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Analysis of Custom IoT Based Electricity Monitoring System

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Analysis of Custom IoT Based Electricity Monitoring System

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Abstract. Electricity is a resource that currently exists in various sectors of the community. Each person's electricity needs are different depending on the needs of the electronic equipment used. Excessive use of electronic equipment creates extreme electrical power. Electricity consumption is an issue that discussed since a long ago. This research aims to present a custom electronic sensor to monitor electricity consumption based on the Internet of Things. It also explained the correlation between input and output points from the custom electronic sensor. This research method consists of 4 steps: system requirement, system design, system implementation, and last, testing and analysis. The system developed is able to get the current, voltage, and power data. The data then processed by Arduino UNO and directly send by ESP8266 to Blynk Application on Android smartphones via Internet communication. The voltage testing is done in the voltage and current sensors to get the program's main loop's constant values. The system input value and the Blynk Application value are also measured to check the system's error.

1. Introduction

Electricity is a resource that currently exists in various sectors of the community. Each person's electricity needs are different depending on the needs of the electronic equipment used. Excessive use of electronic equipment creates extreme electrical power. Electricity consumption is an issue that discussed since a long ago. The energy impact also has been carried out since it generally indicates the environmental effects and the direct impact of ICT equipment on electricity consumption [1]. Research about the trend of electricity usage also done to check the appliances usage behavior [1]–[5] Besides checking the electricity consumption, it is also essential to research electricity saving. Research provides a comparison of electricity saving tariff [6] and evaluation of household electricity savings are done [7]. To prevent waste electricity usage, various research to develop an electricity monitoring system, and a technique to estimate power consumption are also done [8]–[11] Besides used as electricity monitoring usage, a monitoring system can be used to check the parameter's value such as voltage, current, and power to prevent electronic equipment damage. That's how monitoring electricity usage can be crucial.

This research aims to present a custom electronic sensor to monitor electricity consumption based on the Internet of Things. Different from [12], this research using an Android smartphone with Blynk Application instead of a web-based monitoring system. Compared to [13], this research focused on the development process and the correlation of the input and output current and voltage measured in the custom electronic sensor.

2. Literature Review

2.1. Arduino UNO, ESP 8266, and Blynk

Arduino UNO is a microcontroller board based on Atmega 328P with 14 digital I/O pin (6 pin support as PWM) and six analog inputs. It provides USB and power jack connection. USB connector, AC/DC adaptor, and batteries can be used to supply the board [14]. It is the board to start with, and it comes in two flavors, through-hole and SMD. Compared to Arduino Mega, Arduino Due, and Arduino Leonardo, it has the correct amount of pin to be used in the system [15]. Arduino UNO does not come with wireless communication so that it is usually added with another board to support communication via the Internet.

Comparing to several wireless boards named Arduino Wi-Fi Shield, Genuino Yun Shield, Genuino MKR 1000, ESP8266, and Onion Omega, ESP8266 is suitable for this system. The board using Tensilica Xtensa LX106 processor, support 5 V from USB or 3.3 V from VIN power supply, 3.3 V I/O, Internal RAM: 64 KB for instructions, Internal RAM: 96 KB for data, QSPI flash: 512 KB to 4 MB. It also supports SPI, I2C, I2S, and UART. It also supports the Arduino IDE and has the smallest board dimension and price compare to others [16].

Blynk was designed for the Internet of Things. It supports mobile IoS and mobile Android to control Arduino, Raspberry Pi, and other hardware via the Internet. It provides three major components which are the Blynk App, Blynk Library, and Blynk Server [17].

2.2. Custom Sensor Circuit

The custom sensor circuit used consists of several parts, the voltage sensor circuit, current sensor circuit, voltage regulator circuit, and Operational Amplifier circuit in the current sensor, as shown in Figure 1.

