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The Application of Energy Management Systems Using the Internet of Things to Improve the Efficiency of Electrical Energy Usage in the MSMEs Sector

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Abstract **– Monitoring the electrical energy of the MSME sector is necessary because the current use of electricity is less effective and consumes more electrical power. The use of electrical power can only be seen through the kWh meter measuring instrument and only shows the cumulative amount of electrical energy used. The analog panel design constraint only displays aggregate consumption data, not real-time. This study aims to develop an energy management system through Internet of Things communication for monitoring and controlling electrical devices in MSME sector buildings. Designer of a real-time measurement system that can read the parameters of the amount of electricity consumed so that MSME users can monitor the use of electricity consumption quickly and accurately via the internet and become a solution for more efficient monitoring work. The monitoring system is designed for load groups in buildings by using the ESP32 NodeMCU as a data processor for data received from the PZEM-004T sensor and sent directly to the Blynk server so that the data can be monitored and controlled on the Blynk interface via a smartphone. The data displayed on the Blynk application is in the form of voltage (volts), current (amperes), power (watts), electrical energy (kWh), and electricity usage rates in rupiah in real-time. The results of the study obtained show that the proposed method can read the energy consumption data of the electrical load used with an error value of 0.54% in voltage measurement and an error value of 2.93% in current measurement and has a delay in sending data to the monitoring application of an average of 3 seconds. The proposed draft Energy Management System can improve electricity efficiency if applied to solve the problem of electrical energy consumed in MSME sector buildings.**

Keywords: EMS, Electrical Energy, UMKM, PZEM-004T.

I. Introduction

One of the energies that has received particular attention in Indonesia is electrical energy because it is a primary need in the human environment [1]. The electricity consumption of the industrial sector and MSMEs consumes more electricity than the home sector [2]. This can affect the availability of electricity in two sectors where the amount is quite large. Monitoring the electrical energy of the MSME sector industry is necessary because electrical energy is currently inefficient and expensive [3].The accumulative average amount of consumer electrical power consumption can only be measured and controlled by looking directly at the kWh meter measuring instrument without knowing the number of usage rates [4]–[5]. The user needs to learn the load of the power tool used, so they can only control the electricity pulse once the electricity credit runs out quickly [6] and results in going over budget [7]-[8]. Thus, a remote monitoring system is needed that can provide real-time electrical power information to obtain periodic data updates that can be analyzed quickly to save electrical energy [9].

Research on electrical energy monitoring systems has recently been widely carried out. Measuring tools for electrical energy parameters have been widely studied in sensors and power meter modules. Research [6]–[10] monitors the current and power of inductive and resistive loads. However, sensor usage is different for each parameter and cannot be saved to the database. This study also revealed that measurements are required to break the phase wire to read the current value, which is dangerous in terms of safety for the operator, electrical equipment, prototypes, and systems. Meanwhile, research [11] monitors the use of electrical power, costs, duration of use, and the estimated cost of using future kWh of electricity. However, the study used only dc electrical equipment-specific sensors, and the delay in sending sensor data to the database averaged 312 milliseconds. Research [5]–[12] revealed that the PZEM-004T module could monitor the value of current, voltage, power, and the accumulation of electrical energy connected to the user's smartphone. However, it has not been able to monitor 3-phase electrical energy, and data communication still uses a local network without the Internet of Things (IoT) feature. Several studies have explored how IoT-based monitoring for measured loads includes all electrical equipment connected to a central kWh meter [1]–[4].

Based on related works, it only shows monitoring relies on sensors or modules, and loads are limited to electrical equipment that is not comprehensive with a kWh meter system. Only now has research on monitoring electrical energy with coverage of all loads of electronic equipment connected to specific electrical panels for the MSME sector been reported in Indonesia. Therefore, this study provides an essential solution for the real-time MSME sector electricity kWh monitoring system through an IoT-based web service interface [9]. This research focuses on designing a panel electrical kWh measuring device using the PZEM-004T module, which can avoid voltage drops because it does not require other power supply circuits. Contributions of this research to the literature The proposed system allows the user to better understand the electrical energy consumption of each electronic equipment, thus leading him to make smarter choices in terms of energy consumption. The proposed system allows for improving electrical energy efficiency through proper management of each electronic piece of equipment, depending on the rules specified by the user.

