Internet of things-based electrical energy control and monitoring in households using spreadsheet datalogger

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ABSTRACT

Today, the demand for electrical energy is paramount in various daily activities. Hence, individuals must be aware of the amount of electrical energy consumed to maintain the quality of electronic devices. Knowing the quality of electronic devices is essential since it can impact the performance and lifespan of electrical equipment. The value of electrical power is determined by the quality of electrical power and the number of hours. Monitoring electrical energy involves collecting or measuring data to assess the current level of energy consumption. The author is interested in researching the use of Datalogger Spreadsheets to monitor and gather real-time information on energy use, which is made possible through integration with internet of things (IoT) and microcontrollers. Through data analysis and observation, solutions to existing problems are sought by comparing and matching data. Monitoring daily energy usage in a home setting produces output data that can be viewed directly and remotely with real-time results. This tool is expected to address current issues.

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1. INTRODUCTION

The utilization of electrical energy is crucial in many modern-day activities. Electrical energy is a necessity for nearly all electronic devices [1]–[3]. Individuals need to be aware of the amount of electricity required to uphold the standard of electronic devices. Being aware of this standard is crucial as it can impact the performance and longevity of electrical equipment [4]–[8]. Aspects that can influence the value of electrical power are the quality of electrical power multiplied by the unit of time (hours) [9]–[11].

As per the regulations mentioned in the Minister of Energy and Mineral Resources of the Republic of Indonesia (ESDM-RI), Number 14 of 2012, it is necessary to manage energy consumption for medium and long-term programs, including increasing equipment efficiency. A measurement stage is conducted to determine electrical energy usage [12]. Electrical energy monitoring is designed as a routine process of collecting or measuring information source data, which determines the level of achievement of electrical energy consumption in real-time [13], [14]. By using real-time information technology, the operating conditions of the hardware system and programs have clear time frames [15], [16].

A monitoring system that uses the PZEM-004T sensor to measure voltage and electric current has been designed. Nordin and Hassan [17] have provided input on this system. The system includes a NodeMCU module for transmitting data to a database and a relay for controlling operations. The calculated electrical power is sent to the Firebase real-time database and can be accessed remotely from an Android device, making this monitoring system highly efficient. The sensor reading has a minor error margin, with an accuracy of ±1.8% compared to a digital multimeter. Based on the research results, the author developed a new idea for simplifying the measurement process by monitoring electrical energy using the Blynk platform, which is faster and more flexible [17].

Research in the internet of things (IoT), initially introduced by Kevin Ashton, the executive director of the Auto-ID Center at MIT, in 1999, has been conducted. IoT is a technology that enables devices to transmit data over a network without human intervention or a computer, and these devices can be accessed remotely from faraway locations. The IoT system allows users to monitor electrical energy usage without going directly to the area [18], [19].

The author is interested in researching the use of Datalogger Spreadsheets and obtaining sources of information about them. The research aims to monitor these spreadsheets in real-time, as they are integrated with the internet of things (IoT) and microcontrollers. This is what differentiates this research from previous studies that have been conducted.

2. METHOD

The data collection method in this research is observation and data analysis. These two methods were chosen based on the needs and suitability of searching for data in this research with this method. Below are the stages and details of each part.

2.1. Flow diagram

The flow diagram was created to make analyzing and implementing an internet of things (IoT) based electrical energy monitoring and control system in homes easier. Block diagrams were designed to facilitate the process of completing research. Thus, it provides an overview of the relationship between the components' input, process, and output parts [20], [21]. Figure 1 shows the block diagram of a one-way electrical energy monitoring system:

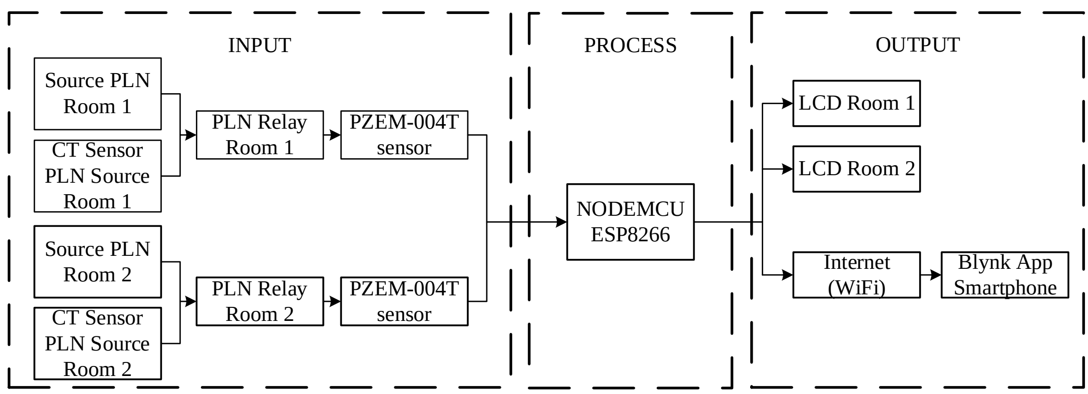

Figure 1. Block diagram of the design system

The following is a description of the flow diagram for the tool's working system:

