Implementation of the Electricity Load Monitoring Trainer and Internet of Things-based Power Factor Improvement

Irgi Surya*, Jaja Kustija*

* Department of Electrical Engineering Education, Faculty of Technology and Vocational Education, Indonesian University of Education, Bandung, Indonesia

DOI: 10.29322/IJSRP.12.11.2022.p13127
http://dx.doi.org/10.29322/IJSRP.12.11.2022.p13127

Paper Received Date: 29th September 2022
Paper Acceptance Date: 30th October 2022
Paper Publication Date: 14th November 2022

Abstract- Electrical problems that often occur, such as in industry, one of which is caused by the low working power factor so that the electric current becomes high and reactive power (VAR) must be paid and charged to consumers, this is certainly a problem and losses to PLN consumers have been widely discussed but in the reality is that the power factor is still low and not ideal. This research aims to design, create, control, and evaluate a trainer that can improve power factor on electrical loads and can monitor it in real time and can even be controlled remotely using the internet. The method used is through the Analysis, Design, Development, Implementation, Evaluation (ADDIE) approach. The results show that this trainer is feasible to use because based on experiments this trainer is able to work well and provide convenience for users and can monitor in real time current, voltage, energy, frequency, power factor, real power, apparent power, and reactive power both only using smartphones, laptops, tablets, or computers. It is hoped that in the future this research will be able to continue to be developed so that the use of electrical energy in industry can be much more effective and efficient.

Index Terms- Trainer, Power Factor Improvement, Monitoring, ESP32, PZEM004t, Adafruit.IO.

I. Introduction

In this research a real-time IoT-based power factor monitoring and power factor improvement trainer was designed to improve electrical energy efficiency so that the use of electrical energy can be optimized and high reactive power (VAR) payment losses from low power factors can be avoided[1][2]. The advantages of this trainer include being able to improve the power factor automatically because it is based on IoT[3] this system can be interconnected with digital devices that support the internet such as smartphones, laptops, tablets, or PC computers so that usage is more flexible because it can be monitored from anywhere and anytime as long as it is connected. with internet access[4]. Users are not limited, meaning that as long as users have access to the server using a username and password, they can access multiple people at once (multiuser) to monitor electrical loads and improve power factor[5]. It's not difficult to use because users only need to wire and connect the trainer to the electrical load to be tested, then just log in to the Adafruit server[6].

This research aims to design, create, control, and evaluate a trainer that can automatically improve power factor on electrical loads and can monitor it in real time and can even be controlled remotely using the internet[7]. The method used is through the Analysis, Design, Development, Implementation, Evaluation (ADDIE) approach, namely by studying the literature to analyze the research object, then designing and developing the design results and implementing the design results and then implementing it on the research object[8][9][10]. improvement of this system, the novelty of this research is to help users monitor electrical loads in real time and make power factor improvements automatically and without the need to use applications or software that must be downloaded first[11], users only need to enter the AdaFruit website, this is certainly far easier and more flexible in its use, unlike in previous studies that have been carried out the user must first download a software or application and this system is also equipped with the use of sensors so that this system can work more efficiently[12].

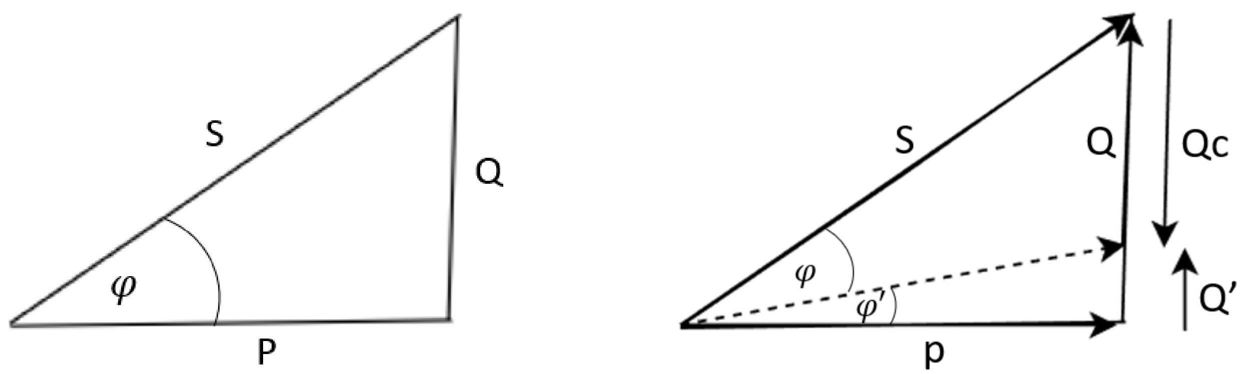
The term "internet of things" refers to the idea in which items or objects are embedded with software and sensors for the purpose of interacting, connecting and sharing data with other devices as long as those devices are connected to the internet[13]. The idea behind the Internet of Things is that anything can transmit data over a network without requiring human-to-human or human-to-computer communication[14]. The degree of convergence of wireless technologies, microelectromechanical systems (MEMS), the internet, and

QR (Quick Response) Codes provides insight into the growth of the Internet of Things. RFID (Radio Frequency Identification) is another communication technique that is often associated with the Internet for everything. Along with its development, the internet of things has modernized many electronic equipment by changing systems that still use traditional programming into systems that can be controlled, monitored, or monitored remotely[15].

