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# IoT-based Single-Phase Power Factor and Control Panel Monitoring System

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***Abstract*—The power factor is a value obtained by comparing the actual power value and apparent power in an electric circuit. Because it is related to the quality of the distributed power, this power factor needs to be monitored. Devices with inductive loads generally cause power factor distortion, causing losses. Power factor monitoring is carried out periodically to ensure the efficiency of electricity distribution to the building. Power factor monitoring is usually done on the control panel of a building by measuring the voltage and current flowing. Manual monitoring could be more ineffective in terms of time and effort and has the potential for recording errors. This study proposes a power factor monitoring system on the control panel to facilitate recording. The system created is integrated with IoT technology so that it can monitor and record automatically anywhere and anytime. The developed system has an error percentage of 1.53% for the voltage sensor and 5.02% for the current sensor.**

***Index Terms*— Electric Control Panel, Internet of Things, Monitoring System, Power Factor, Single-Phase Power Factor**

## I. Introduction

In the last few decades, the construction of power plants has been increasingly massive. The construction of this massive power plant is a response to the rapid economic surge throughout the country, triggering a high demand for electrical energy [1]. The power plants built, from conventional to renewable energy, provide the energy surge that is felt today. This abundant electrical energy accelerates economic growth by building industries [2], [3]. However, all regions within a country do not feel this surge in electrical energy. In some cases, some areas have yet to be maximally electrified. This hampers economic growth in the region, resulting in social inequality.

One of the problems is the low quality of the power produced. Industries with high induction loads, such as inductive loads, sodium vapor, electric motors, and metal halide lighting, have a high absorption of inductive loads and cause thermal problems [4]. These devices distort the power factor causing losses. This reduction in power factor has an impact on reducing the efficiency of electric power, which should be used to operate equipment in the industry [5].

Power factor can be monitored on the control panel to monitor the performance and efficiency of power usage. Several researchers have contributed to the development of a power usage monitoring system. The proposed research measures buildings' voltage, current, and power factors [6], [7]. This measurement is carried out on the cable that delivers electrification to the building. Other research focuses on monitoring household needs [8], [9]. However, these studies utilize websites and local hosts as the primary display of measurement results. The monitoring system can be improved even better if everyone can access it easily anytime and anywhere.

Currently, digital transformation has penetrated various sectors. A new technology that is also developing massively is the Internet of Things (IoT). This IoT technology supports changes in the industrial sector, commonly referred to as industry 4.0. This technology allows remote monitoring and control of the system through a single device. Hakim et al. [10] monitored electric current, voltage, power, and power factor. Monitoring is carried out utilizing IoT with smartphone devices as displayed through the Android application. However, this study did not monitor the control panel.

The electrical control panel in a building is crucial for monitoring. In addition to measuring the resulting voltage, current, power, and power factor, the control panel needs to monitor environmental conditions such as temperature and humidity. This aims to ensure the health of the control panel and monitor it in case of overheating, which could result in a fire. Dharmawan et al. [11] monitor the data contained in the electrical panel, namely in the form of voltage, current, and frequency. However, this study did not use IoT technology. In this study, an IoT-based control panel monitoring system is proposed. This study aims to monitor the resulting voltage, current, power, and power factor. Furthermore, this study also monitored environmental conditions in the control panel. The monitoring carried out is supported by IoT technology through a smartphone application so stakeholders can monitor it anytime and anywhere.

## II. Single-Phase Power-Factor

Power factor has been the subject of interest since the early 1920s. Initially, the power factor was stated to be the ratio of the actual power to the greatest possible power absorbed by any load taking the same r.m.s voltage current [12]. In 1927, powers in single-phase systems with distorted waveforms were proposed by Budeanu [13]. In this model, a three-dimensional resolution of the apparent power S, with the components P active power, Q reactive power, and D distortion power, is proposed. Finally, the IEEE 1459-2010 standard was put forward for the calculation of the power factor to date [14]. The power factor is a value obtained from the comparison between the actual power value and the apparent power contained in an electric circuit. In other words, the power factor represents the phase angle between actual power and apparent power. According to the IEEE 1459-2010 standard, the power factor is defined as

$$PF = \frac{P}{S} = \frac{P}{\sqrt{P^2 + Q^2}} \quad (1)$$

## III. IoT Design

The IoT architecture has systems that can be physical or virtual, consisting of hardware such as active physical objects, sensors, actuators, and software such as cloud services, IoT protocols, and communication layers [15]. This technology allows someone to access data on a physical parameter being measured without the need to be present directly at that location. Until now, IoT technology has been widely applied in the fields of health [16]–[18], security [19], [20], environment [21]–[23], learning [24], [25], and is no exception in the field of power electronics [26]. In this research, IoT design will be discussed in depth in two parts. The first part describes the proposed device being developed, while the second part describes the smartphone application used.