a. Input: The detectors of electrical parameter values are the current transformer (CTs) and source inputs present in each phase. These parameters are then regulated by the Relay and measured by the PZEM-004T sensor.
b. Process: The main component of the monitoring system is located here. It serves as a command processor, managing input and output data to produce and display the necessary information.
c. Output: The tool for monitoring electrical energy has a final component that allows output results to be displayed on an LCD. The NodeMCU can provide IoT access to send data to a smartphone application for display through a Wi-Fi connection.

Before entering the realization stage, it is necessary to understand the working system of the tool that will be made. This needs to be done so that the implementation of the design can be arranged according to what is desired [22]. The following is a flow diagram of the electrical energy monitoring work system in Figure 2.

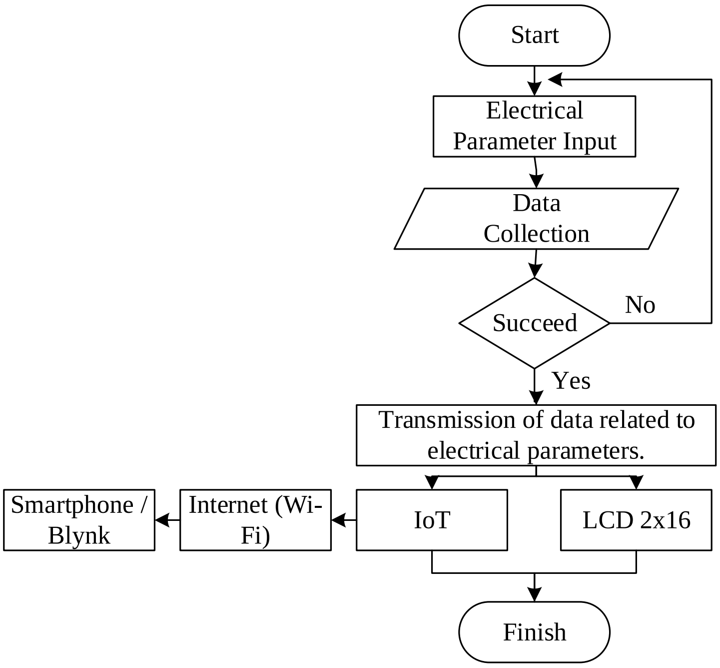

Figure 2. Flow diagram of the tool working system

The tool working system flow diagram can be described as follows:

a. Input electrical parameters are measured using CT and source input from voltage, current, power, energy, and power factor sensors.
b. Data acquisition is the electrical parameter values that have been measured, including voltage, current, electrical power, electrical energy, and power factor, which work according to commands. If successful, the data can be processed; if not, the sensor rereads the electrical input.
c. Electrical parameter data transmission on the LCD and IoT access using NodeMCU is sent to the server via Wi-Fi.

Next, identify needs with the aim of finding out what is needed at this research stage. The design tool includes hardware design and the programs used [22]. The following are the stages of each design.

2.1.1. Hardware

Hardware design, or what can also be called hardware, is divided into two stages, namely mechanical design for making electrical energy monitoring control boxes and electronic design, including electronic components used in the design of monitoring system equipment, with details as follows:

a. The NodeMCU ESP8266 is used as a microcontroller to run each component; this module has sufficient pinouts for the needs used for research.
b. The PZEM-004T sensor measures electrical parameters: voltage, current, power, energy, and power factor. This sensor is used because it can measure these parameters with only one sensor.
c. Relays control electrical energy that you want to turn off or on.
d. LCD and I2C display the output of electrical parameters from the control box.
e. The power supply is used for each component that will be used in the control box.

2.1.2. Program

After the hardware design is complete, the next step is to design the program and software used to run the tool according to the existing problem identification.

a. Arduino IDE is software that functions to create programs using C language, which are uploaded from the computer to the platform [23].
b. Blynk is a server for operating IoT principles designed to read quickly and easily in real time. It was chosen because it is easy to understand and can be run via a personal smartphone [24].

After knowing what needs are needed in this research, we continue designing an electrical energy monitoring design. Advanced design consists of three types, namely mechanical design, electronic design, and program design. In the description below it will be explained.