NodeMCU is an open source IoT platform. Consists of hardware in the form of an on-chip ESP32 system made by Esperessif System. NodeMCU can be analogous to an Arduino board connected to the ESP32[16]. The ESP32 microcontroller is made by a company called Espressif Systems[17]. One of the advantages possessed by the ESP32 is that it already has Wi-Fi and Bluetooth in it, so it will be very easy when we learn to create an IoT system that requires a wireless connection[18]. The ESP32 microcontroller has the advantage of a low-cost, low-power system with a WiFi module that is integrated with the microcontroller chip and has dual-mode bluetooth and power-saving features making it more flexible[19].

Adafruit IO is an MQTT server service provider for the Internet of Things, this service can be used to make ESP32 NodeMCUs can be controlled remotely by using subscribe and publish facilities[20]. Without the need to use other applications or software, users only need to access the available websites, the advantage of Adafruit IO is that users are not charged when creating an account and using it as a server that will be connected to the NodeMCU ESP32[21].

A. Literature Review



a). b).

Figure 1 a). power triangle before repair b). power triangle after repair

- $S = V.I$ (1)
- $P = V \,.\, I \,.\, \text{Cos}\ \varphi$ (2)
- $Q = V \,.\, I \,.\, \text{Sin}\ \varphi$ (3)

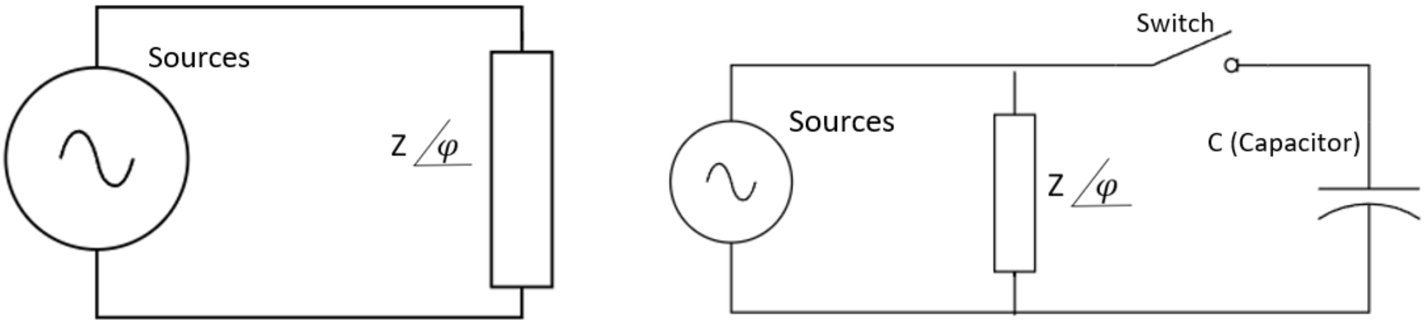
S = Apparent Power
P = Active Power
Q = Reactive Power

The effect of changing cos is getting closer to 1 ;
- S getting down
- I getting down

- $Qc = Q - Q'$ (4)
  $= P\ \text{tg}\ \varphi - P\ \text{tg}\ \varphi'$ (5)
  $= P\ (\varphi - P\ \text{tg}\ \varphi')$ (6)

Based on the Figure 1 , Power factor or work factor is the ratio between active power (watts) and apparent power/total power (VA), or the cosine of the angle between active power and apparent power/total power (see power factor improvement figure). High reactive power will increase the angle and consequently the power factor will be lower[22]. A good power factor ranges from 0.85 to near perfect or one. In theory, if all the power loads supplied by the state electricity company (PLN) have a power factor of one, then the maximum power transferred is equivalent to the capacity of the distribution system[23]. Thus, with an induced load if the power factor ranges from 0.2 to 0.5 [12][22][24]then the capacity of the electricity distribution network becomes depressed and the current will be higher as a result PLN equipment will become ineffective because this high current is a loss for PLN so that PLN will charge reactive power costs (VAR) for companies or industries that have a power factor below 0.85, which is required by PLN[25]. So the reactive power (VAR) should be as low as possible for the same kW output in order to minimize the total power requirement (VA) and lower the electric current[26]. The power factor or work factor describes the phase angle between the active power and apparent power. Low power factor is detrimental because it results in high load currents[27]. This power factor improvement uses KVAR capacitors[28]. Capacitors to improve power factor can be done by paralleling KVAR capacitors to improve power factor on electrical loads in factories or industries[29].

B. Power Factor Improvement Concept



a) b)

Figure 2 a). circuit not with capacitor b). circuit with capacitor

Based on the Figure 2 , it can be seen that a power source with mixed loads is generally in the inductive load industry, the dominant inductive load will result in a low power factor of the installation system used[30], this of course results in high electric currents that work as well as safety equipment and electrical components used. becomes ineffective, this is certainly a problem that needs to be solved[31], the solution to this problem is to install a KVAR power factor improvement capacitor in parallel with the electrical load as shown in the figure, then by installing it in parallel the power factor will increase and result in a decrease in electric current due to a good power factor or more than 0.85[32].