## IV. Proposed Device

The system was built by adjusting the measurement needs, namely on low-voltage power lines 220V-230V. The system built uses a microcontroller based on the AT mega 328 chip, namely Arduino Uno as a data processor. To measure the voltage and current in the cable, ZMPT101B and SCT013 sensors are used, respectively. At the same time, the measurement of environmental conditions in the control panel in the form of temperature and humidity is carried out by the DHT11 sensor. To support IoT data communication, the main microcontroller is integrated with ESP12. In addition to displaying data via a smartphone, this system also has an LCD embedded in the toolbox to display measured data. The 12V 2A adapter is used to supply power to all electrical components of the system. The schematic of the proposed system is shown in Figure 1. Meanwhile, a list of components and their functions is shown in Table I.

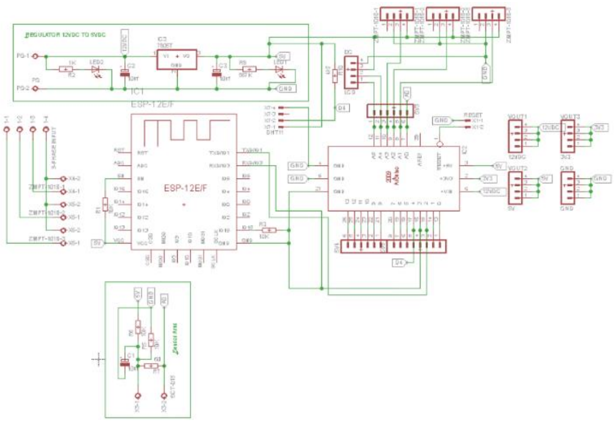

**Fig. 1.** System's schematic.

TABLE I
Tool Components and Their Functions

| Component | Function |
|---|---|
| Arduino Uno | Microcontroller board as a data processor |
| ESP12 | Wi-Fi module for IoT communication |
| ZMPT101B | Voltage sensor |
| SCT013 | Current sensor |
| DHT11 | Air temperature and humidity sensors |
| LCD + I2C | Displays data on the LCD screen |

### A. Blynk App

To display measured data on a smartphone, the Blynk application is used [27]. This application can display, sort, and control devices remotely as long as the device are connected to the internet. The IoT communication structure using Blynk is shown in Figure 2.

**Fig. 2.** IoT communication structure using Blynk [27]

Blynk has several main components, including the Blynk App, Blynk Server, and Blynk Libraries [28]. Blynk App offers flexibility in making the interface according to the project being built. Blynk App has complete features that can be adapted to project needs. Communication between devices placed at data collection locations and smartphones is carried out by the Blynk Server. To support Blynk Source, Blynk Cloud is presented in an open-source manner. Meanwhile, the hardware can access communication with the server and process incoming and outcoming commands through Blynk Libraries.

## V. Result and Discussion

The design and manufacture of a power factor monitoring system and control panel on a single-phase low-voltage power network based on IoT technology have been completed. Figure 3 shows the tool that has been completed. To validate the monitoring system, several tests were carried out. This test was carried out at PT Haleyora Power Area Yogyakarta. The test was carried out on a low-voltage power network, namely 220V-230V with a frequency of 50Hz, by providing a load in the form of a rice cooker, dispenser, and grinder. At the time of testing, the device was supplied with a 12VDC adapter and used the Wi-Fi network of the related building.

The test was carried out with a load of rice cooker, dispenser, and grinder for 30 iterations each. Testing is carried out by measuring voltage and electric current and then comparing them using a multimeter. Testing in this way aims to validate the measurement accuracy of the ZMPT101B voltage sensor and SCT013 current sensor. Figure 4 shows a test tool that compares a volt meter and an ampere meter.

