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# Developing Control System of Electrical Devices with Operational Expense Prediction

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# Developing Control System of Electrical Devices with Operational Expense Prediction

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**Abstract**. The purpose of this research is to develop a system that can monitor and record home electrical device's electricity usage. This system has an ability to control electrical devices in distance and predict the operational expense. The system was developed using micro-controllers and WiFi modules connected to PC server. The communication between modules is arranged by server via WiFi. Beside of reading home electrical devices electricity usage, the unique point of the proposed-system is the ability of micro-controllers to send electricity data to server for recording the usage of electrical devices. The testing of this research was done by Black-box method to test the functionality of system. Testing system run well with 0% error.

## 1. Introduction

In recent years, the use of electrical energy has become the basic human needs in daily activity. However, the electrical energy needs every year has increased in line with population, wealthy, and the overall economic growth. One important factor to support economic growth, i.e., the rapid growth of electricity demand of Indonesia's consumers for product and services. Deputy Minister of Energy and Mineral Resources, Rudi Rubiandini and Indonesia's state utility company, PT Perusahaan Listrik Negara's (PLN) Director of Planning and Risk Management said that Indonesia's annual electricity usage is expected to rise by 9% in 2013, while The National Energy Council (DEN) expects a broader threefold increase in energy demand by 2030 [1]. The awareness of society towards electricity usage of electrical devices is less. This behavior make users tend to behave wasteful. So, the use of electricity energy excessively in the household lead to wastage of electricity expense every month. [2], it showed that the amount of unused energy from electrical devices, which are connected to a voltage source, is about 5%-10% from its normal used. It can affect in financial loss and decrease the efficiency of electricity usage.

In order to improve the efficiency of electricity usage in household, control system has been developed rapidly. In the modern era, integrating new technologies in control system could improve the quality of human life.The aim of this paper is to develop a control system which can help users to control the electricity usage and also to develop a system for monitoring and controlling home electrical devices. Currently for monitoring electrical quantities, it is mostly done by installing electrical measuring instrument at the electrical panel before going to its electrical devices. However, this method has some lacks, that is difficult to identify which electrical devices waste the use of electrical power, it also does not have data record for monitoring electrical power usage [3].

This paper proposes a solution that is advantageous for (1) providing information of electricity status without checking directly at the location where the measuring instrument is installed, (2) providing recorded information for monitoring electrical power usage for analysis, (3) providing an expense prediction of electricity usage for each electrical devices, and (4) providing controlling facility for electrical devices remotely, and setting usage permissions of electrical devices**.**

The developed system requires module controllers, and web-based application in server. The module controllers that is installed to electrical devices, use Arduino Nano as microcontroller [4], while ESP8266-01 as WiFi module [5]. Current sensor of Electronic Brick TA12-100 Itead Studio [6] is used to inform the electricity usage, while relay driver is used to switch the electrical devices either "On/Off". The data of electrical current that has been read by microcontroller is sent by WiFi module to the server so that the measurement result can be stored in database. The server in home network can be connected to internet, so the monitoring process can be done remotely.

The rest of this paper is organized as follows. Section II presents the proposed method to develop the system. In Section III describes the result and discussion about the performance of proposed method. The last, Section IV present the conclusion.

## 2. Method

The proposed method that used to develop this system is Systems Development Life Cycle (SDLC). [7], i.e., a methodology that used to develop a system in the field of engineering, information system, and software system. This method is described in several processes, i.e. planning, analysis, design, implementation and maintenance.

### 2.1. System

The designed system is shown in Fig 1. The system is sent by detect the status of electrical devices which is shown as "On/Off" based on the information from current sensor.