C. Example of Calculation Case for Power Factor Improvement

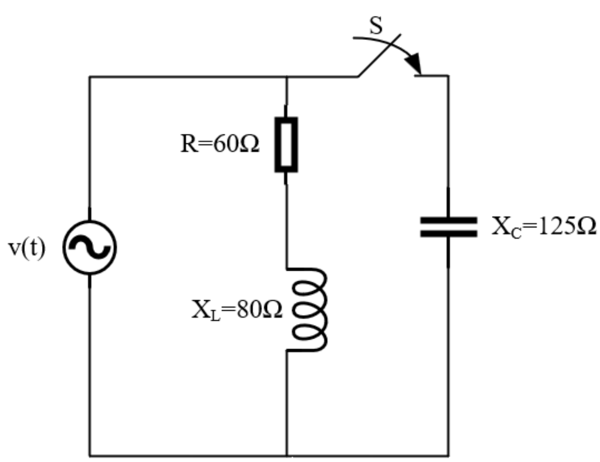


Figure 3 example of calculating the condition of the closed switch S

- $Z_1 = R + jX_L = 60 + j80 = 100 < 53{,}13^o$ (7)

$Z_2 = -jX_C = -j125 = 125 < -90^o$ (8)

$Z_{total} = Z_1 // Z_2 = \frac{Z_1.Z_2}{Z_1+Z_2} = \frac{(60+j80)(-j125)}{(60+j80)+(-j125)}$ (9)

$Z_{total} = \frac{-j7500-(-10000)}{60-j45} \frac{10000-j7500}{60-j45} = \frac{12500<-36{,}87^o}{75<-36{,}87^o}$ (10)

$Z_{total} = 166{,}67\Omega$ (11)

- $\bar{I}_{eff} = \frac{\bar{V}_{eff}}{\bar{Z}_{total}} = \frac{100<0^o}{166,67<0^o} = 0,6 < 0^o\ Ampere$ (12)
- $P = VIcos\angle_I^V = Re[\bar{V}_{eff}\bar{I}_{eff}^{\ *}] = Re[(100 < 0^o)(\ 0,6 < 0^o)]$ (13)

  $P = 100\ .\ 0,6\cos(0^o) = 60\cos 50^o = 60\ .\ 1 = 60\ watt$ (14)
- $Q = VIsin\angle_I^V = 100\ .\ 0,6\sin(0^o) = 60\sin 0^o = 60\ .\ 0 = 0$ (15)
- $S = V_{eff}I_{eff} = (100)(0,6) = 60\ VA$ (16)
- $power\ factor = pf = \frac{P}{S} = \frac{60\ watt}{60\ VA} = 1$ and $\varphi = cos^{-1}(1) = 0^o$ (17)

II. METHODS

The research method used in this research is using the ADDIE method (Analysis, Design, Development, Implementation, and Evaluation) using this research method is expected to produce industrial products and can also be used to produce learning media. In this study, the learning product made was a trainer monitoring power factor improvement. These learning products are used as learning media in electrical circuits and IoT courses. The research procedure in this study can be seen in Figure 4.

