

Data Acquisition of Electric Power Usage as the Implementation of the Internet of Things at Smart Home

A.A. Kusuma Dewi¹, Gede Suweken², K.A. Ady Aryanto³, K.Y. Ernanda Aryanto⁴

Magister of Computer Science Study Program, Department of Mathematics
Universitas Pendidikan Ganesha
Bali, Indonesia

apriyana.beklencipss15@gmail.com¹, gede.suweken@undiksha.ac.id²,
agus_ady@stikom-bali.ac.id³, yota.ernanda@undiksha.ac.id⁴

Abstract— Data from the ASEAN Center for Energy (ACE) shows that Indonesia has the highest level of energy consumption in Asia. Home automation, a smart home scheme utilizing the vast development of the latest networking and AI technologies, has been proposed to tackle the problems. In this work, we have provided IoT-based portable devices for controlling and monitoring, containing the Node MCU ESP8266 and using the Message Queuing Telemetry Transport Protocol (MQTT) for the data communication. The results shown that the modules could monitor the energy consumption of the household electrical devices they were attached on in real time and warn the owner through the developed application. However, the data acquisition provided that the modules still have an average of 3% of differences between the values in the modules compared to the actual electrical devices' specification leaving a call for future research to improve the electric power monitoring to provide a better home automation system.

Keywords—smart home; Internet of Things (IoT); monitoring system; data acquisition.

I. INTRODUCTION

According to the data of Indonesian Outlook Energy 2019 [1], the largest segments of energy usage were 97.8 thousand GWh (42%) for household, 76.9 thousand GWh (33%) for industry, 59.5 thousand GWh (25%) for commercial sector, and 274 GWh (0.12%) for transportation. However, [2] discovered that Indonesia is a country with the highest level of energy use in Asia. It was mainly caused by the improper lifestyle in using electricity, for example letting the unused electronic devices remain plugged in the electric socket. The improper usage of electric devices, the switch that does not work perfectly, or the incorrect modification of electronic devices may cause some equipment work abnormally and result in a waste of energy. Based on those facts, several researchers were conducting researches to tackle such issues. Reference [3] provided a centralized wireless home control system that can handle various appliances in an automatic, centralized, and computerized manner. With the system, user can interact with the home appliances through a user-friendly interface provided for the system. Reference [4] designed an energy management system utilizing the emerging technologies such as the internet of things (IoT) and big data. In the proposed system, each home device acquired data using

the embedded module based on IoT technology thus resulting a large mesh wireless network of devices. Reference [5] designed a prototype which is equipped by several features, such as module registration, data management process, system configuration process, and the calculation process to determine the home electronic devices that are in a normal or abnormal condition. Reference [4] develop a prototype that can measure the increase of electric use of air conditioner and can be used to turn off the air conditioner with a dirty air filter. Reference [6] designed a system that able to observe and control the home appliances and electronic machines through a website built in the system. The designed system included also an online billing system that convert the energy used into the appropriate costs in order to provide billing information for the users.

Based on the researches mentioned above, it can be concluded that the previous researches which have been done have a weakness. That is the absence of explanation which can make the users easier to know the calculation process to determine whether the home electronic devices work normally or not. This research completes the weakness found in the previous researches. The improvement done in this research is expected to be more focused on the data management process, configuration system process, or the module and standardization of electronic devices, as well as its calculation to determine whether the home electronic devices work normally or not based on the comparison of real value with their energy usage and the calculation of accuracy of electronic devices' usage. This is to warn the user if the electrical usage is over than limit.

II. LITERATURE REVIEW

A. Energy Consumption in the Household Environment in Indonesia

According to the data of Indonesian Outlook Energy 2019, the segments of energy usage were household sector, industry sector, commercial sector, and transportation sector, arranged descending based on the amount of energy consumption. Therefore, the data shown that household environment has a big impact on energy utilization. The chart below shows the final energy needs in the household environment.