The Energy Management System (EMS) includes all planned and implemented actions to ensure energy consumption for current activities [13]. EMS systematically records energy flux and is the primary basis for investing in energy efficiency. A functioning EMS helps the university comply with the commitments made in its energy policy and systematically improve its energy performance [9]. The energy management system affects the technical procedures of an organization as well as behavioral patterns, reducing the total operational energy consumption [14] to continuously improve energy efficiency in the enterprise [15]–[16]. EMS includes all elements of the organization necessary to create and define energy policies to achieve strategic goals. Thus, it includes the organizational structure and information necessary to implement energy management, including resources [3]. The study develops and implements energy policy through planning, implementation, operation, monitoring and measurement, control and correction, internal audit, and regular management reviews [1–7].

According to PLN records, the electricity customers who are indicated to be the highest in the use of electrical energy are customers in the industrial sector [17]. If energy is used at peak loads, namely electricity consumption from 18:00 to 22:00, this situation makes PLN implement a restriction program by increasing tariffs. Knowing the balance between the production and consumption of electrical energy requires integrated and continuous scientific studies.

IoT is an idea that aims to expand the function of continuously connected internet connectivity [9]. As for the uses possessed, such as sharing data, remote control, and so on, including objects in the real world [13], IoT in the real world can be used to monitor or control various aspects of foodstuffs, electronics, collections, and any equipment, including living objects connected to local and global networks through embedded and always-on sensors [11]. A web service is a system designed to support interoperability and communication interactions between systems (applications) in a network. Web services are widely used to provide data to the public. Monitoring must provide the information required by the user, and the information must be compact with the concept of SMART (Specific, Measurable, Attainable, Relevant, and Timebound). Problems in the manual recording process of electrical energy are carried out at different meter locations, so it takes time to obtain results or data. If any data is missed, it must be looked back at where the electrical panel is located. Meanwhile, you use an IoT-based website. In that case, you do not need to look at the data to determine the panel's location; just use a computer application that can be accessed through the control room or other monitoring places connected to the internet network. Data can be directly obtained and analyzed to be used in a report.

Research [11]–[18] uses the IoT to support remote monitoring. When researching monitoring electrical energy using a wireless network paired with a smart meter device, some of the things monitored are electricity consumption, electrical voltage, electrical power, and electric current; all these activities are monitored online through websites and equipment connected to the internet. IoT-based monitoring allows users to connect, control, and monitor systems directly over the internet. Many studies use this type of wireless real-time monitoring, such as Bluetooth, SMS, and the Internet. The monitoring application uses the Blynk application to control hardware, display sensor data, store data, and visualize [10]. A Blynk application has three main components: the application, server, and libraries. Blynk servers handle all communication between smartphones and hardware. This type of server can use Blynk Cloud or a private server.

In this study, Arduino and IoT-based wireless energy monitoring devices were implemented using the Blynk application, designed to obtain information related to energy measurements in real-time, including electric current, voltage, and power, which can be accessed using the internet at any time. Ethernet Shields are devices that connect Arduino to the internet.

II. METHOD AND DESIGN

The research was conducted in the MSME building, a small business sector (Toko Reyhan) located on Jl. Sepinggan Baru, South Balikpapan District, Balikpapan City. This selection considers 1) having routine problems with employees who constantly check the electrical panels by direct observation; and 2) having potential users for work effectiveness. This building has kWh-meter panels sourced from the PLN electricity network. In this building, several electronic devices are the primary data sources in this study, so they help read data in real time. The sampling data for this study consisted of 3 AC lamps and a 1-unit AC fan. Figure 1 shows the process of collecting the electricity amount data read by the PZEM-004 module, and then the electrical data is sent to the Arduino for display on the LCD. The ESP32 MCU Node Wi-Fi module sends data as output to the Android app. While the Real Time Clock (RTC) module tracks the period to match the sample data taken, it also sets the ON/OFF time of the lamp. Data from this RTC module will also be sent to the ESP32 MCU node. Four-channel relays are controlled using the Android app. The unit load has a living mass of 24 hours, which is beneficial for real-time data reading. The load used is 1 Philips LED 12-Watt lamp, 2 Philips LED 10-Watt lamps, and 1 Maspion 50-Watt fan.