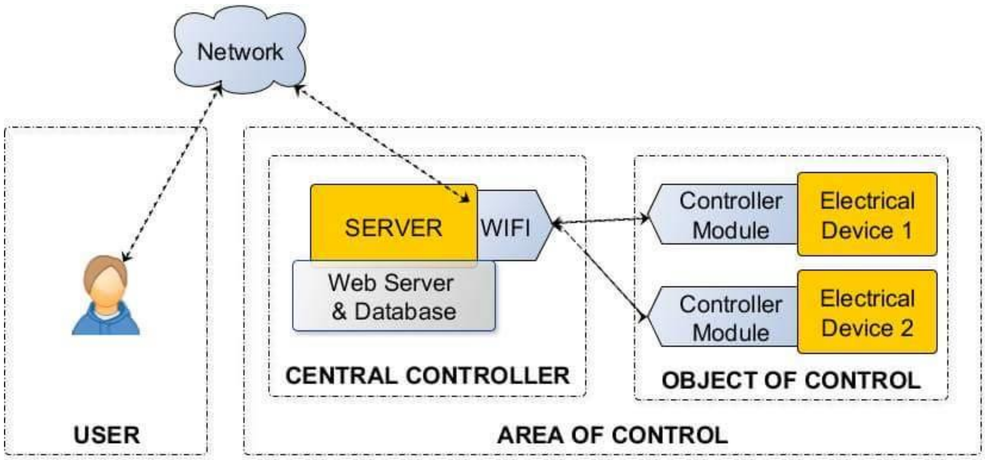


Figure 1 The Designed System

Each electrical device has its own module controller, which given action control from microcontroller based on information of current sensor. The current sensor transfers its current data to microcontroller Arduino Nano to be processed by action control. The information of electrical devices status is sent via micro-controller to server. The server's duty is to receive an input and control module through wireless network. In order to the system can be accessed by users from several devices, the application has been designed in web based.

On the server, collected data in database will be processed to be useful information and presented to the user which include data of electricity usage and prediction of operational expense daily, monthly or in the specific time. The designed system works as the flowchart shown in Figure 2.

