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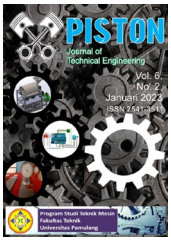

Smart Home Electricity Usage Monitoring and Controlling System using Raspberry Pi

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Abstract: Almost all household appliances nowadays using electricity as power, increasing the use of electricity in each household. Usually human use electricity excessively and uncontrollable, leading to overpayment of electricity each time and decreasing the electricity resource itself, where saving energy including electricity is necessary. A smart system that can monitor and control the usage of electricity based on need become one of the best approach to tackle the problem of excessive and uncontrollable usage of electricity. In this paper, we create a smart system that can monitor and control electricity usage in household using Raspberry Pi and Current Transformer Sensor to process and detect electricity data, relay to control and build a web application as interface using PHP and MYQL database for human to configure and setting the usage of household appliances in their own. This smart system also give report and notification to the user that can be configured daily, weekly, or monthly so that the user know how much electricity they has been used. They information we provide includes implementation of raspberry pi and current transformer sensor, designing and building web application interface, data and result of the smart system.

Keywords: Electricity Usage, Raspberry Pi, Current Transformer Sensor, PHP and MSQL, Smart System.

Abstrak: *Saat ini, banyaknya alat-alat rumah tangga yang membutuhkan sumber daya listrik, membuat pemakaian listrik semakin meningkat. Namun dalam pemakaiannya, manusia seringkali berlebihan dalam menggunakan listrik dan tidak dapat dikontrol dengan baik. Pemakaian listrik yang berlebihan tersebut membuat biaya semakin besar pula. Hal ini akan sangat merugikan baik dalam segi biaya maupun daya listriknya. Smart system menjadi salah satu pendekatan untuk mengatasi masalah manusia yang selalu lupa untuk mematikan alat-alat elektrik yang sedang digunakan. Pada paper ini kami membuat sebuah smart system yang dapat melakukan pemantauan dan kontrol terhadap penggunaan peralatan listrik menggunakan Raspberry Pi dan Current Transfor Sensor untuk mengolah dan mendeteksi data penggunaan listrik, relay untuk kontrol dan membangun sebuah aplikasi web menggunakan PHP dan basis data MYSQL sebagai antar muka pengguna agar dapat melakukan pemantauan dan kontrol penggunaan listrik mereka. Informasi yang disajikan berupa implementasi raspberry pi dan current transformes sensor, desain dan perancangan antar muka aplikasi web, data dan juga hasil dari smart system.*

Kata Kunci: *Listrik, Raspberry Pi, Current Transforme Sensor, PHP dan MYSQL, Smart System.*

INTRODUCTION

Electricity is an important source of power for almost all household appliances nowadays. Usually human use electricity ineffectively where they use it excessively and unctrollable [1], sometimes leading to overpayment to the provider and increasing electric power consumption per capita in a country. In 2019 the electric power consumption in Indonesia has reach about 1,084 kWh per capita [2] showing indication that the power consupmtion in Indonesia increase each year. When using electricity in each household applilances, sometimes human forget to switch it off after using it or can not manually switch it off when they go outside their house. Human need to use electricity in efficient way so that a system for monitoring and controlling the electricity usage for each household need to be built. Many research has been done to analize the power

consumption in household, but they only give the performance data and metric of electricity usage, none of them build a system that can help human to monitor and controll the electricity usage and power consumption [3]–[5].

Based on the problems mentioned, we create a system that can monitor and control electricity usage in any household appliances using Raspberry Pi as main processor and server [6], Current Transformer Sensor to detect and sense the electricity when used by household appliances for monitoring, and using Relay to control the usage whether to switch on or switch off the electricity. This smart system also has web application built using PHP as programming languange and MYSQL as database in order to give the human interface to interact with the system, configure the setting, monitor the usage, and can control the electricity from web application, this system also give report to the human about their power consumption daily, weekly, or monthly and give the notification about the system. This smart system provide an automatic switch off using thresehold input, duration, and time range, to make sure that the electricity usage are not excessive and uncontrol whenever human forget to switch off.

This paper intend to give deep explanation for smart system that can monitor and control electricity usage in household appliances and also give more contribution in building more better way to controlling the system.