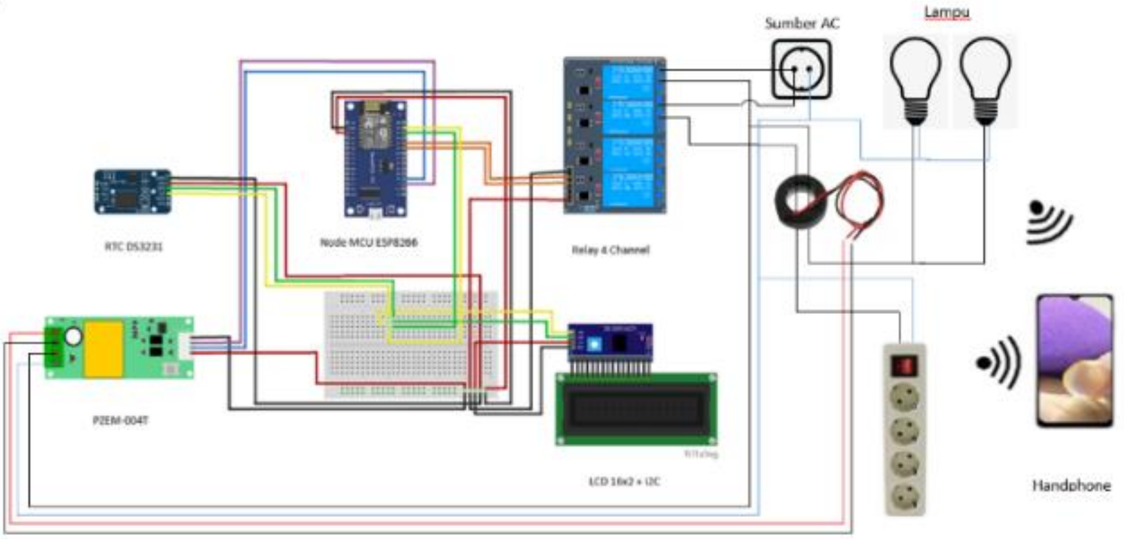


Figure 1. Proposed monitoring power meter system

Figure 1 presents a research design for a monitoring system to monitor electricity consumption in MSME buildings. The design of this research system consists of an electrical power magnitude sensor device, item PZEM-004T, an electrical magnitude data operational processing device using a NodeMCU ESP32 microcontroller, a timer module on load using the RTC DS3231 module, a device for displaying outputs, namely a 16x2 i2C LCD, and the Blynk Android application version 1.6.3. The parameters measured are voltage, current, power, kWh, and cost. The initial step of variable measurement is disconnecting the electronic device from electrical energy in addition to the observed object of study. When the system is activated, the program will initialize the monitoring system. The sensor attached to the electricity meter panel will read the electricity amount data. The data value is processed with PZEM-004T, which produces four output values: voltage, current, active electrical power, and power consumption costs. The analog data output value is processed by NodeMCU ESP32 into digital data and calculated to produce electrical energy consumption costs at load, which are further transmitted via Wi-Fi to the Android Bully application interface. Android displays measurement result data: voltage, current, electrical power consumption, and cost estimation, so that it becomes information that functions to find out the electricity consumption that is being used. Data collection on electricity usage is varied and is retrieved every 10 minutes for 60 minutes. This method has been carried out by [11], which has produced a system for monitoring the university building's power and electrical energy consumption. The communication protocol in this study uses an adaptive publish-subscribe method where data is sent when there is a change from the previous data.

