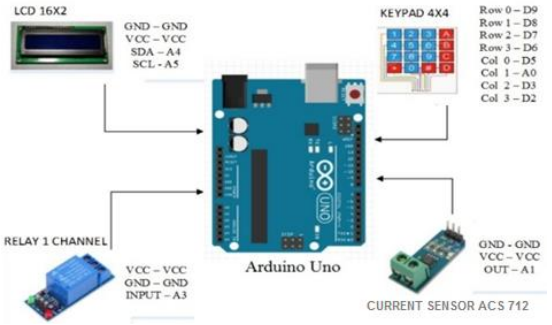

Figure 2. The Design of kWh Meter Device for the 1st Room

b. The design of kWh meter Hardware for the 2nd and 3rd Room

Unlike the device in the 1st Room, the devices for the 2nd and 3rd Room are equipped with Arduino Nano board which has easier tasks compared to the board in the 1st Room. Below is the design of kWh meter for the 2nd and 3rd Room.

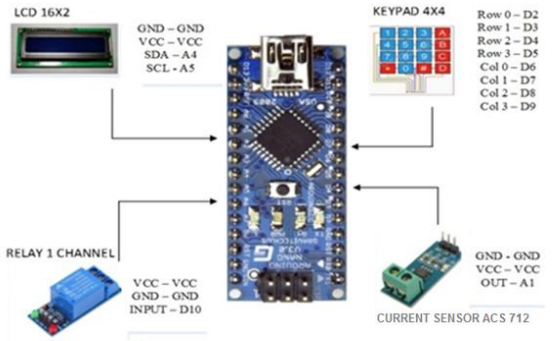

Figure 3. Design of kWh Meter for the 2nd and 3rd Room

c. The design of communication between Arduino boards

In order to make sure that all the three kWh meter devices can communicate, Figure 4 shows the connection between Arduino boards.

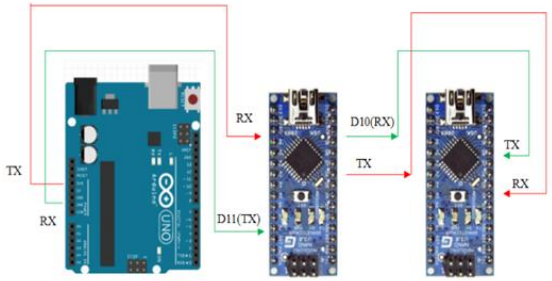

Figure 4. Communication between Arduino Boards

3.2 Software Designing

Data Flow Diagram (DFD) in Figure 5 explains the designing of the software.

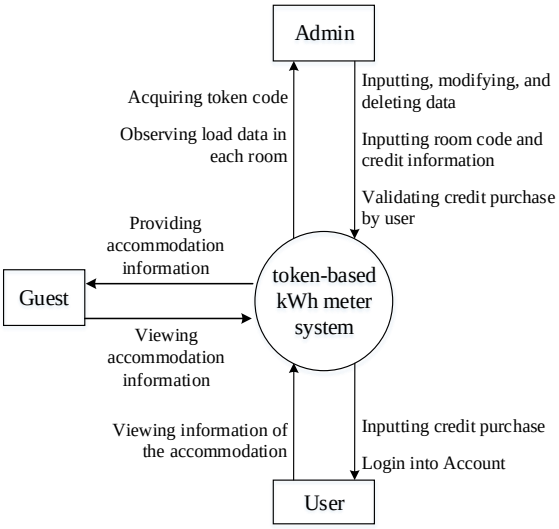

Figure 5. Data Flow Diagram Level 0

DFD Level 0 describes the process happening in the website dedicated for token-based kWh meter system. The design has three entities which include the administrator or the student accommodation owner, the user or the accommodation occupant, and the guests who are the visitors of the web.

Figure 6 shows the development of DFD Level 0. The Level 1 diagram contains the processing of data which involves the administrator (student accommodation owner), the user (the occupant), and the guest. The administrator can perform data monitoring on electricity consumption in each room and validate the purchase of the electricity token credit. The user can view the consumption of electricity in their room and can purchase electricity token credit which needs to be validated by the administrator in order to acquire the token code. The guest is allowed to visit the web in order to find information about the student accommodation.