2.1.3. Design electronics

The electronic design contains several components, including the PZEM-004T sensor, 16×2 I2C LCD, and Relay. The following is an explanation of each element:

- Sensor PZEM-004T: The PZEM-004T sensor measures electricity by pairing a current transformer (CT) connected to the PZEM-004T sensor in each phase [25]. Parameters are calculated using a current transformer coil and input source. The PZEM-004T sensor has four connection pins connected to the NodeMCU [26]. The following can be seen in Figure 3 of the PZEM-004T pin configuration with NodeMCU.
- LCD I2C: The LCD is used to display electrical parameter values. The I2C LCD has four pins: serial clock (SCL), serial data (SDA), ground (GND), and voltage common collector (VCC) [27], [28]. The connections on the I2C LCD and the LCD pin configuration on the NodeMCU can be seen in Figure 4.
- Relay: Figure 5 shows the connection to the Relay and the Relay pin configuration with the NodeMCU.

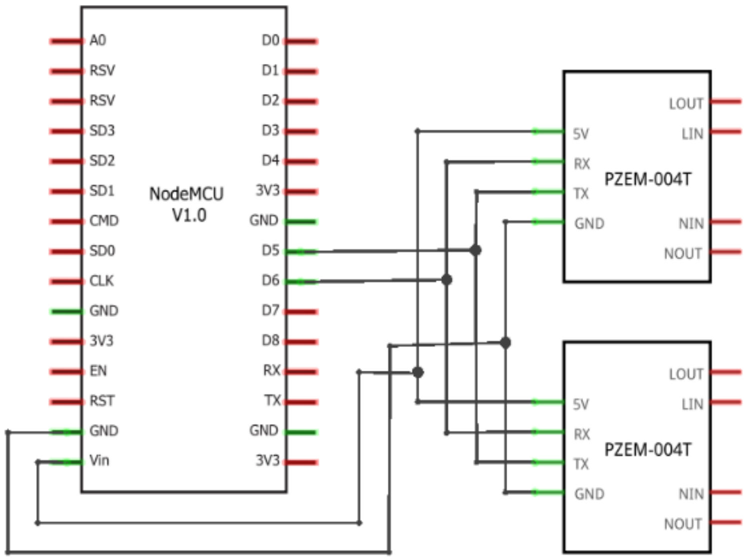

Figure 3. Scheme of attaching PZEM-004T pins to NodeMCU pins

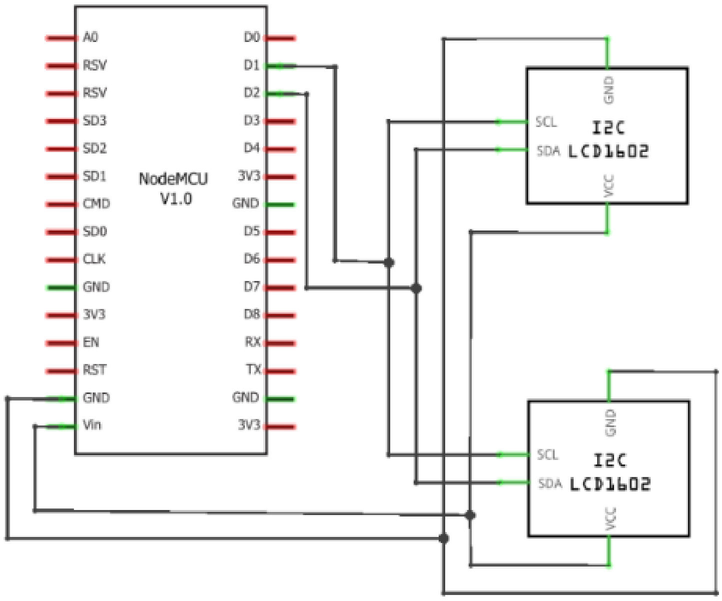

Figure 4. I2C LCD pin design scheme

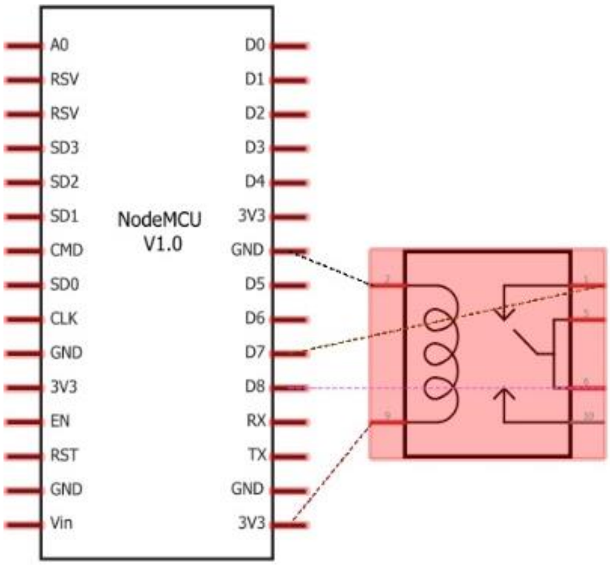

Figure 5. Relay pin design scheme

2.1.4. Program design

Programming design for an electrical energy monitoring system using Arduino IDE software. In Figure 6 is the program flow diagram. Which discusses the stages of the program from start to upload. Program design flow diagram for the design of an electrical energy monitoring system, namely:

- The Arduino IDE functions as command access that carries out all control components in the tool system.
- The NodeMCU ESP8266 program is used for server serial access connections and can be accessed to connect to the PZEM-004T sensor, Relay, and I2C LCD.
- The verify program aims to check for errors in the command program. If there are no errors in verification, the program can be immediately uploaded and tested for suitability.