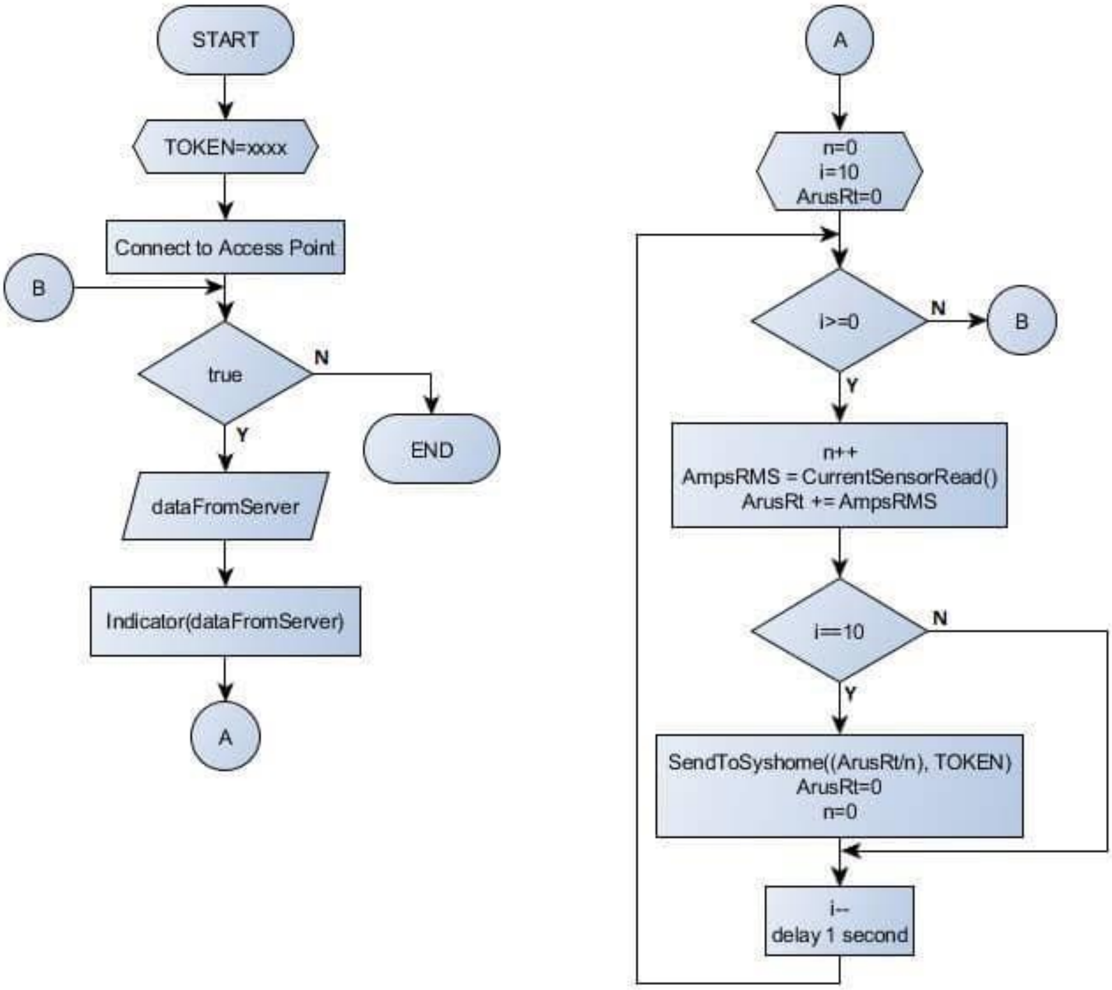


Fig 2. Flowchart System

### *2.1.1. Module Controllers*

Module controllers are devices that used to monitor and control electrical devices. Module controllers has five main parts, i.e. microcontroller (Arduino Nano), WiFi module (ESP8266-01), current sensor (TA12-100 Itead Studio), indicator, and driver circuit using relay for controlling the status of "On/Off" in electrical devices. Fig 3 shows the designed module controllers.

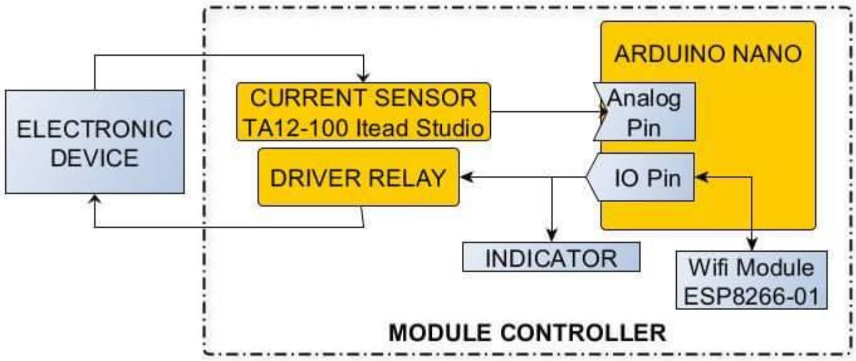


Fig 3. Designed-controller module

The Microcontroller that used has twelve digital pin and eight analog pin. Current sensor will be connected to an analog pin. Relay access driver will be handled by digital pin. While indicator circuit as an status information of module controllers uses eight digital pin.

### *2.1.2. Web-based Application*

Website, i.e., part of system that handle all process in server and as a controlling interface by users. Here is some steps to design website :

- Design database and analyze web application to be divided into several part.
- Design website layout.
- Web programming in each part of website, that include : (1) *Log in* process page; (2) *Form* page to manipulate master data (*retrieve*, *input*, *update*, and *delete*) of module controller, electrical devices, and electricity expense / kWh; (3) *Form* page to define module controller; (4) *Form* access control setting page; (5) Notification page; and (6) *Report* page.
- Evaluate each part of software

Data Flow Diagram (DFD) is graphical representation of system that describes components. Fig 4 shows data flow diagram (DFD) level 0 of developed-system.

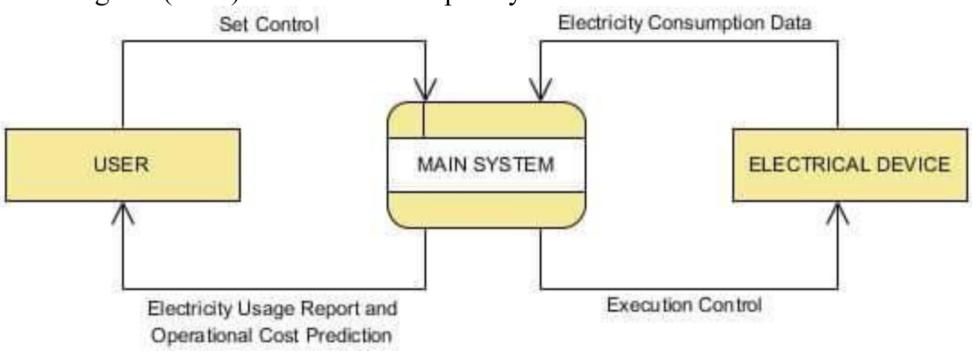


Fig 4. The Data Flow Diagram Level 0 Context Diagram of system

This diagram describes the basic process, where user can input data of control time setting to the system as a system reference to Main System. In the Main System data will be proceed to execute the controlling in electrical devices.