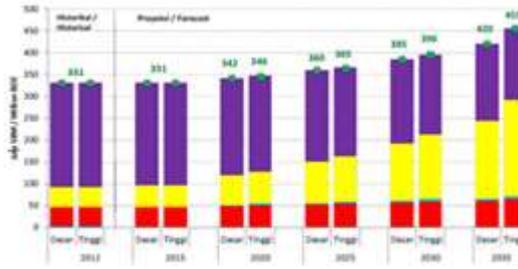


Fig. 1. Chart of Energy Final Needs in Household Environment

B. The Increase of Electric Power Efficiency

In its designing process, energy-saving is defined as a design in a building in which can reduce the use of energy without limiting the function in the building or terms of comfort or the productivity of people living there [7]. A building implementing the energy-saving system is a way to create sustainable architecture. According to [8], ecological design is a bioclimatic design, a design with regional climate and design with a low energy system. The passive design emphasizes on the regional climate by considering the things listed below:

- 1) Building form and trail planning
- 2) Reviewing the shape of the building (main exterior and not)
- 3) Exterior design (including window, location, size, and details)
- 4) Solar radiation retaining devices (eg sun shading on the exterior and windows)
- 5) Passive devices during the day
- 6) The color and shape of the closed building
- 7) Vertical plants
- 8) Natural wind and ventilation

A building that has a high foundation can be designed in order to make more efficient electrical use and the use of air conditioner with CFC (Chloro-Fluoro-Carbon) can be decreased to avoid the depletion of the ozone layer. The thing that can be done to save the energy use in the high buildings is to plan a closed building by optimizing the sunlight and natural wind in a certain area of the building, including the area and the materials used to build it. By doing so, the use of electrical power for lighting can be reduced optimally.

III. RESEARCH METHOD

A. The Design of Hardware

The hardware used consists of a controller, mechanic, and data processing parts. All those hardware are integrated into one like a single board computer, a board of Wi-Fi Node MCU ES12-E, mechanical drives, relay, and various sensors, and power supplies containing power converter board.

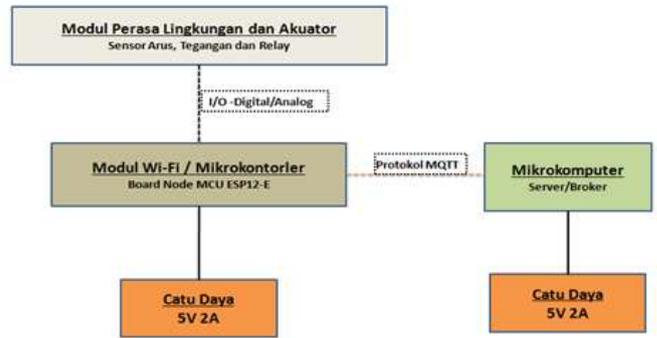


Fig. 2. Design of Hardware Development

Communication technology of this system uses the 802.11 standard technology which is well known as Wi-Fi. The use of internet connecting allows the system to be implemented and integrated easily and quickly on other internet network systems. The ESP8266 module used will be a communication bridge between the device and the server. This module can easily be placed and it does not take a lot of space since the module comes in a small size. This component is very important for the implementation of the research conducted. Due to changes in value that occurs will be read by sensors which are then used as input for the system management process in producing outputs according to their priorities.

B. Data Communication Between Module and Server in Realtime

In the software module, there is a web-based interface program. Through this interface, users can monitor the management of all activities in the home. The interface is created using modern web languages where this technology is compatible with a variety of devices with various screen sizes, making it easier for users to use the system.

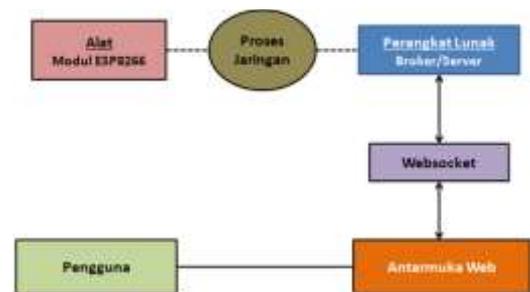


Fig. 3. Design of Data Communication between Module and Server

The server of the software system is built on an Apache-based web server where the platform is compatible with PHP based programming languages. On the server-side, a broker for the MQTT protocol is also installed which is in charge of handling the process of sending and receiving data with the MQTT protocol. This broker has a very important task because all the communication processes with the tool that is ESP8266 must be connected here first which is then taken by

the client through the help of WebSocket for the next process either stored in a database or displayed into a web page.