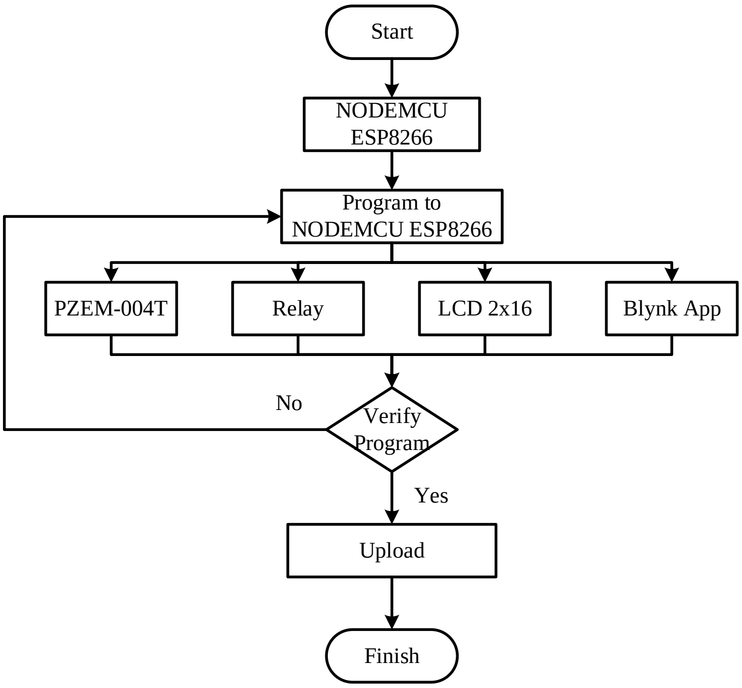

Figure 6. Program flow diagram

3. RESULTS AND DISCUSSION

An electrical energy monitoring tool, or what can also be called a tool, has been designed and built and has undergone testing. The testing stage is carried out by conducting functional and performance tests of the entire system to determine the level of success and accuracy of the monitoring tool. Once the tool works well, it can monitor electrical energy in the household. Home monitoring is done to see daily electrical energy usage to produce output data that can be observed directly and remotely with real-time output results. Data from testing and monitoring at home can be discussed as a reference in the conclusion.

3.1. Results of the design of an electrical energy monitoring tool

3.1.1. Program design results

The results of the program design work according to design. Programs or commands used to run components using Arduino IDE software. The design uses a NodeMCU microcontroller is shown in Figure 7.

```
void tegangan() {
  uint8_t result1;
  uint8_t result2;
  result1 = node1.readInputRegisters(0x0000, 10);
  result2 = node2.readInputRegisters(0x0000, 10);
  ESP.wdtEnable(1);
  ESP.wdtEnable(2);
  if (result1 == node1.ku8MBSuccess)
  {
    tegangan_1         = (node1.getResponseBuffer(0x00) / 10.0f);
    lcd1.setCursor(0,0);
    lcd1.print("TEGANGAN:");           lcd1.print(tegangan_1);           // V
  }
   if (result2 == node2.ku8MBSuccess)
  {
    tegangan_2         = (node2.getResponseBuffer(0x00) / 10.0f);
    lcd2.setCursor(0,1);
    lcd2.print("TEGANGAN:");           lcd1.print(tegangan_2);           // V
  }
  delay(1000);
}
```

(a)

```
void arus() {
  uint8_t result1;
  uint8_t result2;
  ESP.wdtDisable();
  result1 = node1.readInputRegisters(0x0000, 10);
  result2 = node2.readInputRegisters(0x0000, 10);
  ESP.wdtEnable(1);
  ESP.wdtEnable(2);
  if (result1 == node1.ku8MBSuccess)
  {
    arus_1            = (node1.getResponseBuffer(0x01) / 1000.000f);
    lcd1.setCursor(0,0);
    lcd1.print("ARUS    :");          lcd1.print(arus_1, 3);             //  A
  }
   if (result2 == node2.ku8MBSuccess)
  {
    arus_2            = (node2.getResponseBuffer(0x01) / 1000.000f);
    lcd2.setCursor(0,1);
    lcd2.print("ARUS    :");          lcd1.print(arus_2, 3);             //  A
  }
  delay(1000);
}
```