In data analysis, testing is needed to determine whether the monitoring system's hardware and software have met the design criteria. The design criteria in this study are that the PZEM-004T detects electrical energy through LED indicators on the detector, uploads data to the database server, and the application can download and process data from the database server as displayed on the main display of the Blynk application. After that, data analysis is carried out through standard measurements with a digital multimeter to measure current and voltage values and measurements through the design of our proposed monitoring system. The design monitoring system can read the amount of electricity and then test its accuracy by comparing the actual measurement data that has been calibrated so that the error deviation value is obtained. The error rate in percent (%) is obtained by equation (1). In addition, the system response time to the Android application is also calculated to read the electricity amount data..

$$Error = \frac{\text{Measured consumtion} - \text{Expected consumtion}}{\text{Measured consumption}} \text{x100} \qquad (1)$$

Keterangan:

Error	= Error percentage value
Measured consumption	= Measurement values
Expected consumption	= Reference value

III. Results and Discussion

This research is an EMS case study that can monitor the amount of electricity and control the ON/OFF load installed in the electrical installation of the store building using IoT technology. This system was developed for a mini-market building in Balikpapan. The system's structure consists of four layers: the perception layer uses a PZEM-004T power sensor, the network layer uses a server, the physical layer uses a smartphone, and the application layer uses the Blynk application.

Figure 2 presents a monitoring system architecture with IoT that provides an overview of the status of each gateway. Figure 3 is a snapshot of the monitoring tool for EMS via the Blynk Android app, showing respectively the monitoring of the amount of electricity, monitoring the cost of electricity consumption, and the ON/OFF control panel of the installed light load..

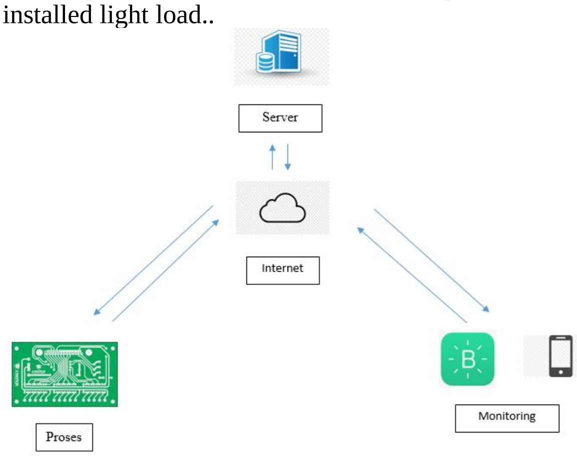


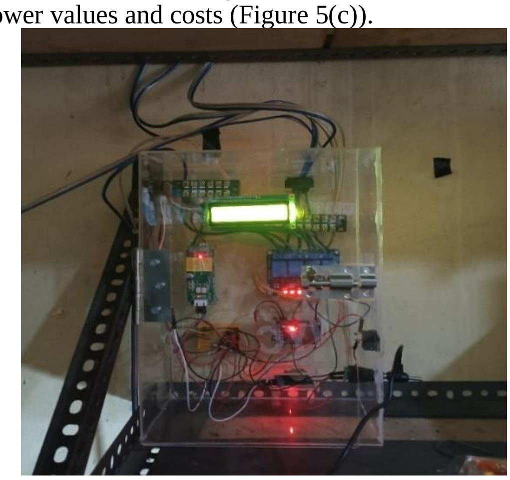
Figure 2. Energy management system with IoT

Figure 3 Display of monitoring results via Android application (Blynk)

This EMS achieves its goals through several functions. Its main function is to turn on and off the light depending on the activities of the store where the implementation is carried out. The lights are lit in the building room when there is a buying and selling process. Otherwise, the lights remain off and can be controlled remotely through the app. In addition, users can see the results of calculating the cost of electrical energy consumption over a certain period. The amount of electricity that is running can also be monitored in this EMS application.Through this system, MSMEs can achieve the maximum possible savings.

The proposed EMS supports the following functions: (1) A remote lighting and light load control panel in the building (2) Calculate the total energy consumption for each monthly usage record. The management feature of making consumption calculations allows the user to print specific results of the use of electrical energy.