Modules from electronic devices and NodeMCU ESP8266-12E that are connected to the network will be able to request data both from client to server and from server to client with various configurations that have been done before both on the server and on the client module. The data that has been obtained will be stored in a database using MySQL software.

While the process of communication between objects and web servers or that handles communication tasks between modules is the NodeMCU ESP8266-12E board. The addressing of communication of each object is previously set for each device that is used as the primary in conducting communication. To receive and send data to the webserver, the objects must open communication by accessing the webserver and then determine the action to be performed. Technically, the client must have a communication network with the webserver based on the server's IP address.

IV. RESULTS AND DISCUSSION

A. Energy Consumption in the Household Environment in Indonesia

The hardware implementation is done to get data that can be used in this study. Hardware testing is carried out on several electronic devices in turn. A sensor or aquatic, both digital and analog has been installed in the designed hardware. This is done to support the design of processing data management system at brokers and servers. This step explains how the implementation of the hardware is started until it is displayed on a website. Below is the explanation of each step.

1. The first step is connecting the module and power cable to the power outlet in the hardware to one of the power outlets which is directly connected to the electrical flow.
2. Plug the power cord of the electronic device into a power outlet contained in the hardware module/circuit (which will be used later to get data on its use).
3. The next step is using a mobile phone as a router to connect between module and website. It is used to send the data of electric usage and stored it in the database. Data is stored in a real-time. The Wi-Fi hotspot in the mobile phone should be set based on the coding/ syntax used in the designed software.
4. The last step is when the users want to check the results of electronic devices power usage, they have to connect the connector cable that has been provided to the module and installed to the laptop or computer used to check usage through the website. The users also can download the use of electric power that has been stored in a database.

B. The Design of the System

This chapter shows the functions of the overall system which are explained using use case diagram. In carrying out all the functions, there will be an actor who can access all the

system. The use cases that can found in the system are login, logout, energy usage monitoring, print results, devices analyzing, and system setting.

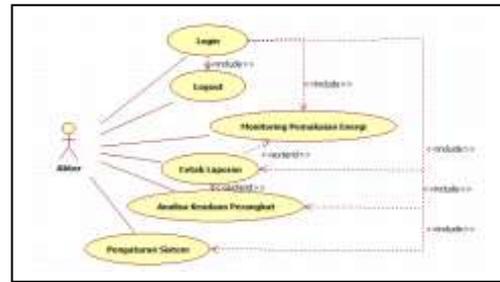


Fig. 4. The Use Case Diagram

The above use case diagram explained in detail each set if events occuring in the system.

TABLE I. THE DESCRIPTION OF USE CASE DIAGRAM *LOGIN*

Name of Use Case	<i>Login</i>
Purpose	To access the main page of the system
Main Actor	Actor, Web
Initial Condition	Actor access the web application
Final Condition	System displays the main page
Series pf events	
Actor's Actions	System's Responses
1. Actor access the web application .	2. System display the page of login.
3. Actor input the data of his/her account; username and password.	5. System validates the account.
4. Actor click the login button.	6.a System displays the main page.
Alternative Series of Events	
	6.a System displays the login page.

Table 1 explains the description of use case diagram from the login process. In the flow, the actor is asked to input his/her account's identity, such as username and password which will be validated by the system. When the identity is accepted, the actor can access the go into the main page, but when the identity is not accepted, the actor will be back to the login page.

TABLE II. THE DESCRIPTION OF USE CASE DIAGRAM LOGOUT

Name of Use Case	<i>Logout</i>
Purpose	Ending the session of accessing the system.
Main Actor	Actor, web
Initial Condition	Being in the main page
Final Condition	System displays the login page
Series of events	
Actor's Actions	System's Response
	1. System displays the main page.
2. Actor clicks the logout button.	
	3. System process the request to end the session.
	4. Displaying the login page.
Alternative Series of Events	

Table 2 shows the description of the use case diagram to do logout process. In this process, the actor clicks the logout button to end the session and lose access. If it is successful, the system will display the login page.