METHODOLOGY

General Architecture Design

Figure 1 show the general system of electricity monitoring and controlling and its communication between components. Electricity power source is transfering current to household applilance, where Current Transformer Sensor (CT Sensor) will tap and record [7] the moving current into Arduino UNO. Data in Arduino UNO, about how much electricity used by household appliance (in kWh) will then be transferred to Raspberry Pi 3, where Raspberry Pi 3 will process the data and save it into database. Web application retrieve data from database to be shown in the interface, user/human will be able to see the electricity usage data from the web. The communication between user to web application and Raspberry Pi 3 is two way communication, meaning that user can also give command and instruction to the system to control the electricity usage. User can set threshold of each appliance, they can set the amount of electricity usage or the duration of use of each houshold appliance. The system will detect if the current electricity is over the threshold limit or over the duration, and then send signal to relay to switch off the power line for coresponden household appliance. This system can be monitored and controlled by user even if they are not in their own house because the system can be access publicly using internet connection, the system can also give notification to the user thus prevent excessive and uncontrollable usage of electricity in their own house.

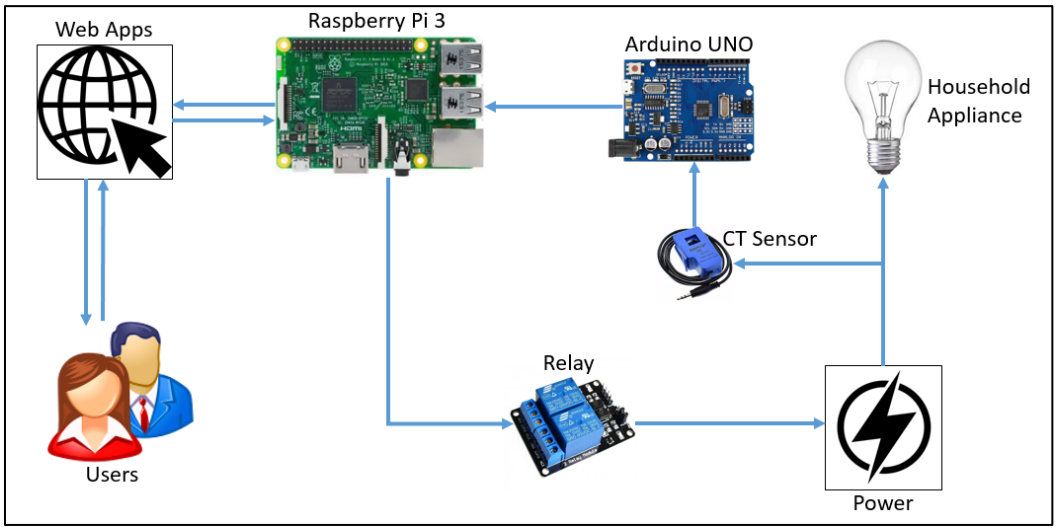

Figure 1. General Architecture Design of Electricity Monitoring and Controlling System

Raspberry Pi 3

Raspberry Pi 3 is a mini and compact computer. Raspberry Pi 3 is similar with regular computer where it has processing unit, storage, common port, and ethernet network. Plus many additional features like digital input/ouput (GPIO), JTAG, and CSI. GPIO is very useful when combining other embedded devices and sensors to Raspberry Pi. Raspberry Pi 3 that we use in this research has this specification: Broadcom Chip BCM2835,

CPU 700MHz, GPU Broadcom videocore IV, Memory 514 MB, and 32 GB external storage to store all the data recorded by the system. Raspberry Pi 3 will process all the data from sensor and relay, and translate all command and instruction from users to coresponden components like relay [8]. Raspberry Pi become mini server where web application and all processing reside.

Current Transformer Sensor

Current Transformer Sensor (CT Sensor) is a sensor used to measure electricity current usually alternating current (AC). Particularly useful to measure household appliance power consumption and can work with high level voltage. CT Sensor has a primary winding, a magnetic core, and secondary winding [9]. Electric AC flowing in primary winding produces a magnetic field in the core CT Sensor, which induces the secondary winding circuit. The current in secondary winding is propotional to the current flowing in the primary winding with this formula.

$$I_{secondary} = CT_{turnsRatio} \times I_{primary}$$

$$CT_{turnsRatio} = Turns_{primary} / Turns_{secondary}$$

The primary winding of CT Sensor is the wire carrying the current that need to be measure, and CT Sensor is connected to Arduino UNO pin to store all the data it has been measured. The installation of CT Sensor need to be precise for the sensor to correctly measured the electric current and evading any error that could harm human [10].