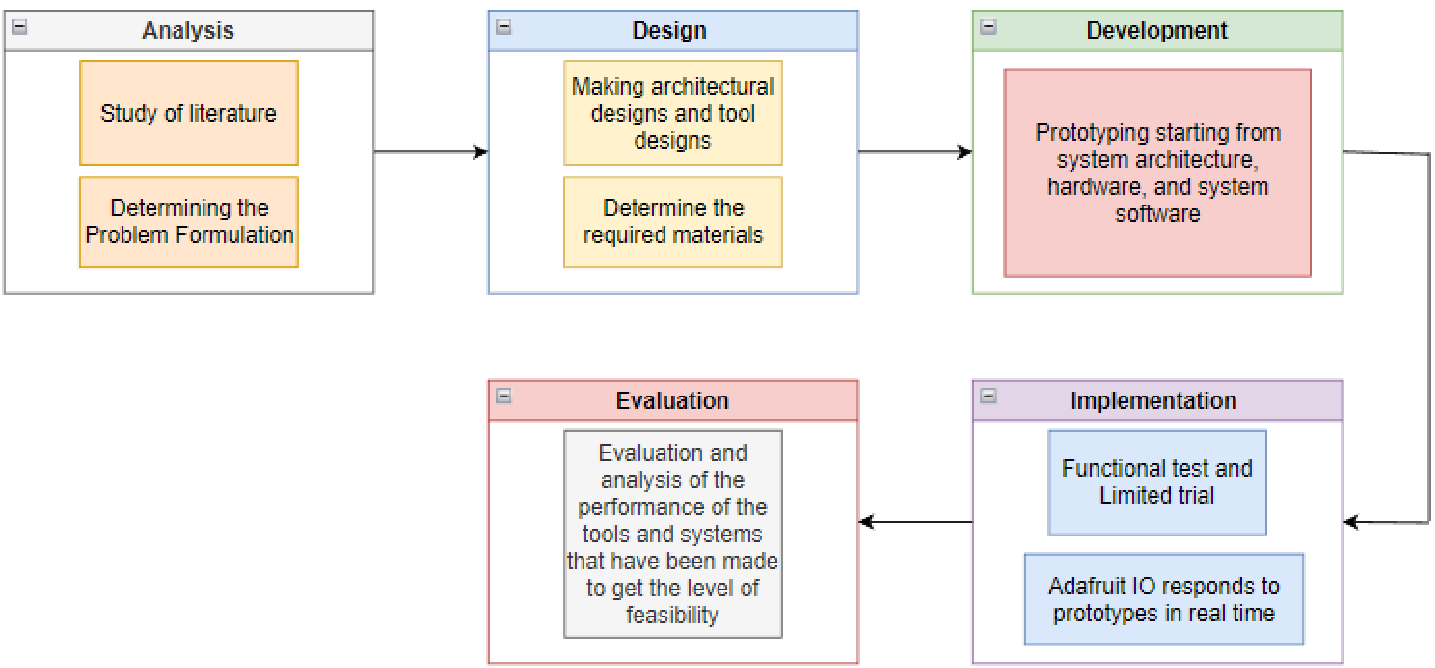


Figure 4 research method block diagram

Based on Figure 4, the research procedures and stages are explained, at the analysis stage the researcher conducted a literature study by observing and collecting information and analyzing the needs of learning media in electrical circuits and IoT courses. At the design stage, the researcher designs learning media products according to the needs of the results obtained from the analysis in the first stage. At the development stage, the researcher compares the learning products that have been made with the planning in the previous stage, then the trainer monitoring the power factor improvement is tested functionally, and the instrument is tested for validity. The implementation phase consists of two stages, namely functional testing and limited testing and seeing the response of the Adafruit dashboard whether it is connected properly or not. Limited tests to determine the extent to which the reliability, effectiveness and accuracy of the trainer's measurement results are carried out so that when the tool is used the specifications of this tool are known. Finally, an evaluation and analysis of the performance of the tools and systems that have been made is carried out to obtain the level of feasibility.

III. RESULTS AND DISCUSSION

A. Trainer Architecture

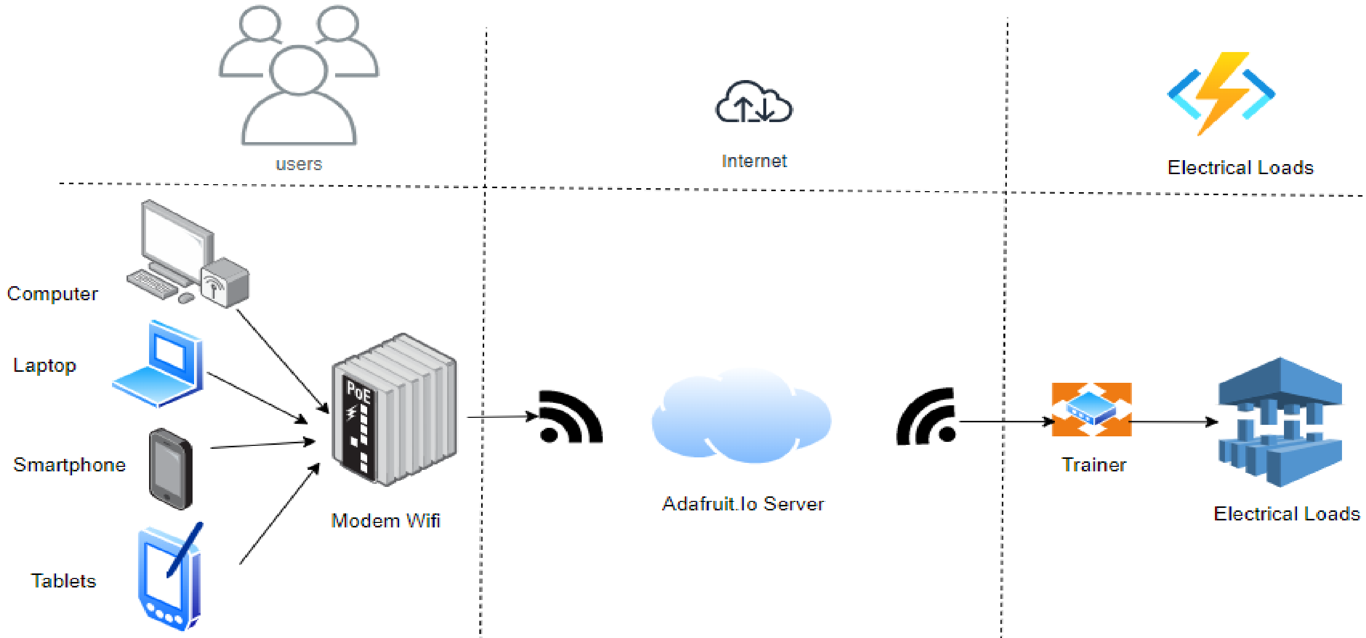


Figure 5 trainer architecture

Based on the Figure 5 it can be seen that the architecture of this system consists of 3 main parts, namely, users, internet servers, as well as trainers and electronic equipment loads. Users can use smartphones, laptops, tablets, or PC computers to monitor electrical loads and make power factor improvements and control them directly and in real time just by logging in to the Adafruit IO mqtt server which can be accessed via the website without the need to download an application first, The internet and servers are liaisons through the internet network between users and electronic devices which will later be monitored and controlled remotely as well as multiuser.

The function of each part of the architecture:

a) Internet in this case is a liaison between users and trainers

b) The NodeMCU ESP32 used in this trainer works as an interface liaison via wifi to the Adafruit.IO mqtt dashboard

c) Mqtt Adafruit.IO is a dashboard that functions to display the results of measurements as well as a controller via pushbatton available on Adafruit.IO