The hardware of the EMS product placed on the building kWh meter shown in Figures 4 and 5 shows the results of the reading of the values of the amount of electricity monitored on the LCD. The system can display the time in real-time (Figure 5(a)), read voltage and current values (Figure 5(b)), and read electrical power values and costs (Figure 5(c)).



Gambar 4. Display of EMS product devices

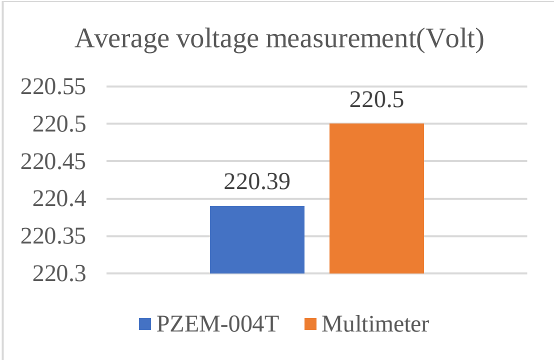
(a)

(b)

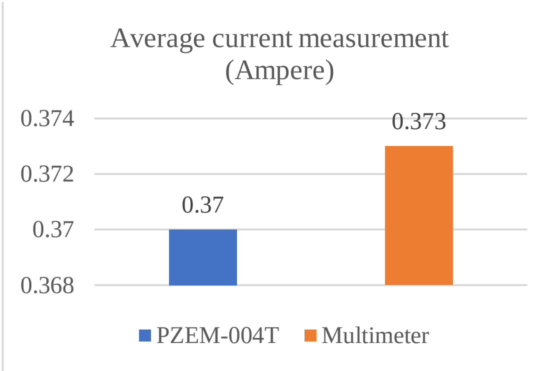
(c)

Figure 5. (a) The result of the system time reading, (b) the reading result of the voltage and current value, and (c) the reading result of the electrical power and cost value

Figure 6(a) presents the values of the voltage measurement test results obtained from the PZEM-004T sensor. The mains voltage shows the measurement value, with the proposed method getting an average of 220.39 V. In comparison, the average measurement value with a multimeter measuring instrument is 220.5 V. Figure 6(b) presents the value of the test results for the current measurement obtained from the PZEM-004T sensor. Electric current shows the measurement value with the proposed method, getting an average of 0.37 A, while the measurement value with a multimeter measuring instrument gets an average of 0.373 A.



(a)



(b)

Figure 6. (a) The results of monitoring the voltage value by the proposed system, and (b) monitoring the current value by the proposed system

Table 1 presents the results of readings of the use of electrical energy obtained from the PZEM-004T sensor. Electrical energy consumption shows readings with the proposed method of obtaining energy results of 0.83 kWh for Rp. 1240.00. Table 2 presents the delay in changing the data obtained from the ESP-32 microcontroller. The time delay shows the time the data was sent for 3 seconds.

Table 1. Measurement of electrical energy consumption and costs

Date	**Time (WITA)**	**Energy (kWh)**	**Cost (IDR)**
16 Juli 2022	00.00 – 12.00	0,23	332,00
16 Juli 2022	12.00 – 18.00	0,29	418,00
16 Juli 2022	18.00 – 00.00	0,63	910,00
17 Juli 2022	00.00 – 12.00	0,63	910,00
17 Juli 2022	12.00 – 18.00	0,63	910,00
17 Juli 2022	18.00 – 00.00	0,83	1240,00

Table 2. Calculation of delay in sending data to the application

Experiment	**Electrical load 1**	**Electrical load II**	**Electrical load III**	**Delay (second)**
1	OFF	ON	ON	3
2	ON	OFF	ON	3
3	ON	ON	OFF	3
4	OFF	OFF	ON	3
5	OFF	ON	OFF	3
6	ON	OFF	OFF	3
7	OFF	OFF	OFF	3