Relay

Relay is electronic component that act as an operated switch, consist of a set of input terminals for single or multiple control signal, and a set of operating contact terminals. Relay work with electric signal received from other programmable components [11], in our research Raspberry Pi 3 act as main processor that translate the instruction from human to electric signal and relay send that signal to other component mainly to turn the switch on or off. With this scenario, electricity current flow in each household appliances can be controlled centralized in Raspberry Pi 3.

Arduino UNO

Arduino UNO is a microcontroller board based on the ATmega328P. Arduino has 14 digital input/output pins (6 pins can be used as PWM outputs), 6 analog inputs, 16 MHz ceramic resonator (CSTCE16M0V53-R0), a USB connection to connect to other devices (in our research it connect ot Raspberry Pi 3 USB port), power jack, an ICSP header and a reset button. Arduino UNO is popular mini board to support the microcontroller. Our research use Arduino UNO to be interface between Raspberry Pi 3 and CT Sensor [12]. CT Sensor can not connect to Raspberry Pi 3 directly, thus Arduino UNO is needed so that all the data recorded by CT Sensor can be transferred to Raspberry Pi 3 database system.

Flowchart System

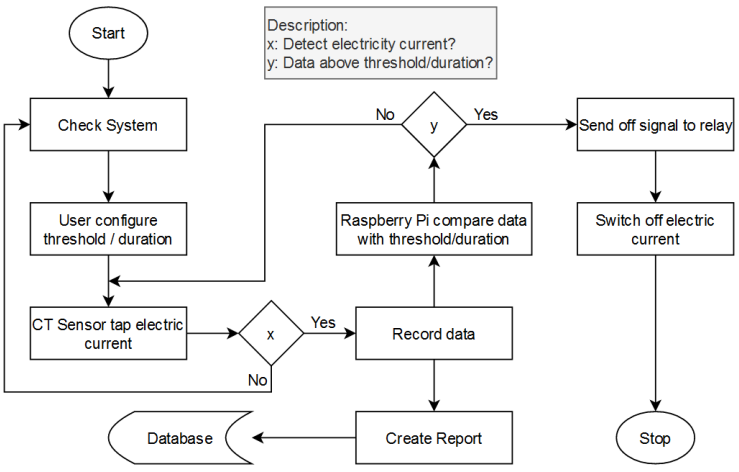

Figure 2. Flowchart System

Flowchart system shown in Figure 2 give information how overall flow of the system work. The process of monitoring and controlling electricity usage in household aplliance begins with the user checking the system via web applications. The user can input and configure the threshold of how much electricity current can be used, and also can configure duration or time range of each houshold appliances usage. Curret Transformer Sensor (CT Sensor) is clamped into mounted power line of each household appliances, it can be clamped into lightbulb power line or electric plug where each houshold appliances connected into.

CT Sensor detect current flow in each power line, whether it detecting current flow or no at the time, the data will then be saved into database system. This data is presented into web application so user can view and analayze electric current status of each power line. All data recorded CT Sensor will be saved in database system, where web application can also make a report and notification for user daily, weekly, or monthly. This data can also be convert into currency (regarding on the price for each electricity provider) so that user has better understanding on how much they pay for the electricity they have been used.

The system save the threshold, duration, or time range from user input then compare it to data recorded by CT Sensor. If the recorded data by CT Sensor is above threshold, then Raspberry Pi 3 will send signal to Relay and then switch off the power line for corresponding household appliance. This way, there will be no excessive use of electric current.

System Communication Design

The communication between Raspberry Pi 3, Relay, and houshold applilances need to be implemented so each components of the system can communicate to each others.

