Turnitin_Smart Postpaid Electricity Meter Using Arduino

by Abdul Ghofir

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Dear Author(s),

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Track	:	Computing
Paper Title	:	*Smart Postpaid Electricity Meter Using Arduino*
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We are pleased to inform you that your paper has passed the review process and is **accepted** for presentation at the 2019 International Conference on Sustainable Engineering and Creative Computing (ICSECC), to be held in Grand Tjokro Hotel, Bandung, on 20-22 August 2019.

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Conference Chair

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Smart Postpaid Electricity Meter Using Arduino

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***Abstract* — Manually dealing with electricity meters takes time because someone needs to access the postpaid electricity customer premises. Dealing with customers who fail to pay their electricity bills will be more complicated because specific action needs to be taken to cut off the power lines. A smart postpaid electricity meter is proposed in this research to overcome the above problems. This system is designed not only to record data of the amount of electricity usage but also to take action to cut off the electricity when the customer is in arrears. Arduino as a microcontroller is applied as the main control process. Internet of Things (IoT) technology is adopted to make the meter be controlled remotely through internet access. Required features and functionalities of the system are identified first before designing the system. Coding is written base on the design result. Unit test followed by integration test will be conducted to measure whether iteration steps are required or not. The test result shows that all proposed meter functions work well, so it can be said that the project works as expectations and the meter is ready to be used nationwide replacing the previous one.**

Keywords— Arduino, Microcontroller, IoT, Smart electricity meter.

I. INTRODUCTION

Postpaid electricity customers have to pay their electricity bills usually in monthly basis. The amount of electricity consumption provided by the electricity meter must be recorded every month and given to customers as a form of electricity bills to be paid by customers. In the case of PLN as an Indonesian government-owned corporation that covers a large number of customers around the country, a staff member is assigned to access the customer's premises every month to get data of the amount of electricity consumption displayed by the meter. This activity not only takes time but requires costs for assigning staff members as well. Even though prepaid electricity is starting to take effect throughout the country, PLN still maintains postpaid electricity to support the government's priority program to provide electricity subsidies right on the specified targets [1]. It was stated that more than four million customers still needed subsidized electricity.

If a postpaid customer has a problem in paying off his electricity bill then special measures need to be taken to cut off the electricity. This action is sometimes not simple because it involves several staffs to take certain actions on electrical installations at and around the customer's premises. The above incident is a picture of inefficiency in handling services to electricity customers, especially related to the continuity of distribution and electricity payments. Overall the operational costs incurred are large to only deal with the above activities and of course affect the company's financial condition.

This research work is developing a smart postpaid electricity meter that has the ability to record data on the amount of electricity consumption and send this data on request to the processing center for the electricity billing and payment process. The Internet of Things (IoT) technology is applied to this system that allows the center to have full control of the meter. Smart here means that this meter has the ability to automatically disconnect and connect electricity based on certain or defined conditions without human intervention. The system also has a capability to calculate power consumption as well as a web-based information so that it provides a more interactive experience.

II. METHODOLOGY

Because the required output and main features, including system functionality, have been determined in advance, Extreme Programming (XP) as one of the agile process models is considered suitable in the development of this system. However, some justifications were taken in accordance with the available system development environment.

Context Four activity frameworks have been determined which include Planning phase, Design phase, Coding phase, and Testing phase [2, 3]. Required output and major features as well as system functionality have initially defined as a target for formulating a plan to develop the system.

Based on the above definition, the application is determined and designed together with preparing the prototype hardware part. The hardware part consists of Arduino microcontroller as main controller and required sensors to obtain control data, includes display unit for presenting number of consumption electricity. This design phase results several preliminery designs that need to be developed and tested as series of unit tests. Integration test of all units is the final phase to ensure that all features and functionality of the whole system are in accordance to the pre-defined system requirements.

III. LITERATURE REVIEWS

Arduino is the main control circuit board used in this research. It is a programmable microcontroller in which control process is written using a language similar to C++ in an environment called IDE (Integrated Development Environment). Sketch is a list of Arduino microcontroler codes [4]. Some additional hardware modules must be

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connected to Arduino to become a smart electricity meter system which includes the following

The developed system must have a capability to be connected in wireless modes. An additional microcontroller development board which is operating a protocol of 802.11 wireless is implemented to meet the wireless connection requirement. Furthermore, Wemos D1 mini PRO [5] is the brand name of this board.