In Figure 6(a), the comparison test of the average measurement results of the voltage shows the difference in the average value of the measurement results using the proposed method and the value of the average result of the measurement using measuring instruments. It can be concluded that the proposed method has a high degree of accuracy with a difference of 0.76 V. In Figure 6(b), the comparison test of the average measurement results of the current also shows the difference in the average value of the measurement results by using the proposed method and the average yield value using measuring instruments. It can be concluded that the proposed method has a high degree of accuracy with a difference of 0.003 A. In Table 1 of the calculation of the cost of use, there are values for the results of measuring electrical power, electrical energy, and costs. It can be seen that the comparison from 00.00 to 18.00 and from 18.00 to 00.00 shows the difference in the value of energy results and costs used; this is because in the period from 00.00 to 18.00, the use of electricity is relatively minimal, while from 18.00 to 00.00, almost all electrical components are used. The value of the result shows a relationship between the amount of energy used and the amount of load used: the more load used, the greater the energy and costs used, and vice versa. In Table 2, the calculation of the delay in sending data to the application shows a slight difference in sending data to the monitoring application. However, the difference is relatively minimal, indicating that the system can send data quickly.

EMS products may be one way to increase the efficiency of electricity use. This model can be helpful in cases of excessive use of electricity. In this method, monitoring the use of electrical energy can provide information to customers on the amount of electrical energy they use. In this system, we can find the amount of electricity used and the costs incurred. Based on Table 1 of the calculation of usage costs, the actual accumulated cost of using electricity loads in a building with several electronic devices can be monitored with this system. In this regard, [6] has reported a monitoring system for electrical energy that is free of charge per kWh.This is also related to Research 5—Research 12, which is also in line with this research. Several limitations must be considered, and it is necessary to pay attention to the class of electricity tariffs with the appropriate amount of electric power so that everything runs smoothly in calculating the costs that need to be incurred. Further work on the efficiency of electrical energy needs to add a system that can directly detect the class of electricity tariffs applied at the implementation site and use more accurate sensors to minimize errors that occur.

In applying it, EMS can be used as a monitoring system, where the monitoring results can be used as information provided to users. This information can be processed as a basis for user decision-making actions in managing electricity consumption to achieve efficiency. This decision-making is an integral part of the monitoring system, so that through this system, MSMEs can achieve the maximum possible savings in electricity.

IV. CONCLUSION

In this study, we presented the design of an electricity consumption monitoring system with an IoT-based communication system at the MSME Store Building in Balikpapan City, Indonesia. The system can be accessed at any time through the Android app and allows real-time measurements for users. The results of the experiment showed that the accuracy of the reading value of the parameters of the design system is close to the value read by the standard tool of the multimeter. The proposed system allows users to better understand the energy consumption of each electronic equipment, thereby leading them to make smarter choices in terms of energy consumption. Further work can be done by increasing the accuracy of the proposed method and adding some other electrical parameters.

REFERENCES

[1] A. H. Ganesh and B. Zu, “A Review of Reinforcement Learning Based Energy Management Systems for Electrified Powertrains: Progress, Challenge, and Potential Solution,” Renewable and Sustainable Energy Reviews, vol. 154, 2022.

[2] R. Kango, S. Suhaedi, and F. A. Hasanuddin, “Implementation of The Internet of Things for Monitoring The Company’s Electrical Power Consumption,” Journal of Asian Multicultural Research for Economy and Management Study, vol. 2, no. 1, pp. 16–22, 2021, doi: 10.47616/jamrems.v2i1.72.

[3] S. Vasanthapriyan and V. Randima, “Design IoT based smart electricity power saving university: Analysis from a lecture hall,” Journal of Computer Science, vol. 15, no. 8, pp. 1097–1107, 2019, doi: 10.3844/jcssp.2019.1097.1107.

[4] S. Pencatatan et al., “Sistem Pencatatan Pemakaian Listrik Menggunakan Aplikasi Arduino,” PROtek : Jurnal Ilmiah Teknik Elektro, vol. 6, no. 2, pp. 73–78, Sep. 2019, doi: 10.33387/PROTK.V6I2.1229.

[5] A. F. Ikhfa and M. Yuhendri, “Monitoring Pemakaian Energi Listrik Berbasis Internet of Things,” JTEIN: Jurnal Teknik Elektro Indonesia, vol. 3, no. 1, pp. 257–266, May 2022, doi: 10.24036/JTEIN.V3I1.233.