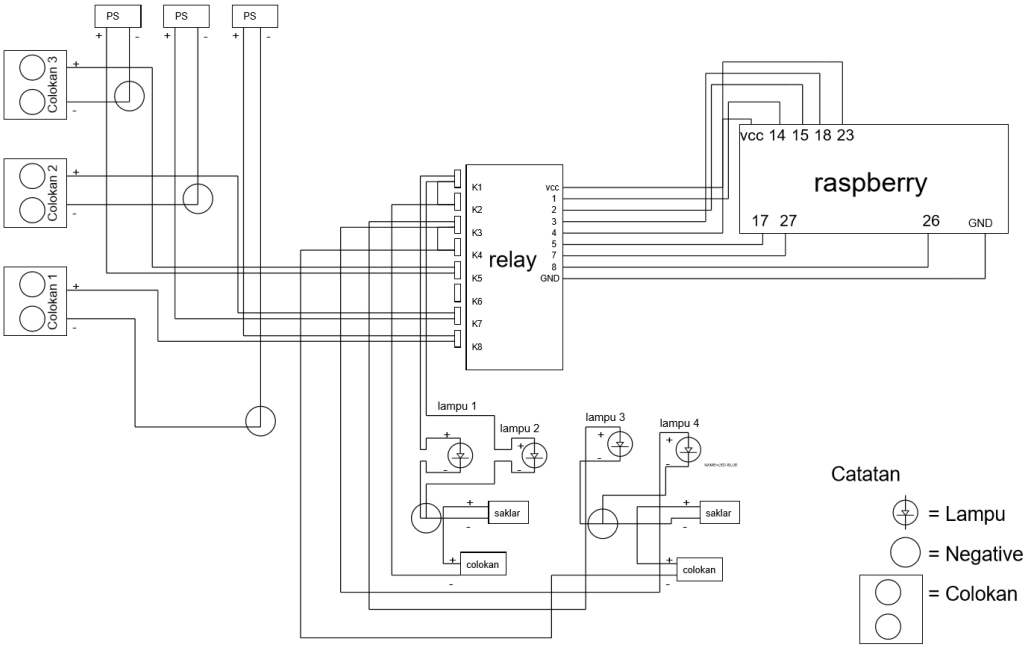

Figure 3. System Communication Design

Circuit in Figure 3 present the communication between Raspberry Pi 3, Relay, and each houshold appliances to their respective port and pin. Relay directly connect to each household appliances and act as main switch to switch on or switch off based on receiving signal from Raspberry Pi 3. Relay using pin K1 – K8 to each household, while pin VCC, GND, 1-8 is connected to Raspberry Pi 3 as main communication between two components.

RESULT AND DISCUSSION

The result of this research is a system that can monitor and control the electric usage in houshold appliances. This system provide the ability to detect excesse and unctrollable use of electricity, generate report for analysis, interactive control, automated schedule for each household appliance, all in the form of web applications while the system itself is built using Raspberry Pi 3 as main server and processing data, CT Sensor as recording data current, and Relay for translating signal switch off or switch on.

General Architecture Prototype Testing

We build a prototype for testing the entire system that emulate real thing household appliances. We need to test the system in controlled environment first before implementing it into the real houshold appliances. The reason for this, is mainly for security reason where we can minimize adverse effect if such thing happened.

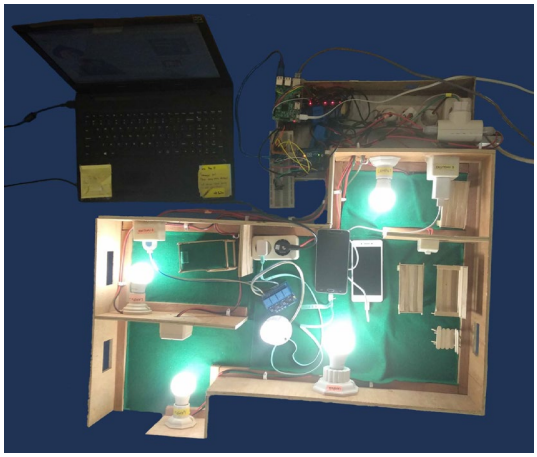

Figure 4. Prototype System for Testing

As shown in Figure 4, we conduct a testing for 4 pieces of lightbulbs and 3 electric plugs (where 2 smartphones, and 1 laptop are connected). All 4 lightbulbs turn on successfully, and also 2 electric plugs can be used for other devices as well, the system is centralized in Raspberry Pi 3 system where the user can monitor and control the household appliances. The spesification and result of each household appliances is shown in Table 1.