(b)

```
void daya() {
  uint8_t result1;
  uint8_t result2;
  ESP.wdtDisable();
  result1 = node1.readInputRegisters(0x0000, 10);
  result2 = node2.readInputRegisters(0x0000, 10);
  ESP.wdtEnable(1);
  ESP.wdtEnable(2);
  if (result1 == node1.ku8MBSuccess)
  {
    daya_1       = (node1.getResponseBuffer(0x03) / 10.0f);
    lcd1.setCursor(0,0);
    lcd1.print("DAYA    :");           lcd1.print(daya_1);           //  W
  }
   if (result2 == node2.ku8MBSuccess)
  {
    daya_2       = (node2.getResponseBuffer(0x03) / 10.0f);
    lcd2.setCursor(0,1);
    lcd2.print("DAYA    :");           lcd2.print(daya_2);           //  W
  }
  delay(1000);
}
```

(c)

```
void faktorDaya() {
  uint8_t result1;
  uint8_t result2;
  ESP.wdtDisable();
  result1 = node1.readInputRegisters(0x0000, 10);
  result2 = node2.readInputRegisters(0x0000, 10);
  ESP.wdtEnable(1);
  ESP.wdtEnable(2);
  if (result1 == node1.ku8MBSuccess)
  {
    faktor_daya_1     = (node1.getResponseBuffer(0x08) / 100.0f);
    lcd1.setCursor(0,0);
    lcd1.print("COS PHI:");           lcd1.print(faktor_daya_1);
  }
   if (result2 == node2.ku8MBSuccess)
  {
    faktor_daya_2     = (node2.getResponseBuffer(0x08) / 100.0f);
    lcd2.setCursor(0,1);
    lcd2.print("COS PHI:");           lcd2.print(faktor_daya_2);
  }
  delay(1000);
}
```

(d)

Figure 7. Program for testing (a) voltage, (b) current, (c) power, and (d) power factor

3.1.2. Results of designing electrical energy monitoring tools

The initial stage of the control box installation process for the electrical energy monitoring system working system, as in Figure 8, is to first turn off the main switch in the house for security during the installation process. The monitoring device is installed by unlocking the source and supply keys in the electrical box. Installation at the source is used as input for electrical parameters, and CT is installed from the sensor at the supply to measure how much electrical energy is used. When the device is installed, continuity is established in the circuit for device safety. After that, you can immediately turn on the main switch at home. To see the success, you can see the output directly on the control box display, after which the remote output can now open IoT access on the Blynk server. Monitoring of electrical energy at home was carried out for five days.

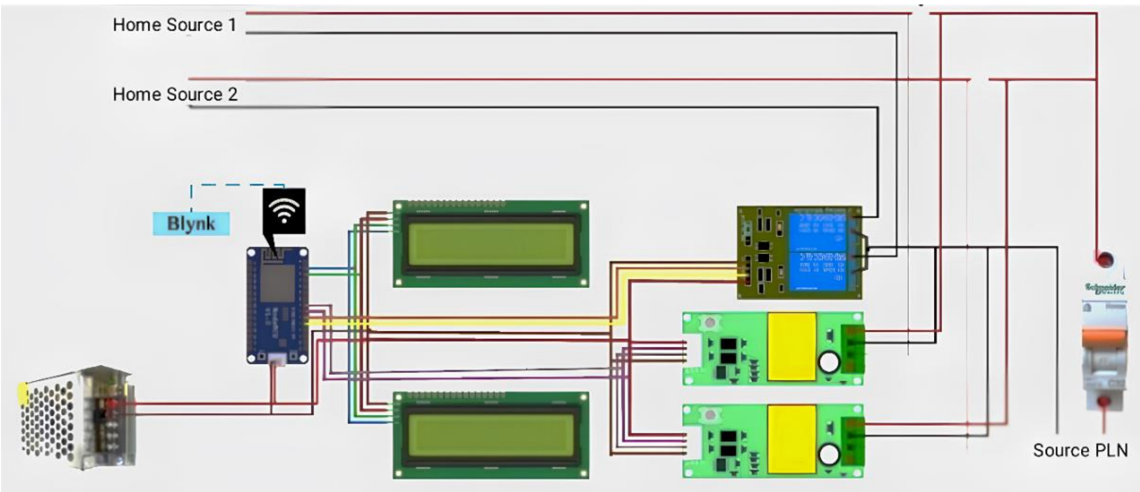

Figure 8. A series of working systems for electrical energy monitoring tools

3.1.3. Electrical energy monitoring equipment test results

The system is tested for performance by reviewing input, process, and output values. Tests were carried out using a 75-watt incandescent lamp load and a source voltage of 220 V AC. The input for this test is in the form of measurement results sent by the PZEM-004T sensor to the Arduino UNO, which then processes the data to obtain electrical characteristic data. Then, after the data is processed, it will be sent to the system output, namely the LCD and IoT access, which has been connected to the spreadsheet server.