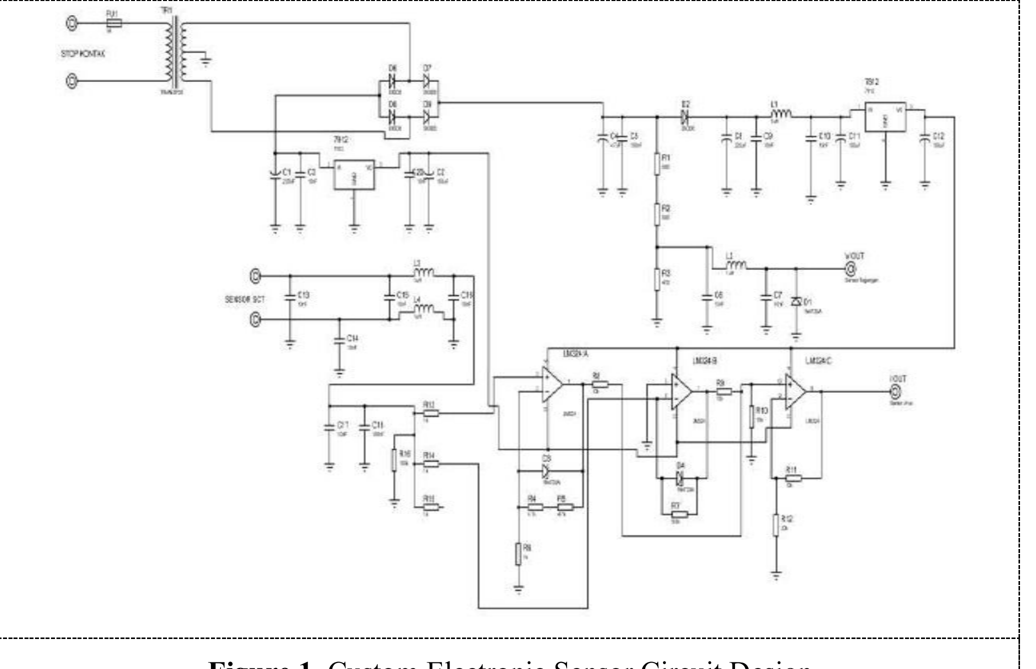

Figure 1. Custom Electronic Sensor Circuit Design

The voltage sensor circuit is used to lower the voltage from the resource to Arduino UNO. It uses CT 18 V step-down transformer to reduce the maximum 220 V to a maximum 36 V. The output is connected to Diode Bridge to change the AC to DC. The current sensor circuit use to lower the voltage ripple that goes to SCT 013-010 sensor. The voltage regulator circuit gives stable 12 V to IC

LM324 [18] in the Op-Amp circuit. The Op-Amp circuit itself uses to reinforce the input from the current sensor circuit so that it can go to Arduino UNO [19].

3. Research Method

The method of this research consists of 4 steps. The first step is system requirement analysis, then system design, system implementation, and last are testing and analysis. From the application requirement analysis, the component's list and the application's functional needs are found. The operational needs of the system are:

- The system must be able to communicate with the Blynk application in an Android smartphone using ESP8266 with Wi-Fi.
- The system can read and process the value from the current and voltage sensor in the system.
- The system can calculate real electricity power used from the current sensor and voltage value.
- The system can show the current value, voltage value, and power value on Blynk Application in Android smartphones.

The non-function needs of the system are:

- The system using the Arduino UNO board as the central controller to process the data, and ESP8266 to send the data to Android smartphones.
- The system using the SCT-013-010 sensor to check the current value in each plug. It uses CT 18V step-down transformer to proceed with the voltage sensor circuit to check each plug's voltage value.
- ESP8266 board used to send the data from Arduino UNO to the Blynk application.
- Arduino UNO in the system using a 9V power supply.

The next step of the research is system design. The system design can be seen in Figure 2. As mentioned before, the sensor circuit used in this research consists of several parts, namely the voltage sensor circuit, the current sensor circuit, the voltage regulator circuit, and the Operational Amplifier circuit.