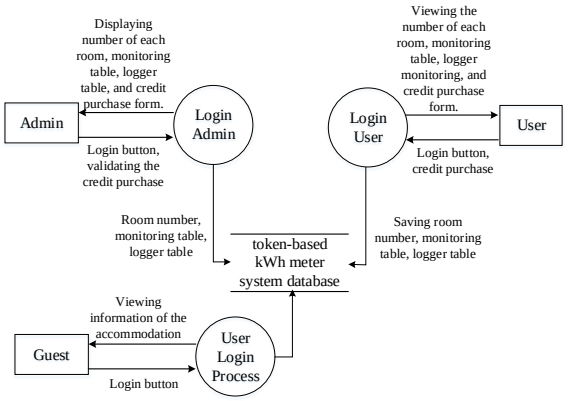

Figure 6. Data Flow Diagram Level 1

4. TESTING AND DISCUSSION

4.1 The Results of Implementing Token-based kWh Meter System

Figure 7 shows the three prototypes of kWh meter devices which have been successfully implemented in the 1th, 2nd, and 3rd Rooms.

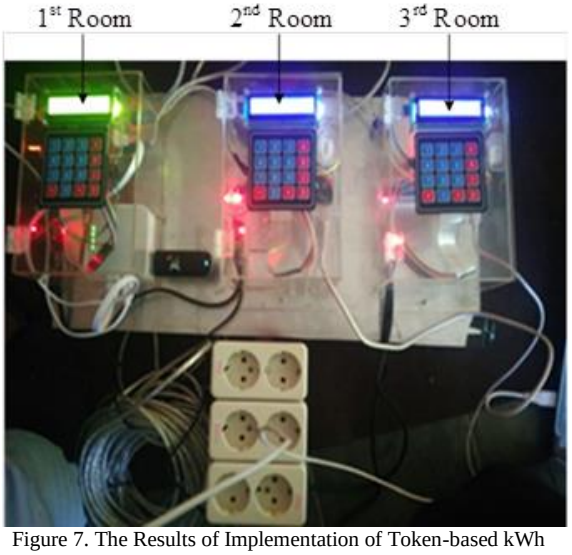

Figure 7. The Results of Implementation of Token-based kWh Meter System

4.2 Web Testing

Figure 8 shows the Menu page for Administrator. This page displays information on the accumulation of electricity power in each room and the credit purchase form including the pricing set by the accommodation owner. The validation button is used to acquire token code when the user (occupant) wishes to purchase token credit. Otherwise, users can also make purchase in the page for User.

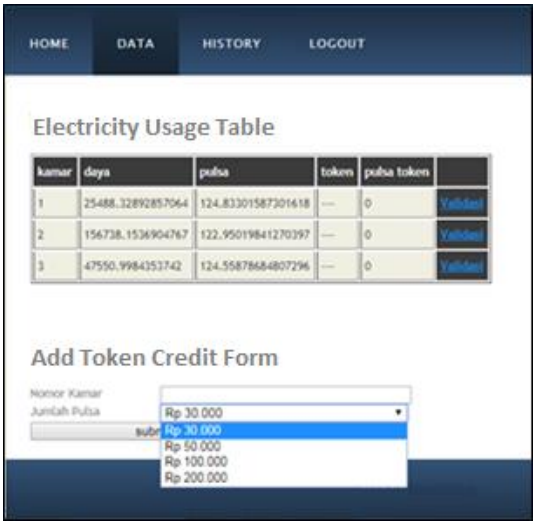

Figure 8. The Data Page in Administrator

Figure 9 shows History page which provides information on the history of electricity token purchases and information on the remaining token credit for each room, namely 1th Room, 2nd, and 3rd.