Testing was carried out to determine the output results on the tool's LCD and IoT access on the spreadsheet. The LCD output will display voltage, current, power, and energy. Recording the output values on a spreadsheet, the researcher pays attention to the time from the start of the test to the end to find the difference in value or delivery time from the tool to the spreadsheet server to find the real-time value. The output data can be seen in Table 1, data from the device's LCD output, and Table 2, data from the production from IoT access via spreadsheet.

Table 1. Output results from the tool display

Voltage (V)	Current (A)	Electrical power (W)	Electrical energy (kWh)
220	0.331	72.00	0.072
	0.332	72.50	0.073
	0.330	72.20	0.072
	0.310	71.90	0.072
	0.330	71.80	0.072
Average	0.328	72.13	0.072
Standard Deviation	0.007	0.26	0.000

Table 2. Output monitoring results from Spreadsheet

Time (t1)	Time (t2)	Time (Δt)	Power on (S)	Electrical energy (kWH)
10:07:16	10:07:19	0:00:04	72.00	0.072
10:07:18	10:07:22	0:00:04	72.50	0.073
10:07:20	10:07:23	0:00:03	72.20	0.072
10:07:23	10:07:26	0:00:03	71.90	0.072
10:07:25	10:07:28	0:00:03	71.80	0.072
10:07:28	10:07:31	0:00:03	71.90	0.072
10:07:30	10:07:34	0:00:04	72.00	0.072
10:07:33	10:07:36	0:00:03	72.20	0.072
10:07:35	10:07:38	0:00:03	72.50	0.073
10:07:38	10:07:41	0:00:03	72.50	0.073
10:07:40	10:07:43	0:00:03	71.80	0.072
10:07:42	10:07:45	0:00:03	71.90	0.072
10:07:45	10:07:48	0:00:03	72.00	0.072
10:07:47	10:07:50	0:00:03	72.20	0.072
10:07:50	10:07:53	0:00:03	72.50	0.073
Average		00:00:03	72.13	0.072
Standard Deviation		00:00:00	0.26	0.000

The overall test results of the electrical energy monitoring tool obtained average values and standard deviations. Current has an average value of 0.32 with a measurement deviation of 0.007%, electric power has an average value of 72.13 with a measurement deviation of 0.26%, and electrical energy has an average value of 0.072 with a measurement deviation of 0%. Meanwhile, the output results on the spreadsheet server only display the electrical energy and power used.

Based on Figure 9, it can be seen that there has been an increase in current from 0.331 to 0.332 Amperes; this occurs because of an increase in power usage from 72.00 to 72.50 Watts. The same thing happened when the current decreased from 0.33 to 0.31 Ampere, caused by a decrease in power usage from 72.20 to 71.90 Watts. It can be concluded that the amount of current greatly influences the power used. The output data from remote monitoring can be seen in Table 2.

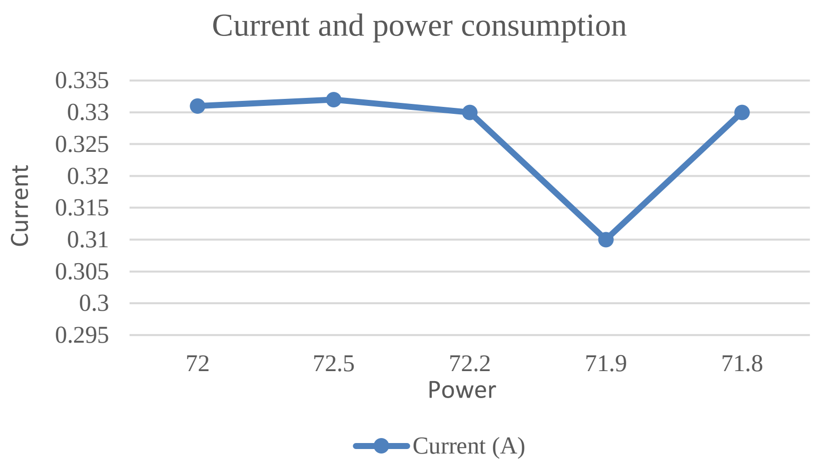

Figure 9. Graph of current versus power used

Testing the entire system on IoT access can determine the difference in sending time values from the tool to the spreadsheet server to determine the actual time value. Where time (t1) is the serial monitor access time while time (t2) is the data entered in the spreadsheet, the difference in delay in sending data from the measurement results is obtained by a difference value of 00.00.03 WIB, with a deviation of 0%. So, from the overall test results, it can be concluded that monitoring electrical energy both directly and remotely produces the same output data with a delivery time delay of 3 seconds.