When a problem of main power interruption happens, then there should be a way to maintain accurate time keeping. A Real Time Clock (RTC) Module, which its type is DS3231, provides an integration of a temperature-compensated crystal oscillator (TCXO) and crystal to maintain such an accuracy [6]. This integration enhances the accuracy of the device in long-term.

To calculate power consumption, a module called PZEM-004T circuit is required as it has an ability to measure AC voltage, current, and power (single phase). It is also equiped with a TTL to USB adapter wire so that connection to microcontroller can be done easily [7].

Dealing with a main power line operating the voltage up to 220V, requires a specified relay when a microcontroller is applied to control it. A relay type SRD-05VDC-SL-C is chosen as it has a capability to connec to the Arduino through three low voltage pins which are Ground, Vcc, and Signal pins [8].

When requires a switching device that must be turned on and off at high frequencies, the switch-mode power supply (SMPS), as an electronic circuit, can be applied here because it is considered to have the ability to change electrical power very quickly like the specifications above. Other names of this circuit are a switch-mode power supply or switching-mode power supply [9, 10].

Dynamic websites with PHP can be built using open source software called CodeIgniter which has the ability to implement web development frameworks quickly. Models and views are considered as optional in CodeIgniter, but controller classes are considered as an important part of development [11].

PALVI device is resulted by the earlier PLN project. It has an ability not just to control postpaid electricity meters but also to connect and disconnect electricity to the customer. All control actions are done through an internet connection. The proposed project resulted an electricity meter with similar capabilities in having control actions executed via internet. However, automatically connecting and disconnecting electricity meter is the advantages features of the meter resulted by the current project. Table I shows comparison overviews of the tree devices resulted from different PLN projects.

TABLE I. COMPARISON OVERVIEWS.

Components	Current project	PALVI	Current Postpaid Electricity Meter
Disconnect/reconnect the electricity	V	V	X
Automatic disconnect/reconnect the electricity	V	X	X
Display	V	X	V
Online payment	V	X	X
kWh calculation	V	X	V
Multi-level login	V	X	X
Automatic create a bill	V	X	X
Email notification	V	X	X
Automatic create customer ID	V	X	X
Device monitoring	V	X	X
Need to come to the customer's house	X	V	V

IV. RESULTS

The description of Results contains into three parts namely: Functional requirement list, System design and implementation, and Test the system.

A. Functional requirement lists.

The followings are the functional requirements of microcontroller devices described in Table II and web functional requirements in Table III.

TABLE II. THE FUNCTIONAL REQUIREMENTS OF MICROCONTROLLER DEVICES.

No	Functional Requirements
1	The device can calculate monthly electricity usage.
2	If the device status is deactivated on the database, the device can disconnect the electricity.
3	The device can disconnect the electricity if the customer is in arrears for two consecutive months.
4	If the customer status is deactivated on the database, the device can disconnect the electricity.
5	The device can send monthly usage to the database.

TABLE III. WEB FUNCTIONAL REQUIREMENTS.

No	Functional Requirements
1	The system can manage two different roles, admin and customer.
2	The admin can display all customers.
3	The admin can add customers.
4	The admin can edit customers.
5	The admin can deactivate customers.
6	The admin can add devices.
7	The admin can deactivate the device.
8	The admin can display all the bills.
9	The customers can only display their devices.
10	The customers can only display their bills.
11	The customers can only see their payment history.
12	The customers can pay bills.
13	The customers can print bills.
14	The system verifies e-mail when the customer is first registered.
15	The system verifies e-mail when resetting the password.
16	The API can make a new bill and send a bill to the customer's email.
17	The API can check the status of the device.

B. System design and implementation.

The objective of this paper is to make a prototype to automating postpaid electric meter and web-based system information. The device itself is designed with a microcontroller with several modules and sensors that can be

seen in Fig. 2 based on the design of the main circuit (see Fig. 1).

The source code for the web application is using CodeIgniter framework that based in PHP for the back-end [12, 13] and Microcontroller that based in C. Every important part of source codes in the development of the system is explained that follows.