At the same time, the system receives an input of electricity data usage from electrical devices to be processed in the Main System. Then the data will proceed as an output record of home electrical device's electricity usage and its operational expense prediction.

*2.1.3. Implementation*
The implementation process is done by creating module controller and website application based on the earlier design process. The system design is translated into codes using programming language i.e., Arduino for hardware programming, PHP for web server programming, HTML, Java script, and CSS for web programming, also MySql as database management system. The program that has been developed will be tested per unit and overall using Black-box method.

In order to observe the implementation of the entire system components, the testing has been held. The test was carried out by testing per sub-system to know the performance of each sub-system and the compliance with design specification. The further testing is done by combining all sub-system to know the assessment result of overall system.

This designed system use case diagram, i.e., to describe a set of actions (use cases) as representation of user's interaction which consists of actors, use case and their relationships are shown in Fig 5.

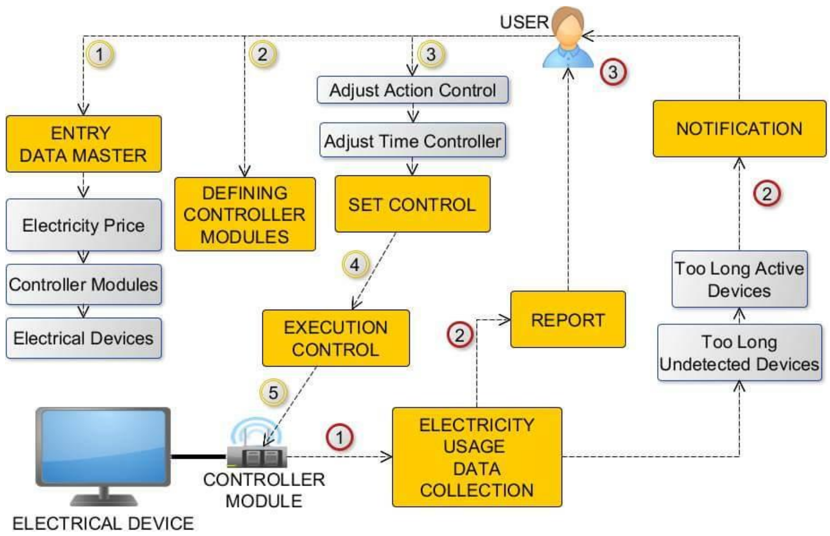


Figure 5 Use Case Diagram of system

The next step was system maintenance. The aims of this step is to ensure the system is always in good performance and also evaluate every error that might be occur. So that system maintenance can improve system performance and keep the system from being obsolete.

*2.1.4. Testing Design*

The functionality is tested using Black box testing method [8]. The testing was carried out on module controller, software (website application) and overall system. The test is used to find errors that occur on the system. The errors were found by analyzed the equation below [9].

$$E = 100 \times (1 - (1 - L)^{n}) \quad (1)$$

Where:
E = Errors found (%)
n = Number of testers
L = Problems found (%)

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## 3. Result and Discussion

### 3.1. Module Controller Testing

The aim of testing controller module is to avoid any errors when the system is being executed. The testing was carried out by testing each part of module controllers, which consist of testing the running of (1) microcontrollers, (2) WiFi modules, (3) current sensors, (4) indicators, and (5) relay drivers. The testing results presented that all parts of module controller was valid and running well.