4. CONCLUSION

Conclusions can be drawn based on the results and discussions of the electrical energy monitoring system created, namely the PZEM-004T sensor, which was tested to evaluate its ability to measure electrical energy consumption. The research results show minimal deviation, namely voltage 0.31%, current 0.01%, electrical power 0.58%, and electrical energy 0.01%. This low deviation indicates that the PZEM-004T sensor is suitable for further observation or monitoring. In another aspect, the tool generates data that can be sent to a spreadsheet server via the NodeMCU module. This involves programming the module with a server URL, enabling real-time data transmission via serial communications, and leveraging internet of things (IoT) connectivity. However, please note that there is a 3-second time delay in real-time data output. The developed electricity monitoring tool is designed to measure daily household electricity usage and offers the convenience of live-view tracking and remote access via a dedicated spreadsheet server. The PZEM-004T sensor was tested to evaluate its ability to measure electrical energy consumption. The research results show minimal deviation, namely voltage 0.31%, current 0.01%, electrical power 0.58%, and electrical energy 0.01%. This low deviation indicates that the PZEM-004T sensor is suitable for further observation or monitoring. In another aspect, the tool generates data that can be sent to a spreadsheet server via the NodeMCU module. This involves programming the module with a server URL, enabling real-time data transmission via serial communications, and leveraging internet of things (IoT) connectivity. However, please note that there is a 3-second time delay in real-time data output. The developed electricity monitoring tool is designed to measure daily household electricity usage and offers the convenience of live-view tracking and remote access via a dedicated spreadsheet server.

REFERENCES

[1] S. Huang, X. Zhu, S. Sarkar, and Y. Zhao, "Challenges and opportunities for supercapacitors," *APL Materials*, vol. 7, no. 10, 2019, doi: 10.1063/1.5116146.

[2] A. G. Olabi, C. Onumaegbu, T. Wilberforce, M. Ramadan, M. A. Abdelkareem, and A. H. Al--Alami, "Critical review of energy storage systems," *Energy*, vol. 214, p. 118987, 2021, doi: 10.1016/j.energy.2020.118987.

[3] W. Li *et al.*, "Biodegradable materials and green processing for green electronics," *Advanced Materials*, vol. 32, no. 33, 2020, doi: 10.1002/adma.202001591.

[4] Y. Liang *et al.*, "A review of rechargeable batteries for portable electronic devices," *InfoMat*, vol. 1, no. 1, pp. 6–32, 2019, doi: 10.1002/inf2.12000.

[5] D. Lumbreras, E. Gálvez, A. Collado, and J. Zaragoza, "Trends in power quality, harmonic mitigation and standards for light and heavy industries: A review," *Energies*, vol. 13, no. 21, p. 5792, 2020, doi: 10.3390/en13215792.

[6] D. D. Sabin and A. Sundaram, "Quality enhances reliability [power supplies]," *IEEE spectrum*, vol. 33, no. 2, pp. 34–41, 1996, doi: 10.1109/6.482272.

[7] A. Hasibuan, A. Qodri, M. Isa, and Others, "Temperature monitoring system using Arduino Uno and smartphone application," *Bulletin of Computer Science and Electrical Engineering*, vol. 2, no. 2, 2021, doi: 10.25008/bcsee.v2i2.1139.

[8] S. Peyghami, Z. Wang, and F. Blaabjerg, "A guideline for reliability prediction in power electronic converters," *IEEE Transactions on Power Electronics*, vol. 35, no. 10, pp. 10958–10968, 2020, doi: 10.1109/TPEL.2020.2981933.

[9] N. Nouri, F. Balali, A. Nasiri, H. Seifoddini, and W. Otieno, "Water withdrawal and consumption reduction for electrical energy generation systems," *Applied Energy*, vol. 248, pp. 196–206, 2019, doi: 10.1016/j.apenergy.2019.04.023.

[10] R. Kurniawan, M. Daud, and A. Hasibuan, "Impact of intermittent renewable energy generations penetration on harmonics in microgrid distribution networks," in *2022 6th International Conference on Electrical, Telecommunication and Computer Engineering (ELTICOM)*, 2022, pp. 30–37. doi: 10.1109/ELTICOM57747.2022.10038200.

[11] S. Hardi, J. D. A. Tambunan, A. Hasibuan, and Others, "Influence of static VAR compensator application for improving power quality in distribution lines supplied industry," in *IOP Conference Series: Materials Science and Engineering*, 2020, vol. 1003, no. 1, p. 12136. doi: 10.1088/1757-899X/1003/1/012136.