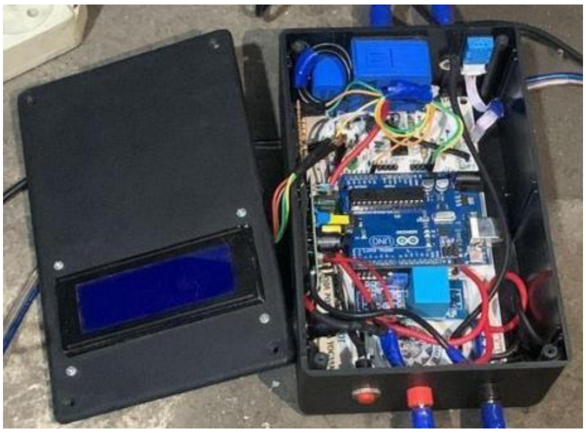

**Fig. 3.** Proposed Power Factor and Control Panel Monitoring System

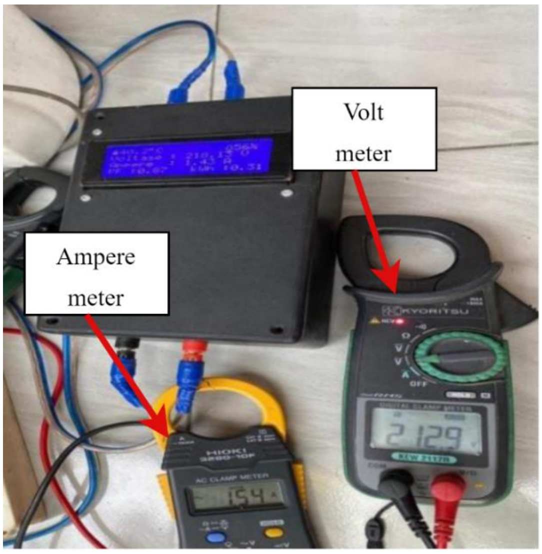


**Fig. 4.** Testing tools compared to volt meters and an ampere meter

Table II shows the data on the results of measuring the equipment with the load of the rice cooker, dispenser and grinder. It can be seen that the measurement of voltage and current carried out by the device does not experience significant inconsistency. The results of voltage and current measurements by a device made with a rice cooker load have an average of 218.94 V and 0.25 A, respectively, resulting in an average rated power of 54.81 W. Measurement results with a dispenser load produce an average rated voltage of 218.13 V, the current is 1.42 A, so the power is 310.18 W. Meanwhile the measurement results with grinding loads show an average measured voltage of 217.37 V, a current of 1.15 A, resulting in a power of 250.12 W.

Measurements made by the tool are also compared with a multimeter. The results of this comparison of voltage and current measurements produce an error value that is not too large. The results of this comparison are visualized in an image shown in Figure 5 to facilitate observation. It can be seen in Figure 5 that the measurement error value between the tool and the multimeter indicates that the tool can work properly. The resulting error percentage is not more than 8%. The average error percentage of the voltage sensor is 1.53%, while the current sensor is 5.02%. This measurement produces an average percentage of power error of 4.52% or equal to 9.44 W.

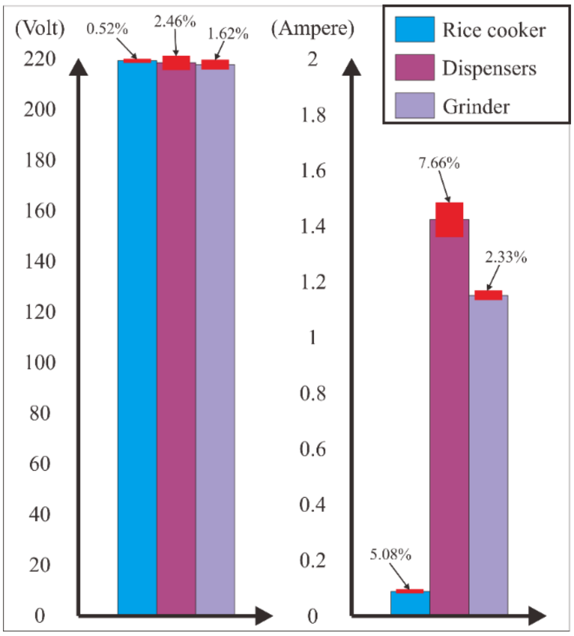


**Fig. 5.** Percentage of system measurement error with a multimeter

After getting the voltage and current values from the measurement results, the next step is to calculate the resulting power factor. Referring to (1), the results of calculating the average power factor can be seen in Figure 6. It can be seen that the overall power factor produced is more than 0.8. The power factor with rice cooker load is 0.89, the dispenser is 0.87, and while grinding is 0.85.