TABLE III. THE DESCRIPTION OF USE CASE DIAGRAM MONITORING ENERGY USE

Name of Use Case	Monitoring Energy Use
Purpose	Finding out the graph of energy used in each device.
Main Actor	Module, web
Initial Condition	Being in the dashboar page.
Final Condition	Displaying the graph of every day use of energy.
Series of events	
Modul's Actions	System's Responses
	1. System displays the dashboard page.
2. Analyzing the conditions of the environment through the sensors.	
3. Sending the results of the system.	
	4. Broker and server receive the results of measurement.
	5. System checks the identity of the sending modul .
	6. System processes the data stores them in the database.
	7. System shows the data stored in the web in form of a graph .
Alternative Series of Events	

Table 3 describes the use of case diagram of monitoring energy use in each module. The results of analyzing the sensors will be sent to the broker and server which then will be stored to the database. The stored data will be processed to be displayed on the dashboard page in the form of a graph in each minute.

TABLE IV. THE DESCRIPTION USE CASE DIAGRAM OF PRINT RESULT

Name of Use Case	Print Result
Purpose	Printing the results of energy use
Main Actor	Actor, web
Initial Condition	Being the page of results.
Final Condition	The results are printed out
Series of events	
Actor's Actions	System's Responses
	1. System displays the results.
2. Actor decides the time to print the results.	
3. Actor clicks the print button.	
	4.a System checks the validation of printing range of time.
	5. System searches the data based on the time range.
	6. System displays the data of energy use in form of an excel.
	7. System downloads the data of energy use.
Alternative Series of Events	
	4.b Not valid, being back to the result page.

Table 4 explains the use case diagram to print the results. The data of the results contain the amount of energy usage from electronic devices based on a predetermined time range. The report data can be saved or downloaded by the actor to make it easier to check the amount of energy used from electronic devices.

C. Module/Prototype Testing

1. Module Testing/Prototype and Web Systems

In the initial stage we will monitor the use of electrical power on electronic devices, where this checking can be done/viewed through the *website* at *localhost* 192.168.43.225/penelitian that will display the login page.



Fig. 5. Login Page

This page can only be accessed by users who have access right that have been previously registered. After logging in, the main page will appear.

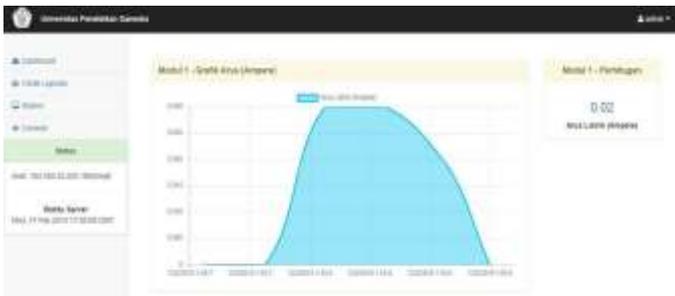


Fig. 6. Main Page

Where this page has a function for monitoring the use of electric power using graphics. Data that is displayed and stored in the *database* is done in *real time* with data retrieve time that is 30 milliseconds. There is also a data management process where the page contains a selection of actions such as the selection of electronic devices and the determination of the timeframe for finding information on electronic conditions. The advantages of the data management process in this study with previous research on the report print feature in previous studies data management can only be displayed on a web page without being downloaded while in this study adding the print report feature in the form of Excel (.xls) which will later monitor power consumption results electricity can be processed and function again.

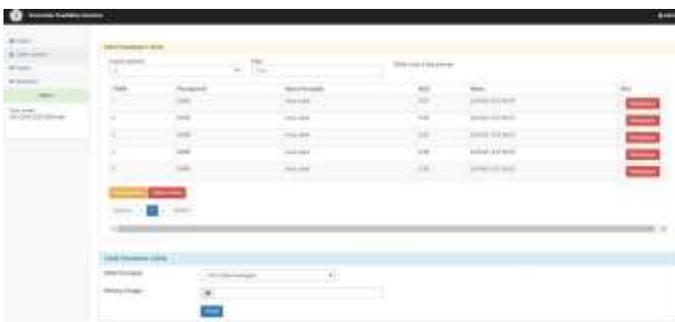


Fig. 7. Data Management Page/Report Print Page



Fig. 8. Data Configuration Page

The data configuration page has the function of stopping and turning off prototypes/modules for storing electrical power usage data on electronics.