[12] I. K. Nti, M. Teimeh, O. Nyarko-Boateng, and A. F. Adekoya, "Electricity load forecasting: a systematic review," *Journal of Electrical Systems and Information Technology*, vol. 7, no. 1, 2020, doi: 10.1186/s43067-020-00021-8.

[13] M. U. Saleem, M. R. Usman, and M. Shakir, "Design, implementation, and deployment of an IoT based smart energy management system," *IEEE Access*, vol. 9, pp. 59649–59664, 2021, doi: 10.1109/ACCESS.2021.3070960.

[14] J. Lorandel, J. C. Prévotet, and M. Hélard, "Fast power and performance evaluation of FPGA-based wireless communication systems," *IEEE Access*, vol. 4, pp. 2005–2018, 2016, doi: 10.1109/ACCESS.2016.2559781.

[15] I. González, A. J. Calderón, and F. J. Folgado, "IoT real time system for monitoring lithium-ion battery long-term operation in microgrids," *Journal of Energy Storage*, vol. 51, 2022, doi: 10.1016/j.est.2022.104596.

[16] P. O'Donovan, C. Gallagher, K. Leahy, and D. T. J. O'Sullivan, "A comparison of fog and cloud computing cyber-physical interfaces for Industry 4.0 real-time embedded machine learning engineering applications," *Computers in industry*, vol. 110, pp. 12–35, 2019.

[17] N. Nordin and O. A. Hassan, "Integration of IoT on power monitoring and control for house electrical system," *Advances in Computing and Intelligent System*, vol. 1, no. 2, pp. 1–8, 2019.

[18] Y. Saleem, N. Crespi, M. H. Rehmani, and R. Copeland, "Internet of things-aided smart grid: technologies, architectures, applications, prototypes, and future research directions," *IEEE Access*, vol. 7, pp. 62962–63003, 2019.

[19] W. A. Jabbar *et al.*, "Design and fabrication of smart home with internet of things enabled automation system," *IEEE access*, vol. 7, pp. 144059–144074, 2019.

[20] H. S. Bunney and B. G. Dale, "The implementation of quality management tools and techniques: a study," *The TQM magazine*, vol. 9, no. 3, pp. 183–189, 1997, doi: 10.1108/09544789710168966.

[21] A. Hasibuan, W. V. Siregar, M. Isa, E. Warman, R. Finata, and M. Mursalin, "The use of regression method on simple E for estimating electrical energy consumption," *HighTech and Innovation Journal*, vol. 3, no. 3, pp. 306–318, 2022, doi: 10.28991/HIJ-SP2022-03-06.

[22] Sharon K. Parker and Gudela Grote, "Automation, algorithms, and beyond: why work design matters more than ever in a digital world," *Applied Psychology*, vol. 17, no. 4, pp. 1169–1653, 2022.

[23] D. K. Halim, T. C. Ming, N. M. Song, and D. Hartono, "Arduino-based IDE for embedded multi-processor system-on-chip," *Proceedings of 2019 5th International Conference on New Media Studies, CONMEDIA 2019*, pp. 135–138, 2019, doi: 10.1109/CONMEDIA46929.2019.8981862.

[24] D. Hasan and A. Ismaeel, "Designing ECG monitoring healthcare system based on internet of things blynk application," *Journal of applied science and technology trends*, vol. 1, no. 2, pp. 106–111, 2020.

[25] N. M. Khoa, L. Van Dai, D. D. Tung, and N. A. Toan, "An advanced IoT system for monitoring and analysing chosen power quality parameters in micro-grid solution," *Archives of Electrical Engineering*, vol. 70, no. 1, 2021, doi: 10.24425/aee.2021.136060.

[26] F. R. Rahman, A. Latifah, M. Afandy, M. Wirandi, and M. F. Azhari, "Implementation of the IoT-based electrical quantity monitoring system at the electrical installation laboratory, Metal Industry Polytechnic of Morowali," in *2021 International Conference on ICT for Smart Society (ICISS)*, 2021, pp. 1–4. doi: 10.1109/ICISS53185.2021.9533259.

[27] Y. Devis, Y. Irawan, F. Zoromi, M. R. Amartha, and Others, "Monitoring system of heart rate, temperature and infusion in patients based on microcontroller (Arduino Uno)," in *Journal of Physics: Conference Series*, 2021, vol. 1845, no. 1, Art. no. 12069. doi: 10.1088/1742-6596/1845/1/012069.

[28] R. Santhosh, M. V. Siddharthan, S. Yadav, and Others, "Protection and control of 3 phase induction motors in industrial plants with smart remote monitoring and control on a centralized system," in *2022 6th International Conference on Trends in Electronics and Informatics (ICOEI)*, 2022, pp. 317–326. doi: 10.1109/ICOEI53556.2022.9776889.

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