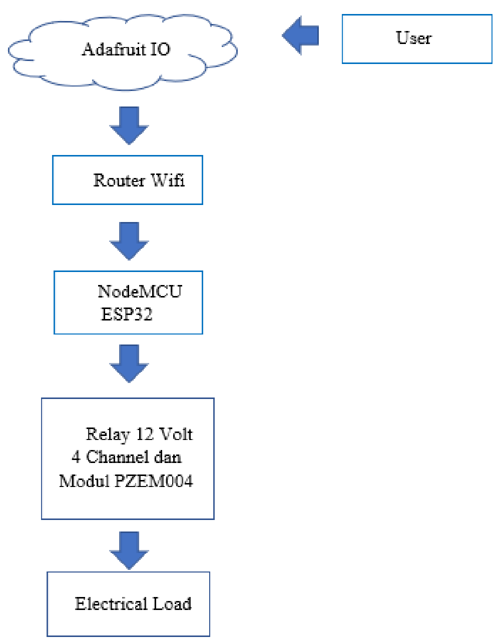


Figure 6 trainer usage flow

B. Flowchart of Trainer Usage

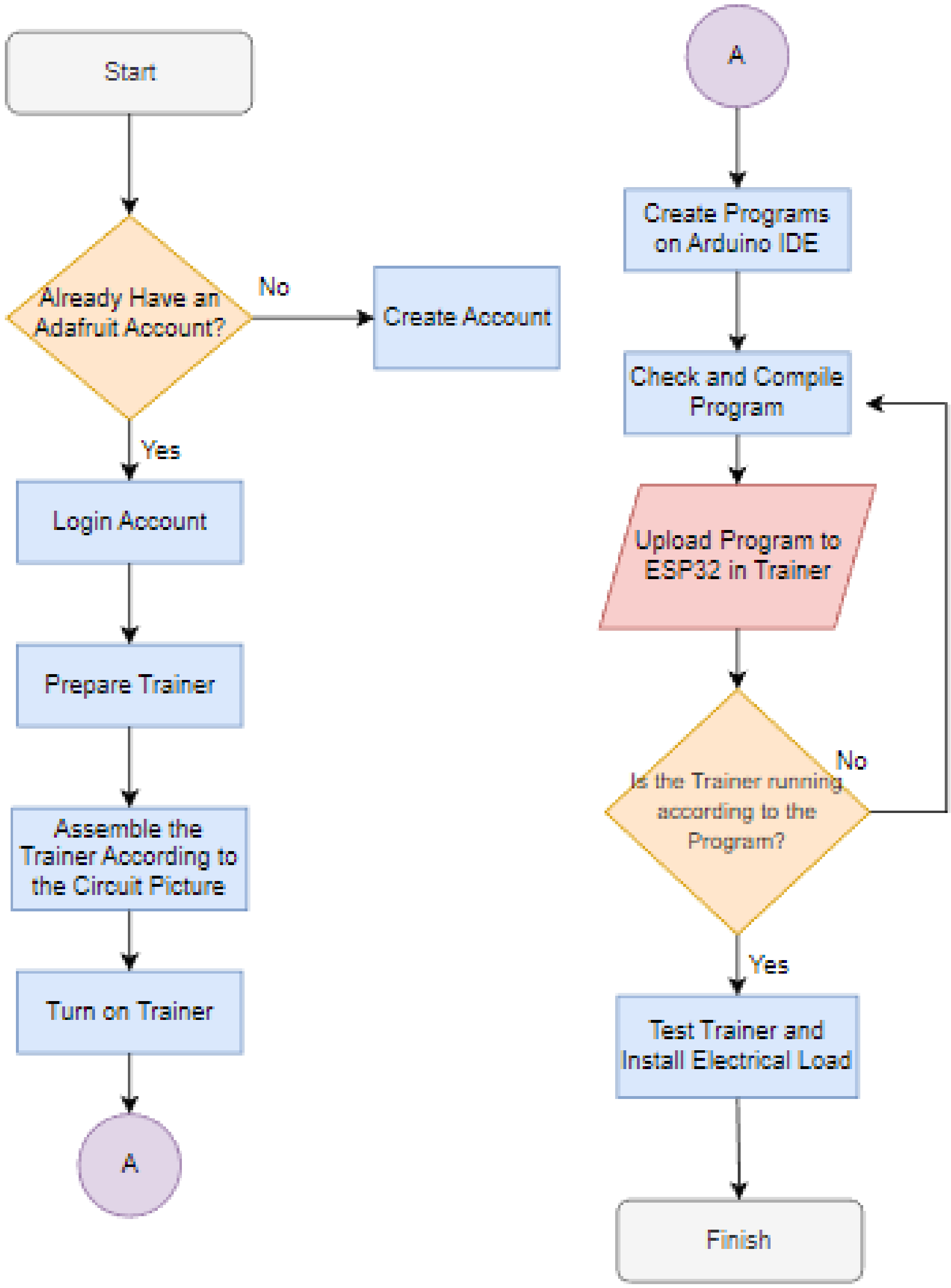


Figure 7 flowchart of trainer usage

Based on the Figure 6 it shows the flow of using the trainer which includes registration and creating an account if you don't have an account to be able to login to the adafruit dashboard, after having access to the adafruit dashboard, the next step is to prepare the trainer and do the wiring first according to the circuit drawing, connecting trainer with an input supply voltage of AC 220 - 240 volts then turn on the trainer by activating the power switch on the trainer, the next step is if you don't have a program to run the trainer, you can make a coding program on the Arduino IDE first, the program can also continue to be developed by adding functions or components that are deemed necessary (continues improvement), if the trainer does not work as planned, it can be checked again on the Arduino IDE coding program or check the wiring.