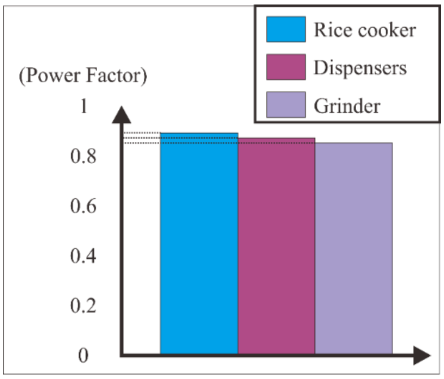


**Fig. 6.** The resulting power factors

The value of voltage, current, power, and power factor has been calculated by the system. The next process is to display these values in the Blynk application. In this application, some additional information is presented, namely in the form of kWh, rated electricity frequency, temperature, and humidity control panel. The final appearance of the power factor and control panel monitoring system at single-phase voltage supported by IoT technology is shown in Figure 7. The application display shown in Figure 7 shows that the tool used to monitor power factors and conditions in the single-phase power network control panel works fine.

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TABLE II
DATA ON THE MEASUREMENT RESULTS OF THE EQUIPMENT WITH THE LOAD OF THE RICE COOKER, DISPENSER, AND GRINDER

| Iteration | Rice cooker | | | | Dispenser | | | | Grinder | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sensor | | Multimeter | | Sensor | | Multimeter | | Sensor | | Multimeter | |
| | Voltage (V) | Current (A) | Voltage (V) | Current (A) | Voltage (V) | Current (A) | Voltage (V) | Current (A) | Voltage (V) | Current (A) | Voltage (V) | Current (A) |
| **1** | 218.94 | 0.25 | 217.80 | 0.28 | 218.13 | 1.42 | 212.90 | 1.54 | 217.37 | 1.15 | 213.90 | 1.14 |
| **2** | 218.94 | 0.25 | 217.80 | 0.24 | 218.13 | 1.42 | 212.90 | 1.54 | 217.37 | 1.15 | 213.90 | 1.14 |
| **3** | 218.94 | 0.25 | 217.80 | 0.24 | 218.13 | 1.42 | 212.90 | 1.54 | 217.38 | 1.15 | 213.90 | 1.14 |
| **4** | 218.94 | 0.25 | 217.80 | 0.24 | 218.16 | 1.41 | 212.90 | 1.54 | 217.39 | 1.14 | 213.90 | 1.14 |
| **5** | 218.92 | 0.27 | 217.80 | 0.28 | 218.16 | 1.41 | 212.90 | 1.54 | 217.39 | 1.14 | 213.88 | 1.16 |
| **6** | 218.93 | 0.27 | 217.80 | 0.28 | 218.20 | 1.40 | 212.91 | 1.54 | 217.41 | 1.16 | 213.88 | 1.16 |
| **7** | 218.93 | 0.24 | 217.80 | 0.25 | 218.20 | 1.40 | 212.91 | 1.54 | 217.42 | 1.17 | 213.88 | 1.16 |
| **8** | 218.98 | 0.24 | 217.80 | 0.25 | 218.20 | 1.40 | 212.91 | 1.54 | 217.40 | 1.15 | 213.88 | 1.16 |
| **9** | 218.98 | 0.22 | 217.80 | 0.24 | 218.20 | 1.40 | 212.91 | 1.54 | 217.33 | 1.16 | 213.89 | 1.15 |
| **10** | 218.98 | 0.22 | 217.80 | 0.24 | 218.28 | 1.41 | 212.89 | 1.55 | 217.35 | 1.16 | 213.89 | 1.15 |
| **11** | 218.98 | 0.22 | 217.80 | 0.24 | 218.31 | 1.41 | 212.89 | 1.55 | 217.38 | 1.15 | 213.89 | 1.15 |
| **12** | 218.98 | 0.22 | 217.81 | 0.24 | 218.22 | 1.41 | 212.89 | 1.55 | 217.43 | 1.11 | 213.90 | 1.14 |
| **13** | 218.95 | 0.25 | 217.81 | 0.26 | 218.13 | 1.42 | 212.89 | 1.55 | 217.48 | 1.11 | 213.90 | 1.14 |
| **14** | 218.95 | 0.23 | 217.81 | 0.24 | 218.13 | 1.42 | 212.90 | 1.54 | 217.52 | 1.10 | 213.90 | 1.14 |
| **15** | 218.94 | 0.23 | 217.81 | 0.24 | 218.13 | 1.42 | 212.90 | 1.54 | 217.52 | 1.10 | 213.90 | 1.14 |
| **16** | 218.94 | 0.28 | 217.81 | 0.29 | 218.13 | 1.42 | 212.90 | 1.54 | 217.48 | 1.12 | 213.90 | 1.14 |
| **17** | 218.88 | 0.28 | 217.80 | 0.27 | 218.04 | 1.44 | 212.90 | 1.54 | 217.38 | 1.15 | 213.90 | 1.14 |
| **18** | 218.88 | 0.28 | 217.80 | 0.27 | 218.04 | 1.44 | 212.93 | 1.53 | 217.38 | 1.15 | 213.92 | 1.12 |
| **19** | 218.88 | 0.28 | 217.80 | 0.27 | 218.05 | 1.45 | 212.90 | 1.53 | 217.36 | 1.15 | 213.92 | 1.12 |
| **20** | 218.95 | 0.28 | 217.80 | 0.29 | 217.98 | 1.46 | 212.93 | 1.53 | 217.36 | 1.15 | 213.92 | 1.12 |
| **21** | 218.95 | 0.25 | 217.80 | 0.24 | 217.98 | 1.46 | 212.91 | 1.53 | 217.36 | 1.15 | 213.92 | 1.12 |
| **22** | 218.94 | 0.25 | 217.80 | 0.24 | 217.98 | 1.46 | 212.91 | 1.53 | 217.36 | 1.15 | 213.91 | 1.11 |
| **23** | 218.94 | 0.25 | 217.80 | 0.24 | 218.12 | 1.42 | 212.88 | 1.55 | 217.36 | 1.15 | 213.91 | 1.11 |
| **24** | 218.94 | 0.25 | 217.80 | 0.24 | 218.12 | 1.42 | 212.93 | 1.53 | 217.36 | 1.15 | 213.91 | 1.11 |
| **25** | 218.94 | 0.25 | 217.80 | 0.26 | 218.12 | 1.42 | 212.89 | 1.55 | 217.28 | 1.18 | 213.91 | 1.11 |
| **26** | 218.87 | 0.25 | 217.80 | 0.26 | 218.13 | 1.42 | 212.90 | 1.54 | 217.28 | 1.18 | 213.90 | 1.14 |
| **27** | 218.94 | 0.25 | 217.79 | 0.26 | 218.13 | 1.42 | 212.90 | 1.54 | 217.25 | 1.20 | 213.90 | 1.14 |
| **28** | 218.98 | 0.25 | 217.79 | 0.27 | 218.13 | 1.42 | 212.90 | 1.54 | 217.28 | 1.18 | 213.90 | 1.14 |
| **29** | 218.98 | 0.25 | 217.79 | 0.27 | 218.13 | 1.42 | 212.90 | 1.54 | 217.28 | 1.18 | 213.90 | 1.14 |
| **30** | 218.93 | 0.25 | 217.79 | 0.27 | 218.13 | 1.42 | 212.90 | 1.54 | 217.28 | 1.18 | 213.90 | 1.14 |