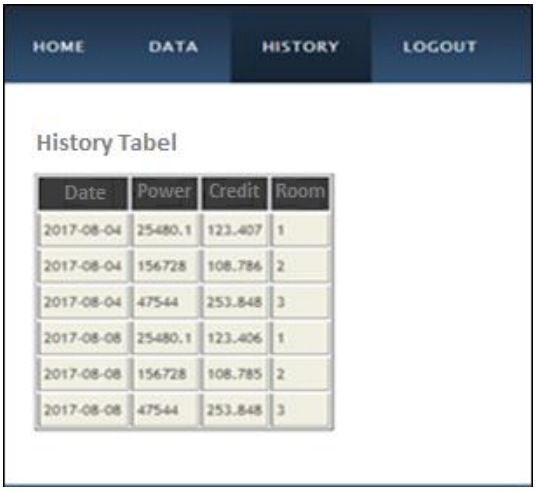

Figure 9. The History Page in Administrator

Figure 10 shows the User page, where users can preview the consumption of electricity and the remaining token credit available. The credit purchase form is also available here, but user needs to acquire a token code which needs to be validated by the administrator.

Figure 10. The Page in User

Figure 11 shows the history page for user. Occupants can view the history of electricity consumption and the remaining token credit.

Figure 11. The History Page in User

4.3 The Testing of Working System

The testing aims to find out whether the system designed can function and work properly and as planned. The testing involves the following steps.

a. Credit purchase testing

In order to conduct sensor testing, the first thing that needs to be done is to test credit purchase. Before testing, the device had 0 balance. The test was conducted in each room and each room was provided with IDR 200.000,00 token credit. Token code was obtained randomly and was recorded in the token database. The calculation of credit is based on the formula below.

Token credit = price of credit - 10% x price of credit / price of electricity per kWh
Where each kWh costs IDR 1.350
Therefore,
Token credit = 200.000 - 10% x 200.000/1.350
Token credit = 133.333

b. The Testing for Current Reader Sensor ACS712

This testing aims to test the sensor for current reader ACS712 in performing the reading of current load. The system was tested in all three rooms and was conducted using the same loads, which were ironing machine with ±380W power and rice cooker with ±300W power. The measurement of duration was conducted in order to find the changes in kWh value measured at 1 kWh. The table below shows the comparisons of the measurement results and the calculation.

Table 1. The results of consumed electricity power measurement at 1 kWh

Room	Loads	Measured Power	Time required to run out 1 kWh	Power used based on calculation
1	Ironing machine	387 W	2 hours 34 mins.	993,3 Watt hours
	Rice cooker	292 W	3 hours 25 mins.	997.7 Watt hours
2	Ironing machine	384 W	2 hours36 mins.	998.4 Watt hours
	Rice cooker	304 W	3 hours 16 mins.	993,1 Watt hours
3	Ironing machine	373W	2 hours 40 mins.	994,7 Watt hours
	Rice cooker	305 W	3 jam 16 mins	996,3 Watt hours

From the Table 1, it can be concluded that all the three token-based kWh meter systems showed reliable performance with measurement results which were relatively similar. For each power consumption increase at 1 kWh, the average error value obtained was 0,0044 kWh.

c. Token Credit Purchase Testing

From the testing of token credit transfer, it shows that the process of inputting token code worked as planned. The token code which was acquired from the web was entered to the kWh meter device instantly. The communication from token code transfer to credit transfer successfully added to balance took around 5 seconds.

d. Relay Testing

The testing aims to find out whether the relay is working properly in cutting off the current when the balance is IDR 0. The testing shows that token-based kWh meter system can be used as electricity measurement unit which is suitable for student accommodation rooms. By using this device, occupants can consume electricity wisely by purchasing credit in the amount needed. Another advantage of this system is that the consumption of electricity (kWh meter condition) and the remaining token credit can be monitored from the web.

5. CONCLUSIONS

Token-based kWh meter system had been tested and successfully implemented in three student accommodation rooms which used ironing machine and rice cooker. It was found that for an increase in electric power of 1 kWh, an average error value at 0,0044 kWh was obtained. The process of credit purchase and the transfer of token credit to each device were successfully conducted with ± 5 seconds of communication time before top up. During the testing, the ON/OFF relay against load current in each room worked smoothly. When the token credit shows 0 balance, the relay automatically cuts off the current.

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