2. Calculation of Electronic Device Conditions

The evaluation of the module/ prototype and website system. Testing the search for the condition of electronic devices is carried out with the workflow that is shown in Figure 9 below.

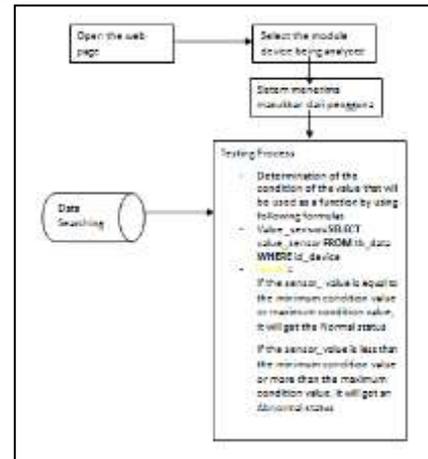


Fig. 9. Flow Testing for the Search for the Status of Electronic Device Conditions

In testing, the determination of minimum and maximum conditions using TL lamp with Philips brand with a power of 15 watts/0,068156 amperes and the production date is March 1, 2019 and the purchase date is July 8, 2019. Asus brand mobile phone charger with 2 amperes power and production date 12 February 2019 for the date of purchase 20 May 2019. In this test an average calculation is done every time to determine the minimum dan maximum values which will be used as a condition value for testing the condition of electronic devices using the IoT module. The results of the determination of the condition value are used as a calculation of the condition value of electronic devices for example the following results from tests that have been carried out on TL lamp devices. By testing using Philips TL lamp power 15 watts/0,068156 and the production date is 11 November 2014 and the date of use is 04 April 2015. The following results of testing the calculation of the condition of electronic devices.

UNDIKSHA Universitas Pendidikan Ganesha Pusat Saraja Ilmu Komputer Jl. Udayana No. 11, Singaraja, Banjar Tegai, Kec. Buleleng, Kabupaten Buleleng, Bali 81116					
Data Pemakaian Listrik					
Nama Perangkat		Tanggal		value	status
1	00001	2019-10-10-00:48:55	0:28		Normal
2	00001	2019-10-10-00:48:56	0:28		Normal
3	00001	2019-10-10-00:48:56	0:28		Normal
4	00001	2019-10-10-00:48:57	0:28		Normal
5	00001	2019-10-10-00:48:57	0:28		Normal
6	00001	2019-10-10-00:48:58	0:27		Normal
7	00001	2019-10-10-00:48:58	0:28		Normal
8	00001	2019-10-10-00:48:58	0:28		Normal
9	00001	2019-10-10-00:48:58	0:27		Normal
10	00001	2019-10-10-00:48:58	0:28		Normal
11	00001	2019-10-10-00:48:59	0:28		Normal
12	00001	2019-10-10-00:48:59	0:28		Normal
13	00001	2019-10-10-00:48:59	0:28		Normal
14	00001	2019-10-10-00:48:59	0:28		Normal
15	00001	2019-10-10-00:48:59	0:28		Normal
16	00001	2019-10-10-00:48:59	0:28		Normal
17	00001	2019-10-10-00:48:59	0:27		Normal
18	00001	2019-10-10-00:48:59	0:28		Normal
19	00001	2019-10-10-00:48:59	0:28		Normal
20	00001	2019-10-10-00:48:59	0:27		Normal

Fig. 10. Print Page Report/Result of Electroni Condition Calculation

Based on the average values mentioned above, it can determine the minimum and maximum values for the electronic lamp conditioning, that is 0,068156 amperes and 0,725 amperes. Meanwhile the from the mobile charger, it was found that the values are 0,067642857 amperes and 0,29172 amperes. comparisons made between the value of the module with the conditioning value, are:

- a. Normal status if the value of the module is more than or equal to the minimum value and less than or equal to the maximum value.
- b. Abnormal status if the value of the module less than the minimum value and more than the maximum value.

Then testing was done to the electronic lamps and mobile phone charger at home, available at appendix 1 regarding whether or not the device is working normally or not.