Table 1. Prototype Result of Each Household Appliances – 1st Trial

Item	Specification Power (Watt)	Consumption (kWh)		
		5 Minutes	30 Minutes	60 Minutes
Light Bulb #1	8	0,00049	0,0039	0,0077
Light Bulb #2	8	0,00042	0,0038	0,0077
Light Bulb #3	8	0,00051	0,0039	0,0078
Light Bulb #4	20	0,00153	0,0098	0,0191
Plug #1 (Smartphone)	10	0,00079	0,0048	0,0099
Plug #2 (Laptop)	320	0,0257	0,1587	0,3182
Plug #3 (Smartphone)	10	0,0008	0,0049	0,0099

Based on our prototype testing, each household appliances has their power spesification in Watt [13]. We use different specification for the household appliances to see the variation testing whether effecting the entire system or not. We also record the data for different duration (5 minutes, 30 minutes, 60 minutes) to see the gradual increase of power consumption for each household appliances. From our prototype testing, our system can record the data and later compare it to the threshold from user input. This data can also be present to user in report form for better analyze.

For better result, we did the testing for 10 times and make the average result into Table 2 below:

Table 2. Average Result of Each Household Appliances

Item	Specification Power (Watt)	Consumption (kWh)		
		5 Minutes Avg	30 Minutes Avg	60 Minutes Avg
Light Bulb #1	8	0,00056	0,0042	0,0071
Light Bulb #2	8	0,00041	0,0036	0,0072
Light Bulb #3	8	0,00048	0,0041	0,0073
Light Bulb #4	20	0,00148	0,0097	0,0195
Plug #1 (Smartphone)	10	0,00081	0,0051	0,0096
Plug #2 (Laptop)	320	0,0251	0,1581	0,3185
Plug #3 (Smartphone)	10	0,0007	0,0046	0,0097

Web Application Interface

We also test the interface for the user to interact with the system in the form of web application. This web application enable user to see their overall electricity usage in each household appliances, and give instruction to the system how to behave (input threshold, duration, or time range).