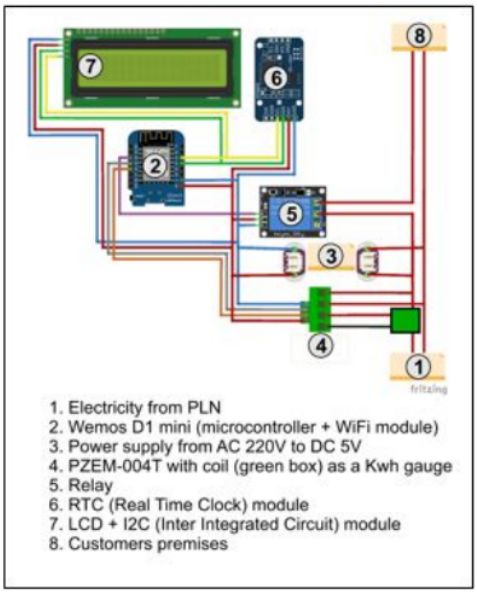

Fig. 1. Main circuit design

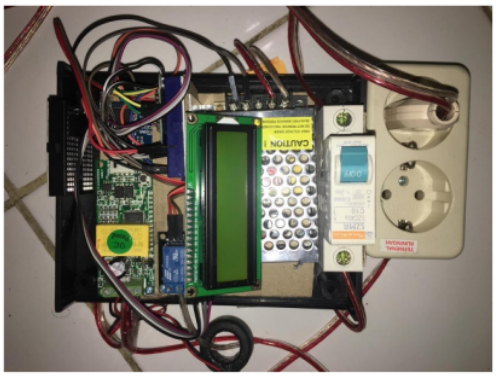

Fig. 2. System hardware

The main concept of this project microcontroller as executor, the action depends on the response of HTTP request to API service. Fig. 3 shows how the device makes an HTTP request to the API service. On this case ESP822 and ArduinoJson libraries is used. ESP822 library used to make an HTTP request and ArduinoJSON to send and read the response with JSON format.

```
String api(String path, JsonObject& JSONencoder){
  char JSONmessageBuffer[255];
  JSONencoder.prettyPrintTo(JSONmessageBuffer, sizeof(JSONmessageBuffer));

  http.begin(host + path);
  http.addHeader("Content-Type", "application/json");

  http.POST(JSONmessageBuffer);
  return http.getString();
}
```

Fig. 3. Http request to the API service.

The system consists of two sides, the first is the device that functions to retrieve and monitor electricity usage data from the meter and store it in a storage. This side is also equipped with the process of sending data in storage to the other side (i.e., the server side) when the device first turns on and is based on a predetermined time. Second is the server side that will process requests made by the device via an HTTP connection. The result of this request is data on electricity usage stored in the meter. This data will be processed so as to produce output that is the basis for actions that must be taken against the customer's meter. These actions include the following.

• Update meter data if the results of the process show that the customer has paid the bill.

• Temporary termination in an effort to give a warning to the customer that the bill has not been paid.

• Permanent termination if the above points have not been completed within a certain period.

Details of the system process can be seen in pseudocode listed in Fig. 4 for device-side process, as well as in pseudocode listed in Fig. 5 for server-side process.

```
Create a JSON Object
Set Parameters for the Object
Send request to server based on the parameters using API
Get response from the server
Parse the response into truly data as array
Save the response into storage

IF Has penalty
    Display penalty message to LCD
    Cut off electricity
ELSE
    Turn on electricity
ENDIF
```

Fig. 4. Pseudocode for device-side process.

```
Get the client (in this case is micro controller) data as JSON
Parse and set as array, the data is device id, power (electricity accumulation in Kwh) and period.

IF device is exist
    Create device activity log
    Get current period from current date time server
    Get current arrears
    IF period device < current period
        Create new bill
        Set new period to device to current period
        Send the bill to customer email
    ENDIF
    CASE number of arrears OF
        2 : Set penalty 2 and cut off electricity
        3 : Set penalty 3 and cut off electricity
    ENDCASE
    return new data to client as JSON
ENDIF
```

Fig. 5. Pseudocode for server-side process.

C. *Test the system.*

A defined scenario is prepared to examine the operational aspects of the system, especially to see how far the Arduino and IoT technology having roles in this system. The scenario will be focused on interaction between Arduino and the center control computer (represented by Web display).

Arduino as the main control will always obtain electricity data from the meter in a periodic basis. The data will also send to the center control computer via internet connection for being stored and displayed on the web as Device logs. This includes date, time, meter status (amount of electricity consumption and active or disconnected status). When the customer is in arrear, Arduino will cut off the electricity through sending signals to the relay.