C. Functional Tests and Limited Trials

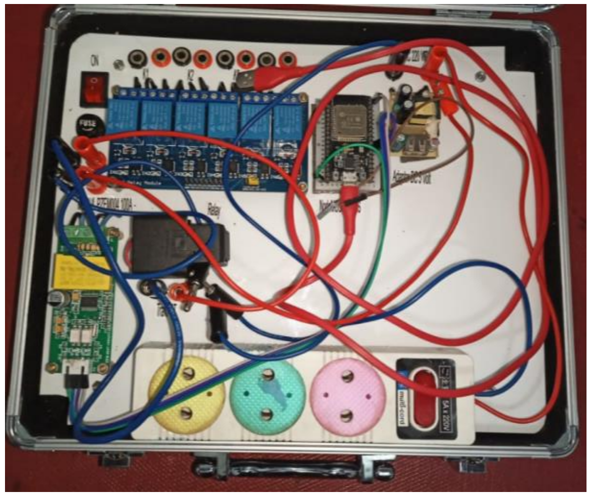
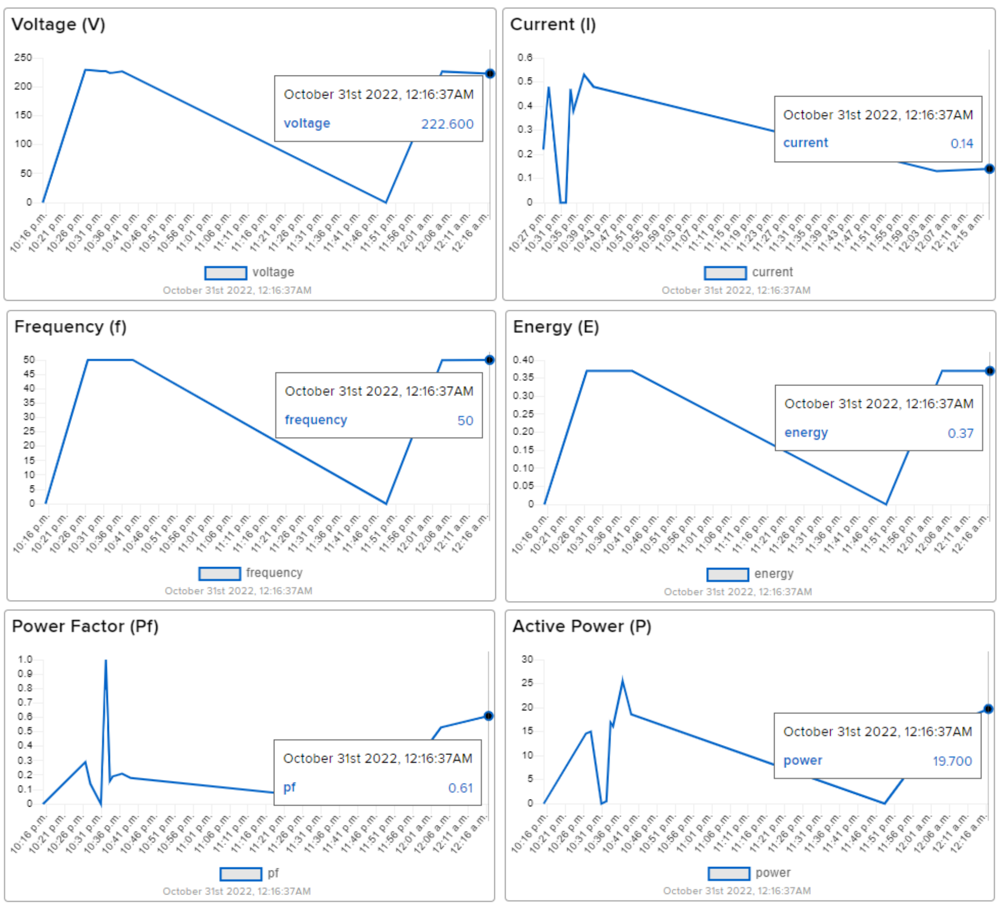


Figure 8 electric load monitoring trainer and power factor improvement



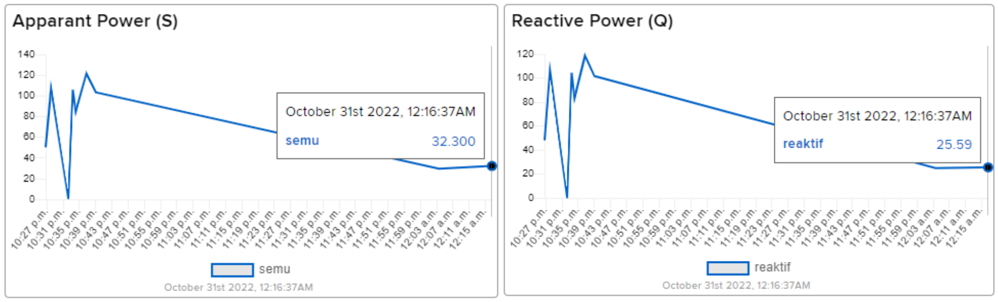


Figure 9 graphical display of results from functional test measurements and limited trials

Based on the Figure 9 it can be seen that the graph shows that there is a decrease in current by 0.4 A from the previous 0.54 to 0.14, there is also a decrease in apparent power from 40 VA to 32 VA but there is an increase in the power factor from the previously not installed repair capacitor. the KVAR power factor is 0.5 and after the capacitor is installed the KVAR power factor improvement becomes 0.61. This is certainly in accordance with the concept of improving the power factor.

IV. CONCLUSION IS

Based on the results of the research, it can be concluded that the electric load monitoring trainer and power factor improvement function well, can take measurements in real time on the electrical load, can monitor and control it remotely as long as it is connected to the internet. The results of the limited trial also show that the measurement results displayed through the Adafruit dashboard are in accordance with the concept of power factor improvement, the results before and after the installation of KVAR power factor improvement capacitors show an increase in power factor of 0.11 in a limited trial using an inductive load with a power of 20 Watt. This trainer has a lot of room for future research and development. This trainer is expected to be able to solve problems related to energy regulation and saving electrical energy. Although in this project there are still many shortcomings that must be investigated in the future.