### 3.2. Software Testing

The software testing is done to avoid errors when the system is executed by testing the functionality each part of website. The testing was done to check the page of (1) *Log in* process page; (2) *Form* page to manipulate master data (*retrieve*, *input*, *update*, and *delete*) of module controller, electrical devices, and electricity expense / kWh; (3) *Form* page to define module controller; (4) *Form* access control setting page; (5) Notification page; and (6) *Report* page. The testing result showed the 0% error percentage. So it can be concluded that the software is valid, running well and ready to be used for system development

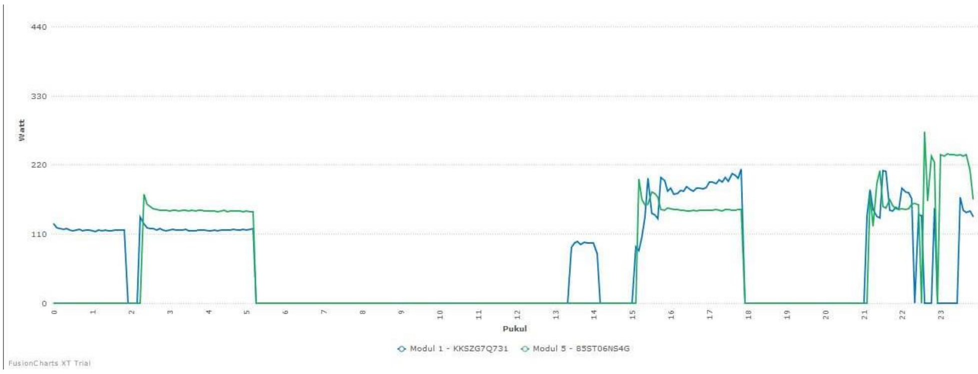
### 3.3. Overall System Testing

The overall system testing is done to ensure that all sub-systems can work together, interconnected and shows good performance. The result of overall system testing generates 0% error percentage which can be concluded that the development of system is valid and overall can run well. Here, the graph on Figure 6 shows the electricity usage daily with each detailed usage for 24 hours.