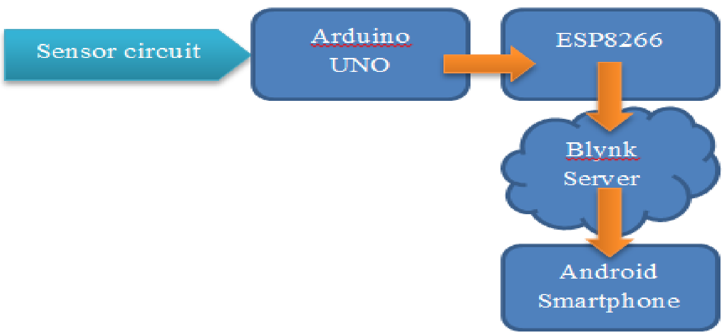

Figure 2. System Design.

The current sensor circuit used to make large input voltage from the voltage source readable in Arduino UNO. The current sensor circuit is used to reduce the voltage ripple at the 013-010 SCT sensor input. The voltage regulator circuit provides a stable voltage of 12V on the LM324 IC in the Operational Amplifier circuit. The Operational Amplifier circuit serves to amplify the input from the current sensor circuit so that it can be accepted on the Arduino UNO.

As for the Android Smartphone, the interface used is from the Blynk Application. Several widgets can be used in Blynk, as on this system used voltage sensor display, current sensor display, power display, and super chart. Super chart widget is used to display the current, voltage, and power result sent from the ESP8266. It is also set to read until two digits decimals.

4. Testing and Analysis

The testing is done by first checking each voltage value read in each input sensor and output. Second, by checking the comparison value between the system and the Blynk application display as a whole system. The test was carried out using a digital multimeter. The load used for testing comes from 1 electric iron, two mobile phone chargers, and one laptop charger.

4.1. Voltage Sensor Circuit Test

The first test is the voltage sensor circuit test. The voltage sensor circuit's voltage value is used to compare the actual voltage input value from the voltage sensor circuit and the real output value from the voltage sensor circuit. The value of the input voltage and output voltage used in the calculation of the voltage sensor will applied in the void loop function on the Arduino UNO board. Testing is done 50 times by measuring the voltage value at the voltage source, then the 18V 500 mA transformer CT's output value. It will then continue with measuring the diode bridge's output value where the value has changed from analog to digital. And the last is measuring the voltage sensor circuit's output value, which is used as a benchmark to determine the ratio of the output voltage value between the sensor circuit and the voltage source. The voltage sensor testing can be seen in Figure 3.

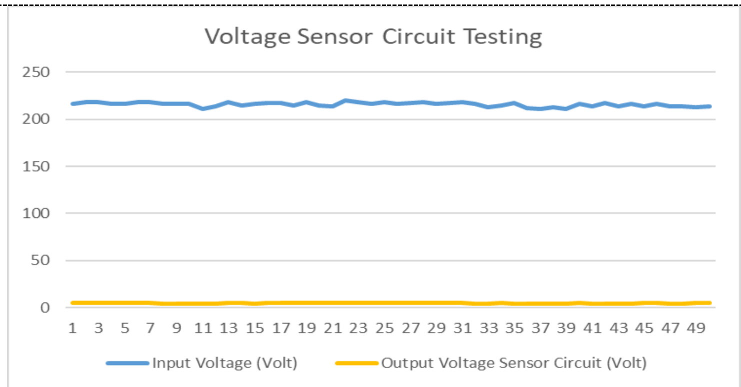

Figure 3. The voltage sensor circuit testing.

The result from Figure 3 showed the comparison of the 50 value of the voltage sensor circuit, CT transformer output voltage, diode bridge output voltage, and output voltage sensor circuit. All 50 values from the input voltage were added and divided with all of the output voltage from the voltage sensor circuit. The result is 47.6 V. The value result is then used as the constant in the voltage calculation in the Arduino IDE void loop, as shown in Blynk Application.