V. DISCLOSURE OF CONFLICT OF INTEREST

The authors declare no conflict of interest.

ACKNOWLEDGMENT

Thank you to all those who have been directly involved in this research, thank you to parents, younger siblings, and all the family who always give encouragement and uninterrupted prayers, thank you to the STE supervisors who always provide direction, input, and knowledge in this research. Last but not least, i wanna thank me, i wanna thank me for believing in me, i wanna thank me for doing all this hard work, i wanna thank me for having no days off, i wanna thank me for, for never quitting.

REFERENCES

[1] J. Kustija, I. Surya, and D. Fahrizal, "Design of automated power factor monitoring and repair tool for industry in real time based on Internet of Things," pp. 0–7, 2022.
[2] H. Husnawati, R. Passarella, S. Sutarno, and R. Rendyansyah, "Perancangan dan Simulasi Energi Meter Digital Satu Phasa Menggunakan Sensor Arus ACS712," *Jnteti*, vol. 2, no. 4, pp. 307–315, 2013.
[3] M. K. Metwaly *et al.*, "Smart integration of drive system for induction motor applications in electric vehicles," *Int. J. Power Electron. Drive Syst.*, vol. 12, no. 1, pp. 20–28, 2021, doi: 10.11591/ijpeds.v12.i1.pp20-28.
[4] made adi surya antara and W. A. Suteja, "Analisis Arus, Tegangan, Daya, Energi, Dan Biaya Pada Sensor Pzem-004T Berbasis Nodemcu Esp8266," *Patria Artha Technol. J.*, vol. 5, no. 1, pp. 76–84, 2021, doi: 10.33857/patj.v5i1.405.
[5] A. Benali, M. Khiat, and M. Denai, "Voltage profile and power quality improvement in photovoltaic farms integrated medium voltage grid using dynamic voltage restorer," *Int. J. Power Electron. Drive Syst.*, vol. 11, no. 3, pp. 1481–1490, 2020, doi: 10.11591/ijpeds.v11.i3.pp1481-1490.
[6] S. Nirwan and H. MS, "Rancang Bangun Aplikasi Untuk Prototipe Sistem Monitoring Konsumsi Energi Listrik Pada Peralatan Elektronik Berbasis Pzem-004T," *Tek. Inform.*, vol. 12, no. 2, pp. 22–28, 2020.
[7] F. Habibi, Nur, S. Setiawidayat, and M. Mukhsim, "Alat Monitoring Pemakaian Energi Listrik Berbasis Android Menggunakan Modul PZEM-004T," *Pros. Semin. Nas. Teknol. Elektro Terap. 2017*, vol. 01, no. 01, pp. 157–162, 2017, [Online]. Available: https://prosiding.polinema.ac.id/sngbr/index.php/sntet/article/view/81/77
[8] J. Kustija and N. Dwi Jayanto, "IoT Implementation for Development of Remote Laboratory (Case Study on Microscope Practice)," *Reka Elkomika*, vol. 3, no. 1, pp. 20–29, 2022.
[9] J. Kustija and Purnawan, "Solutions To Overcome Inequality in Laboratory Facilities and Laboratory Sharing in Similar Institutions Remote Laboratory Based," *J. Eng. Sci. Technol.*, vol. 17, no. 3, pp. 1792–1809, 2022.