The above scenario is applied in the test implementation. All the meter data including active or disconnected status of the meter are displayed on the web as Device Logs and are shown in Fig. 6 Arduino execution to disconnect the electricity to the customer's premises is represented in the zero current data shown in the LCD display of the meter (see Fig. 7).

Description	Kwh Meter	Date Time
Device Check	326.1	24 March 2019 20:16
Device Check	325.6	24 March 2019 20:11
Device Check	325.2	24 March 2019 20:06
Device Check	324.9	24 March 2019 20:01
Device Check	324.6	24 March 2019 19:56
Description	**Kwh Meter**	**Date Time**

Showing 1 to 5 of 942 entries Previous 1 2 3 4 5 ...

Fig. 6. Device logs.

Fig. 7. The lcd display shows zero current (I0.00).

The followings are list of tests conducted to the proposed application system, includes its effectiveness evaluation. Defined features are being tested, includes the response of the system, and evaluation results are listed in Table IV.

V. DISCUSSION

Based on the problems stated in the introductory session, why the proposed system can overcome the above problems will be discussed here. Not only does it solve the problem, but the application of the Internet of Things on postpaid kWh meter devices also makes it possible to make attractive features.

First of all, the proposed system aims to automate the existing PLN working system, to reduce operational costs and minimize electricity arrears. With this, the PLN work system is more effective and efficient. the proposed system uses a microcontroller to make devices and web-based information systems web applications. With the Internet of Things technology, it allows devices to connect to the internet so that tools can be controlled from anywhere via web-based information system applications, automation can be done with systems that have been previously implanted on the device.

Second, automation with the proposed system makes PLN employees no longer need to come to each customer's home to collect bills, cut off electricity, and others that require PLN employees to come to the customer's home.

Third, the proposed system devices can read the use of electric power. Making bills can be done automatically every month, PLN employees do not need to come to each customer's home to record the electricity usage of each customer.

Fourth, an interactive web information system with automatic email notifications. Activities such as registering new customers, registering customer devices, the system sends notification emails automatically to customers.

Fifth, online payments that make it easier for customers to pay bills anywhere through a website, with an the proposed system synchronized system that allows customers to make bill payments online.

TABLE IV. TEST RESULTS

Features Tested	Result
Deactivate Device Manually with Web App.	Success
Activate Device Manually with Web App.	Success
Automatic Disconnect Electricity.	Success
User login	Success
User forgets the password.	Success
Admin view list of customers.	Success
Admin search for a customer.	Success
Admin adds a new customer.	Success
Admin edit customer.	Success
Admin deactivates customer.	Success
Admin activates customer.	Success
Admin view customer's device.	Success

Admin adds a new device.	Success
Admin deactivates the device.	Success
Admin view list of bills.	Success
Admin views a bill detail.	Success
Admin change password.	Success
Admin change kWh price.	Success
Admin search a bill.	Success
Customer change password.	Success
Customer change email.	Success
Customer view all device.	Success
Customer view all bill.	Success
Customer print a bill.	Success
Customer pays a bill.	Success
Customer view transaction history.	Success
Customer edit password.	Success
Customer edit email.	Success

Sixth, monitoring the device. With the automation of the work system, it certainly requires monitoring of devices. With system monitoring through a website, it can make it easier for PLN employees to monitor the activities of each device.

VI. Conclusions and Further Work

This project works as expectations. This project has succeeded in automating the work system on postpaid electrical devices with the Internet of Things. The device can disconnect or reconnect electricity following existing regulations, and the device can calculate electricity usage and make bills automatically with email notifications. Not only solve the problems, the electricity meter device with Internet of Things based able to more than that such as power consumption monitoring and bill automation.

The implementation scenario for this project starts from defining the scheme of special treatment mechanisms and payments for targeted customers. This determined scheme must be based on the results of survey and analysis of customer data. Determining the order of service actions is the next step. The results of the defined actions will be used to configure and manage the system. The execution of this system will then make it function to monitor and take necessary actions automatically without human intervention.

However, this project still needs development to be able to maximize device performance and work system automation. Further work needs to be planned so that the right quality and mechanism can be realized in the real world. The following are points that need to be considered and followed up for further system developments, namely: security improvement, electricity theft detection, alternative internet connection use, ticketing system for complaint services.

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