4.2. Current Sensor Circuit Test

The current sensor circuit testing is used to get the comparison of actual voltage value from SCT 013-10 sensor input and current sensor circuit output. The comparison result of the voltage value is used as the current calculation in the Arduino IDE void loop. The SCT sensor has an output where every 10 Ampere read is the same as 1 V sensor output. The testing was done by measuring the output voltage on SCT 013-010 sensor output, the output voltage on OP-amp 1, the output voltage on OP-amp 2, the output voltage on OP-amp 3. The testing is also done in 50 times to check the reinforcement value from the current circuit sensor. The current sensor testing can be seen in Figure 4.

The result of Figure 4 showed a comparison of each point in the current sensor circuit. The reinforcement value got from the sum of input value then divided with the sum of the gates' outputs. The result is 31.5 V, and this value is used as the constant in Current computation in the Arduino IDE void loop as send to Blynk Application.

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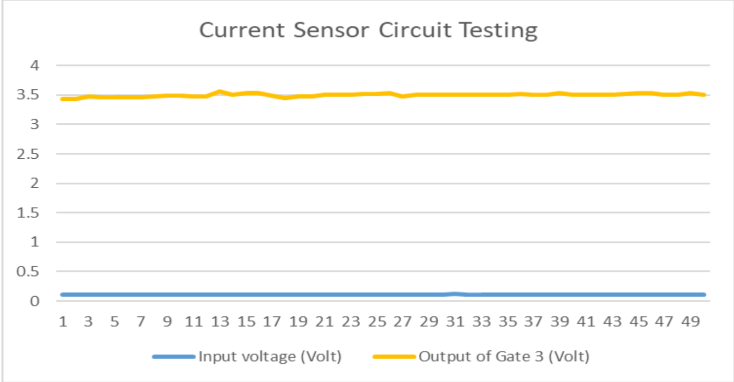

Figure 4. The current sensor circuit testing.

4.3. System Test

After each sensor circuit testing, the final testing is complete system testing. This testing done to check the differences between the values showed in Blynk Application and the current and voltage input in the system. Figure 5 and Figure 6 showed the comparison value of it.

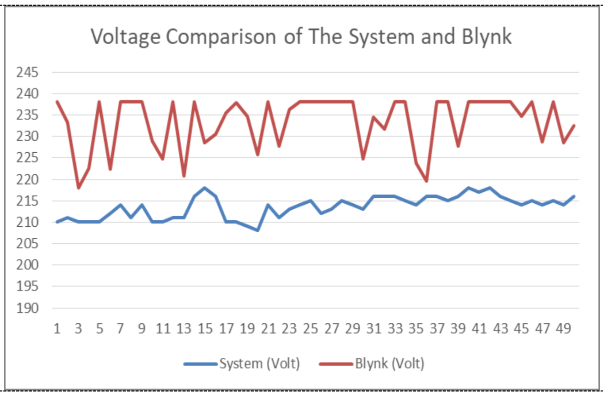

Figure 5. Voltage Comparison on The System and Blynk.

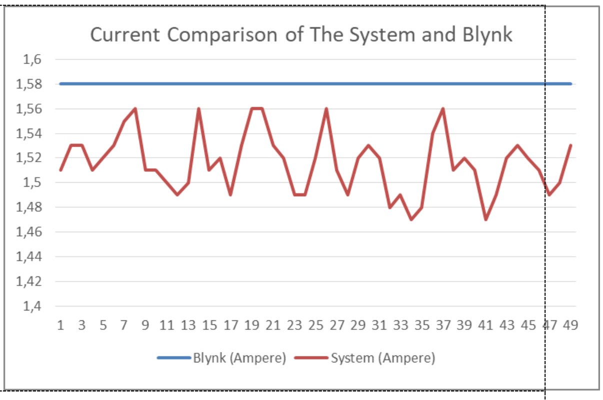

Figure 6. Current Comparison on The System and Blynk

Figure 5 showed the comparison voltage value between the system and the Blynk as a whole system. The average error voltage sensor is 8.41%. Figure 6 showed the current comparison value between the system and the Blynk as a whole system. The average error current sensor is 4.14%. Based on the result, it can be concluded that there 8.41% differences in voltage sensor and 4.14% differences in the current sensor. The possibility of the error happened because the measurement process is done using the values measured at each point on the system. It is better to measure the value by using the peak of the voltage and current value using differentiation.