3. Calculation of Real Difference and Module/Prototype Value

Data analysis in this study is intended to calculate the difference between the real value obtained from the specifications in the cardboard box or those located behind the electrical device with the module/prototype value obtained from the value that has been stored in the database.

Table 5 explains about the electronic devices used in this study with the addition of a usage period that counts in 1 (one) day for 24 hours for electronic devices used in this study which has a usage period of approximately 3 years, this explanation is intended as a reference when calculation later. There are 8 (eight) electronic equipment used in this study, the value of this electronic equipment which will be used to calculate the difference or calculate the accuracy of the value obtained from the installation of modules that have previously been stored in a database.

Because the value obtained from module installation is a value that is calculated per second, it will be calculated using the overall average for 1 (one) day installation for 24 hours. Before that this research was calibrated for a period of using electronic equipment with a maximum time of 3 years. the results of the calculation of the difference between the real value of electronic equipment with the average module value can be seen in table 5. To simplify the calculation, each value is converted to amperes using the following formula.

$$I = \frac{P}{V} \tag{1}$$

Note :

I : Electrical current in *Ampere* (A)

P : Electrical power in *Watt* (W)

V : Electrical Voltage in *Volt* (V)

This change is intended in addition to simplifying calculations because the value stored in the database has

amperage units. the formula used to calculate the difference between real values and module values is as follows.

$$Error\ value = \frac{E1 - E2}{E1} * 100\% \tag{2}$$

Note:

E1 = Real Value of Electronic Equipment (Amperes)

E2 = Module Value (Ampere)

TABLE V. CALCULATION OF DIFFERENCE IN REAL VALUE AND MODULE VALUE

No	Peralatan Elektronik	Nilai Real (Ampere)	Nilai Modul (Ampere)	Selisih (%)
1	Lampu TL	0,068181	0,068	0
2	Charger HP	0,3	0,29	3
3	Televisi	0,5	0,48	4
4	Kulkas	0,454545455	0,42	7
5	Magicom	1,590909091	1,74	-9
6	Mesin Cuci	1,5	1,46	2
7	Setrika	1,590909091	1,49	6
8	Charger Laptop	0,3375	0,33	2
Presentase Kesalahan Rata-Rata Sebesar				15

In the calculation of the difference between the real value and the value of the module described in table 6, there is a quite noticeable difference in the magicom electronic equipment, with the percentage for magicom reaching -9%. Data is sent every 30 milisecond, with an average measuring error of 15% from the results of detection using a module/prototype. So in this module, the process of sharing data was successfully carried out because the data was successfully stored in the mysql database.

Beside calculating using real values that already exist in the specifications of the electronic equipment itself, this study also calculates the difference between the value of the module with the value displayed on the kilometers installed in the house owned by PT. PLN. This calculation is almost the same as the previous calculation but the only difference is that the electronic equipment used is the equipment used on the day when the data was collected using a module.

TABLE VI. THE DIFFERENCE BETWEEN THE REAL VALUE AND THE VALUE MENTIONED IN THE ELECTRIC METER

Electronic Device	Electric Meter Value (Ampere)	Module Value (Ampere)	Difference (%)
TL lamps	2,8	0,068	3%
Refrigerator		0,42	
Television		0,48	
Magicom		1,74	
Total		2,708	

The difference between the measurement of the module value and the kilometer of the house installed by PT. PLN is 3%. The percentage value explains that the performance of the

module/prototype is almost the same as a home kilometer. There is only a difference that can be possible when taking data from electronic equipment that must use a stable mobile network or when the use of electronic equipment that has had a period of approximately 3 years of use.

V. CONCLUSION

Based on the results of the analysis, it can be concluded that all modules can communicate and send values obtained to the broker in real-time using the MQTT protocol that can reduce the size of the data packet as small as possible so that the data transfer process becomes light, the checking system of the home device was done by comparing the results of the module value with the real value of the equipment can run well, as well as the difference between checking the results of monitoring and the value of the kilometres installed on the building owned by PT. PLN only has a difference of 5% percentage. Finally, by testing on 8 household electronic devices, there was a 3% difference between the use of the module value and the real value, where there was a difference in magicom with a difference of -9%.

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