[10] J. Kustija and F. Andika, “Control - Monitoring System Of Oxygen Level, Ph, Temperature And Feeding in Pond Based on Iot,” *REKA ELKOMIKA J. Pengabdi. Kpd. Masy.*, vol. 2, no. 1, pp. 1–10, 2021, doi: 10.26760/rekaelkomika.v2i1.1-10.
[11] J. Kustija, A. Ana, and N. D. W. I. Jayanto, “Web-based and thinvnc remote laboratory implementation to support students skills in mechatronics course to face the industrial revolution 4.0,” *J. Eng. Sci. Technol.*, vol. 16, no. 2, pp. 1800–1813, 2021.
[12] Lisiani, A. Razikin, and Syaifurrahman, “Identifikasi dan Analisis Jenis Beban Listrik Rumah Tangga Terhadap Faktor Daya (Cos Phi),” *J. Untan*, vol. 1, no. 3, pp. 1–9, 2020.
[13] A. Z. Abdullah, M. Isa, M. N. K. H. Rohani, S. A. S. Jamalil, A. N. N. Abdullah, and N. Azizan, “Development of smart online partial discharge monitoring system for medium voltage power cable,” *Int. J. Power Electron. Drive Syst.*, vol. 10, no. 4, p. 2190, 2019, doi: 10.11591/ijpeds.v10.i4.pp2190-2197.
[14] K. Chooruang and K. Meekul, “Design of an IoT Energy Monitoring System,” *Int. Conf. ICT Knowl. Eng.*, vol. 2018-Novem, no. January, pp. 48–51, 2019, doi: 10.1109/ICTKE.2018.8612412.
[15] M. D. Tobi and V. N. Van Harling, “Wireless electric energy transmission system and its recording system using PZEM004T and NRF24L01 module,” *Indones. J. Electr. Eng. Comput. Sci.*, vol. 21, no. 3, pp. 1372–1380, 2021, doi: 10.11591/ijeecs.v21.i3.pp1372-1380.
[16] I. Abed and H. Naser, “ESP32 Microcontroller Based Smart Power Meter System Design and Implementation,” *Al-Rafidain Eng. J.*, vol. 25, no. 2, pp. 137–145, 2020, doi: 10.33899/rengj.2020.127111.1038.
[17] J. Chettouh, “Advanced Sensorless Weather Station Implementation Using ESP32,” *Lecture Notes in Networks and Systems*, vol. 199. pp. 165–174, 2021. doi: 10.1007/978-3-030-69418-0_15.
[18] A. Zuchriadi, Ferdyanto, and J. Julian, “Sistem Kendali Daya Listrik Berbasis PZEM-004T dan Blynk,” *J. Heal. Sains*, vol. 1, no. 8, pp. 1023–1028, 2020, doi: 10.46799/jsa.v1i8.146.
[19] A. S. Priambodo, “Design & Implementation of Solar Powered Automatic Weather Station based on ESP32 and GPRS Module,” *Journal of Physics: Conference Series*, vol. 1737, no. 1. 2021. doi: 10.1088/1742-6596/1737/1/012009.
[20] J. Kustija, K. S. Nur Adillawati, and D. Fauziah, “Smart home system to support Bandung smart city programme,” *Pertanika J. Sci. Technol.*, vol. 25, no. S, pp. 77–88, 2017.
[21] N. A. Afifie, “Evaluation Method of Mesh Protocol over ESP32 and ESP8266,” *Baghdad Sci. J.*, vol. 18, no. 4, pp. 1397–1405, 2021, doi: 10.21123/bsj.2021.18.4(Suppl.).1397.
[22] U. Muhammad and F. Azis, “Rancang Bangun Media Pembelajaran Cos Phi Meter Dan Wattmeter Berbasis Arduino,” *J. Electr. Eng.*, vol. 1, no. 2, pp. 54–56, 2020, [Online]. Available: http://jurnal.politeknikbosowa.ac.id/index.php/JOULE/article/view/111
[23] R. Andari, S. Amalia, and C. D. Tinambunan, “Sistem monitoring pengisian baterai PLTS 100 Wp menggunakan sensor PZEM 004t dan sensor tegangan DC,” vol. 22, pp. 28–38, 2022.
[24] M. D. Tobi and V. N. Van Harling, “Prototype Design of Wireless Electric Energy Transmission System and Distance Electric Recording Record System Using PZEM004T and NRF24L01 Module,” *J. Phys. Conf. Ser.*, vol. 1783, no. 1, 2021, doi: 10.1088/1742-6596/1783/1/012074.
[25] M. N. A. Mohd Said, S. A. Jumaat, and C. R. A. Jawa, “Dual axis solar tracker with iot monitoring system using arduino,” *Int. J. Power Electron. Drive Syst.*, vol. 11, no. 1, pp. 451–458, 2020, doi: 10.11591/ijpeds.v11.i1.pp451-458.
[26] R. Moorthy, “Enhancement of psychomotor skills in children with autism spectrum disorder by employing a mechatronic training kit,” *Paladyn*, vol. 10, no. 1, pp. 1–13, 2019, doi: 10.1515/pjbr-2019-0001.
[27] A. R. M. Khairudin, “Design of portable industrial automation education training kit compatible for IR 4.0,” *Proceeding - 2019 IEEE 7th Conference on Systems, Process and Control, ICSPC 2019*. pp. 38–42, 2019. doi: 10.1109/ICSPC47137.2019.9068090.
[28] P. Roy, S. Karmakar, P. Basak, S. Das, and S. Khatua, “Designing of a device for checking the polarity and continuity of any electrical and electronics circuit,” *Irjet*, vol. 3, no. 7, pp. 170–172, 2016.
[29] Tafakur, “The development of training kit for basic electronic control on automotive field,” *Journal of Physics: Conference Series*, vol. 1700, no. 1. 2020. doi: 10.1088/1742-6596/1700/1/012069.
[30] J. Kustija, E. Mulyana, B. Trisno, and - Hasbullah, “Skill Training Models to Install and Maintain for House Electrical Installation,” no. Icieve 2015, pp. 253–256, 2016, doi: 10.2991/icieve-15.2016.55.
[31] M. Bhattacharya, “Improvement of Power Quality Using PWM Rectifier,” *Int. J. Sci. Res. Publ.*, vol. 4, no. 7, pp. 1–11, 2014, [Online]. Available: https://www.semanticscholar.org/paper/Improvement-of-Power-Quality-Using-PWM-Rectifiers-Bhattacharya/10f29330a7ef4155e8d2c1721f1823d33c8fde37
[32] A. Dekate and P. Ramchaware, “Fault Acknowledgement System for UPS using GSM,” vol. 5, no. 5, pp. 1–4, 2015.

AUTHORS

First Author – Irgi Surya, a student who is pursuing a bachelor's degree in an electrical engineering education study program, research interests include the internet of things, artificial intelligence, Department of Electrical Engineering Education, Faculty of Technology and Vocational Education, Indonesian University of Education, Bandung, Indonesia. irgi.surya@upi.edu

Second Author – Jaja Kustija, a lecturer at the Indonesian Education University, research interests include the internet of things, artificial intelligence, remote laboratory, technology and vocational education, Department of Electrical Engineering Education, Faculty of Technology and Vocational Education, Indonesian University of Education, Bandung, Indonesia. jaja.kustija@upi.edu

Correspondence Author – Irgi Surya, irgi.surya@upi.edu 085759023579.