[6] W. Arsa, Suteja, and A. Surya, “Analisis Sensor Arus Invasive ACS712 dan Sensor Arus Non Invasive SCT013 Berbasis Arduino,” PROtek : Jurnal Ilmiah Teknik Elektro, vol. 8, no. 1, pp. 13–21, May 2021, doi: 10.33387/PROTK.V8I1.2116.

[7] Andriana, Zuklarnain, and H. Baehaqi, “Sistem kWH Meter Digital Menggunakan Modul PZEM-004T,” Jurnal TIARSIE, vol. 16, no. 1, p. 29, 2019, doi: 10.32816/tiarsie.v16i1.43.

[8] Arzul and Mirzazoni, “Perancanan dan Implementasi Sistem Monitoring And Controlling (MAC) Beban Listrik Ruangan Kuliah Meggunakan Wireless Sensor Network dan Arduino,” PROtek : Jurnal Ilmiah Teknik Elektro, vol. 4, no. 1, pp. 1–4, May 2017, doi: 10.33387/PROTK.V4I1.173.

[9] W.-J. Shyr, L.-W. Zeng, C.-K. Lin, C.-M. Lin, and W.-Y. Hsieh, “Application of an Energy Management System via the Internet of Things on a University

Campus," Eurasia Journal of Mathematics, Science and Technology Education, vol. 14, no. 5, pp. 1759–1766, 2018, doi: 10.12973/ejmste/80790.

[10] A. D. Pangestu et al., "Sistem Monitoring Beban Listrik Berbasis Arduino Nodemcu Esp8266," Jurnal Ampere, vol. 4, no. 1, pp. 187–197, 2019.

[11] Tukadi, W. Widodo, M. Ruswiensari, and A. Qomar, "Monitoring Pemakaian Daya Listrik Secara Realtime Berbasis Internet Of Things," Seminar Nasional Sains dan Teknologi Terapan VII 2019, pp. 581–586, 2019.

[12] I. Chairunnisa and W. Wildian, "Rancang Bangun Alat Pemantau Biaya Pemakaian Energi Listrik Menggunakan Sensor PZEM-004T dan Aplikasi Blynk," Jurnal Fisika Unand, vol. 11, no. 2, pp. 249–255, Apr. 2022, doi: 10.25077/JFU.11.2.249-255.2022.

[13] M. Dell'Isola, G. Ficco, L. Canale, B. I. Palella, and G. Puglisi, "An IoT integrated tool to enhance user awareness on energy consumption in residential buildings," Atmosphere (Basel), vol. 10, no. 12, 2019, doi: 10.3390/ATMOS10120743.

[14] A. Bressn, M. Pandian, and P. Talari, "Reduced Energy Management on Atm's Air Conditioners using Iot," International Journal of Innovative Technology and Exploring Engineering, vol. 8, no. 9, pp. 631–635, 2019, doi: 10.35940/ijitee.i7598.078919.

[15] D. Santos and J. C. Ferreira, "IoT power monitoring system for smart environments," Sustainability (Switzerland), vol. 11, no. 19, 2019, doi: 10.3390/su11195355.

[16] H. Hadiyanto, S. Suheidi, and R. Kango, "Evaluasi Intensitas Konsumsi Energi Listrik Di Kampus Politeknik Negeri Balikpapan," JST (Jurnal Sains Terapan), vol. 6, no. 1, pp. 1–7, Apr. 2020, doi: 10.32487/jst.v6i1.832.

[17] H. Semuel, "Penerapan Kebijakan Penggunaan Energi Listrik Terhadap Kinerja Usaha Mikro Kecil dan Menengah Di Provinsi Jawa Timur," Jurnal Manajemen Pemasaran, vol. 8, no. 1, pp. 39–46, May 2014, doi: 10.9744/PEMASARAN.8.1.39-46.

[18] B. Prayitno, "Prototipe Sistem Monitoring Penggunaan Daya Listrik Peralatan Elektronik Rumah Tangga Berbasis Internet of Things," Petir, vol. 12, no. 1, pp. 72–80, 2019, doi: 10.33322/petir.v12i1.333.