MODUL 1 - KKSZG7Q731

| No. | Electrical Devices | Time | Duration | Hour | Cost | Current (A) | Power (W) | Energy (WH) | Energy (KWH) | Total Cost |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Charger Laptop Toshiba 15 inch ( 60 Watt ) | 00:00:24 | 00:00:27 | 0.00750 | 1550 | 0.59 | 129.8 | 0.97350 | 0.00097 | Rp. 1.50893 |
| 2 | Charger Laptop Toshiba 15 inch ( 60 Watt ) | 00:00:51 | 00:00:28 | 0.00778 | 1550 | 0.56 | 123.2 | 0.95822 | 0.00096 | Rp. 1.48524 |
| 3 | Charger Laptop Toshiba 15 inch ( 60 Watt ) | 00:01:19 | 00:00:27 | 0.00750 | 1550 | 0.59 | 129.8 | 0.97350 | 0.00097 | Rp. 1.50893 |
| 4 | Charger Laptop Toshiba 15 inch ( 60 Watt ) | 00:01:46 | 00:00:27 | 0.00750 | 1550 | 0.57 | 125.4 | 0.94050 | 0.00094 | Rp. 1.45778 |
| 5 | Charger Laptop Toshiba 15 inch ( 60 Watt ) | 00:02:13 | 00:00:28 | 0.00778 | 1550 | 0.59 | 129.8 | 1.00956 | 0.00101 | Rp. 1.56481 |
| 6 | Charger Laptop Toshiba 15 inch ( 60 Watt ) | 00:02:41 | 00:00:27 | 0.00750 | 1550 | 0.53 | 116.6 | 0.87450 | 0.00087 | Rp. 1.35548 |
| 7 | Charger Laptop Toshiba 15 inch ( 60 Watt ) | 00:03:08 | 00:00:27 | 0.00750 | 1550 | 0.58 | 127.6 | 0.95700 | 0.00096 | Rp. 1.48335 |
| 8 | Charger Laptop Toshiba 15 inch ( 60 Watt ) | 00:03:35 | 00:00:28 | 0.00778 | 1550 | 0.59 | 129.8 | 1.00956 | 0.00101 | Rp. 1.56481 |
| 9 | Charger Laptop Toshiba 15 inch ( 60 Watt ) | 00:04:03 | 00:00:27 | 0.00750 | 1550 | 0.57 | 125.4 | 0.94050 | 0.00094 | Rp. 1.45778 |
| 10 | Charger Laptop Toshiba 15 inch ( 60 Watt ) | 00:04:30 | 00:00:27 | 0.00750 | 1550 | 0.54 | 118.8 | 0.89100 | 0.00089 | Rp. 1.38105 |
| 11 | Charger Laptop Toshiba 15 inch ( 60 Watt ) | 00:04:57 | 00:00:28 | 0.00778 | 1550 | 0.56 | 123.2 | 0.95822 | 0.00096 | Rp. 1.48524 |
| 12 | Charger Laptop Toshiba 15 inch ( 60 Watt ) | 00:05:25 | 00:00:27 | 0.00750 | 1550 | 0.54 | 118.8 | 0.89100 | 0.00089 | Rp. 1.38105 |
| 13 | Charger Laptop Toshiba 15 inch ( 60 Watt ) | 00:05:52 | 00:00:27 | 0.00750 | 1550 | 0.56 | 123.2 | 0.92400 | 0.00092 | Rp. 1.43220 |
| 14 | Charger Laptop Toshiba 15 inch ( 60 Watt ) | 00:06:19 | 00:00:28 | 0.00778 | 1550 | 0.56 | 123.2 | 0.95822 | 0.00096 | Rp. 1.48524 |
| 15 | Charger Laptop Toshiba 15 inch ( 60 Watt ) | 00:06:47 | 00:00:27 | 0.00750 | 1550 | 0.53 | 116.6 | 0.87450 | 0.00087 | Rp. 1.35548 |
| 16 | Charger Laptop Toshiba 15 inch ( 60 Watt ) | 00:07:14 | 00:00:27 | 0.00750 | 1550 | 0.55 | 121 | 0.90750 | 0.00091 | Rp. 1.40663 |
| 17 | Charger Laptop Toshiba 15 inch ( 60 Watt ) | 00:07:41 | 00:00:27 | 0.00750 | 1550 | 0.56 | 123.2 | 0.92400 | 0.00092 | Rp. 1.43220 |
| 18 | Charger Laptop Toshiba 15 inch ( 60 Watt ) | 00:08:08 | 00:00:28 | 0.00778 | 1550 | 0.55 | 121 | 0.94111 | 0.00094 | Rp. 1.45872 |
| 19 | Charger Laptop Toshiba 15 inch ( 60 Watt ) | 00:08:36 | 00:00:27 | 0.00750 | 1550 | 0.55 | 121 | 0.90750 | 0.00091 | Rp. 1.40663 |
| 20 | Charger Laptop Toshiba 15 inch ( 60 Watt ) | 00:09:03 | 00:00:27 | 0.00750 | 1550 | 0.54 | 118.8 | 0.89100 | 0.00089 | Rp. 1.38105 |
| 21 | Charger Laptop Toshiba 15 inch ( 60 Watt ) | 00:09:30 | 00:00:28 | 0.00778 | 1550 | 0.54 | 118.8 | 0.92400 | 0.00092 | Rp. 1.43220 |
| 20 | Charger Laptop Toshiba 15 inch ( 60 Watt ) | 00:09:03 | 00:00:27 | 0.00750 | 1550 | 0.54 | 118.8 | 0.89100 | 0.00089 | Rp. 1.38105 |
| 21 | Charger Laptop Toshiba 15 inch ( 60 Watt ) | 00:09:30 | 00:00:28 | 0.00778 | 1550 | 0.54 | 118.8 | 0.92400 | 0.00092 | Rp. 1.43220 |

(a) The electricity usage table report




(b) Electricity usage graph record

Figure 6 Example of electricity daily usage

## 4. Conclusions

In this paper, we have developed a control system with aims to monitor and record home electrical devices electricity usage. This research can be concluded that the system has ability as the proposed-system, while it also can predict operational expense daily, monthly or in specific time. Furthermore, this system can control electricity usage of electrical devices remotely with usage permission setting for users.

The testing has been done with functionality test using Black box method. The testing result shows that the system worked properly with 0% error percentage, confirming that the control system of electrical devices and its operational expense prediction can work well and ready to be implemented.

## 5. Acknowledgement

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