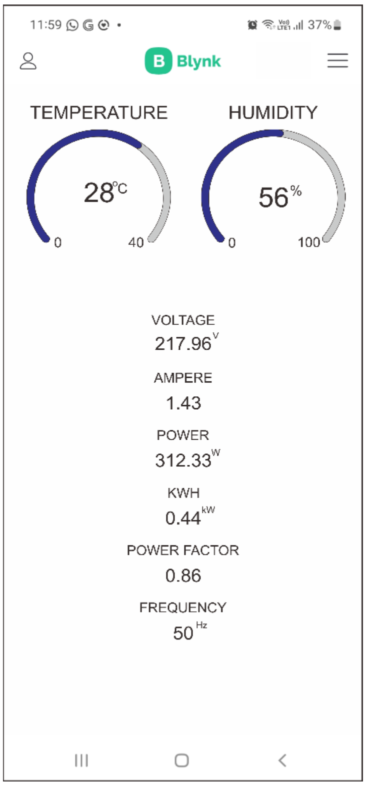


**Fig. 7.** Display of the monitoring system application

## VI. CONCLUSION

The design and manufacture of a monitoring system for the power factor and control panel at single-phase voltage have been completed. This monitoring system is supported by IoT technology which can provide access to related employees to periodically monitor control panel conditions anytime and anywhere. The monitoring system has been tested at PT Haleyora Power Area Yogyakarta. The test was carried out on a low-voltage power network, namely 220V-230V, with a frequency of 50Hz, by providing a load in the form of a rice cooker, dispenser, and grinder. The results obtained show that the system is working properly, indicated by the measured values in the form of kWh, measured electric frequency, temperature, and humidity control panel displayed on the Blynk application. Current and voltage sensor measurements have also been tested with a standard multimeter and give good results, marked by the percentage error of the voltage sensor being 1.53% and the current sensor being 5.02%. The power factor monitored on the control panel with the load of the rice cooker, dispenser, and grinder produces an average value of 0.87.

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