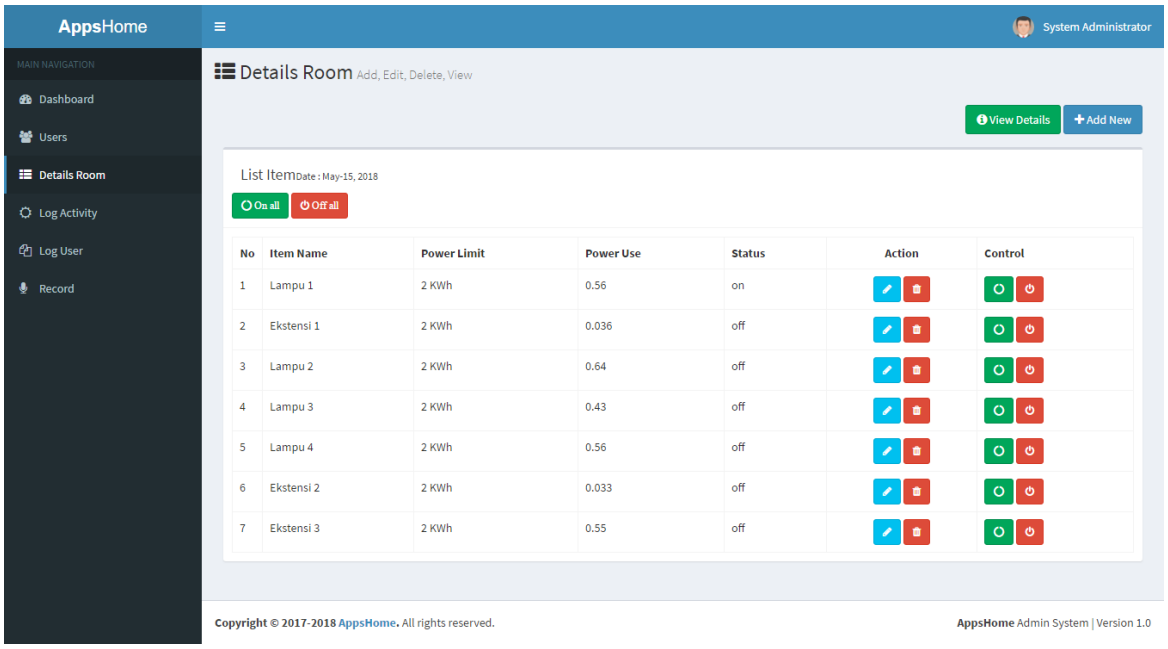

Figure 5. Web Application Interface for user to Monitor and Control

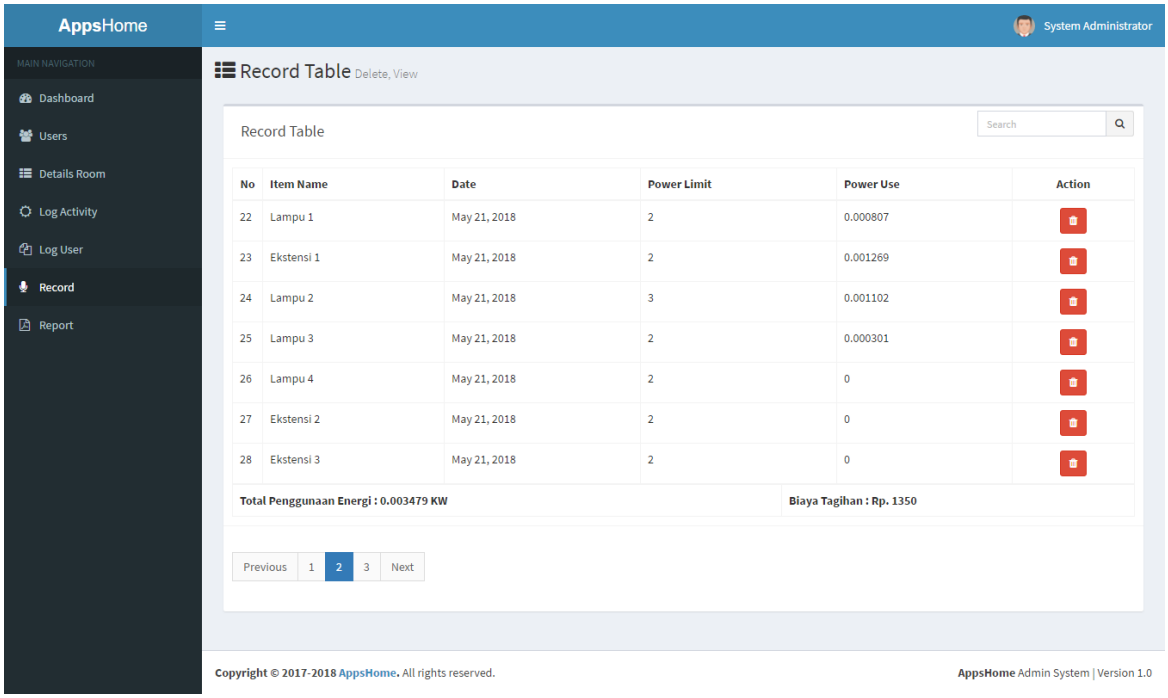

Figure 6. Record Table including Date and Time, and Payment

In Figure 6, user can see all total recorded data of each appliances in their respective date and time, plus aditional payment of how many they should pay to electric provider.

The security of web application is using authentication and autherization method, because the web application system can be accessed publicly so that a security system must be implemented [14].

CONCLUSIONS

The result of this research by designing and implementing then testing the system show that this smart home system can monitor and control the usage of electricity in houshold appliances. The system prevent the excessive and uncontrol usage of electricity, thus helping human to reduce the cost of electricity and also help saving energy. The implementation of this system in large scale will help many user to monitor and control their electricity usage while giving easly access to monitor and control to the system, and also get report generated by the system to help user to analyze their electricity usage daily, weekly, and even monthly. Based on our research, this system can be further developed by implementing more variant sensor for electricity usage, and can be access by mobile phone application not just web application. The aspect of security can also be considered for future development because the system can be accessed publicly, our system has implement authentication and authorization for those who want to accessed the system, but for our concern it's still not enough security.

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