5. Conclusion

It can be concluded that the system build can monitor the current and voltage used in the measuring point and send it to the Blynk application directly. There are 8.41% differences in voltage sensors and 4.14% differences in current sensors during the input and output system's measurement process. It is better to measure the value by using the peak of the voltage and current value using differentiation as a suggestion.

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References
[1] Pothitou M Hanna R F and Chalvatzis K J, 2017 ICT entertainment appliances' impact on domestic electricity consumption *Renew. Sustain. Energy Rev.* **69**, June 2015 p. 843–853.
[2] Firth S Lomas K Wright A and Wall R, 2008 Identifying trends in the use of domestic appliances from household electricity consumption measurements *Energy Build.* **40**, 5 p. 926–936.
[3] Shiraki H Nakamura S Ashina S and Honjo K, 2016 Estimating the hourly electricity profile of Japanese households – Coupling of engineering and statistical methods *Energy* **114** p. 478–491.
[4] Ohler A M Loomis D G and Ilves K, 2020 A study of electricity savings from energy star appliances using household survey data *Energy Policy* **144**, April p. 111607.
[5] Azarova V Cohen J J Kollmann A and Reichl J, 2020 Reducing household electricity consumption during evening peak demand times: Evidence from a field experiment *Energy Policy* **144**, January p. 111657.
[6] Prasanna A Mahmoodi J Brosch T and Patel M K, 2018 Recent experiences with tariffs for saving electricity in households *Energy Policy* **115**, March 2016 p. 514–522.
[7] Laicane I Blumberga D Blumberga A and Rosa M, 2015 Evaluation of Household Electricity Savings. Analysis of Household Electricity Demand Profile and User Activities *Energy Procedia* **72** p. 285–292.
[8] Potapovs A and Obushevs A, 2017 Development and Comparison of Technical Solutions for Electricity Monitoring Equipment *Latv. J. Phys. Tech. Sci.* **54**, 6 p. 3–9.
[9] Laple R Putra S Febia T Q Ndala S and Santoso A J, 2017 Analysis of Prepaid Electricity Monitoring System with SMS Notification **9**, 12 p. 304–307.
[10] Wood G *et al.*, 2019 Sensors, sense-making and sensitivities: UK household experiences with a feedback display on energy consumption and indoor environmental conditions *Energy Res. Soc. Sci.* **55**, March 2018 p. 93–105.
[11] Lam C Zheng Z and Luo X, 2019 Electricity load decomposition prototype for household appliances: System design and development *Energy Procedia* **158** p. 3158–3163.
[12] Alulema D Zapata M and Zapata M A, 2018 An IoT-Based Remote Monitoring System for Electrical Power Consumption via Web-Application in *2018 International Conference on Information Systems and Computer Science (INCISCOS)* p. 193–197.
[13] Suwansit K Konsombut B Hankongkaew P and Tantidham T, 2014 PMA: Power Monitoring Application for Android in *2014 Third ICT International Student Project Conference (ICT-ISPC)* p. 69–72.
[14] Farnell, 2013 Arduino Uno Datasheet *Datasheets* p. 1–4.
[15] Tabular T Arduinos W and Further G, Arduino Comparison Guide a learn . sparkfun . com. [Online]. Available: https://learn.sparkfun.com/tutorials/arduino-comparison-guide/all.pdf.
[16] Plaza P Sancristobal E Carro G and Castro M, 2018 Wireless Development Boards to Connect the World **22**.
[17] 2020, How Blynk Works. [Online]. Available: https://docs.blynk.cc/#intro-how-blynk-works.
[18] Semiconductor O, 2002 LM324,LM224,LM2902 Single Supply Quad Operational Amplifiers p. 1–12.
[19] Carter B and Huelsman L P, 2001 Handbook Of Operational Amplifier Active RC Networks *Networks* October p. 1–85.