Design of a Prototype Device for Measuring Electricity Consumption and Water Density for Hydroponic Plants Based on IoT

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Abstract

One of the problems with hydroponics is that the electrical power consumption and nutrient levels that have been used are not monitored. The monitoring carried out in this research was to determine real-time electrical energy consumption and nutrient levels. The method used is experimental with a design method using a prototype. The system uses eight water pumps with measurement results of 236 W power, 2 A current and 219 V voltage. The load (water pump) in the hydroponics is active for 24 hours, the electrical energy consumption in the hydroponics is 5.66 kWh/day. The cost of using electricity for 24 hours is IDR 8,182.78 if 30 days is IDR 245,483.00. The nutrient level in hydroponics with a capacity of 130 liters and a nutrient mixture of 1.2 liters is 363 PPM, and at a capacity of 100 liters with a nutrient mixture of 1 liter it reaches 495 PPM. The designed measuring instrument functions well.

Keywords*: Potential, Hydrokinetics, Electricity, PLTHk, Kluet River.*

Abstrak

Salah satu permasalahan pada hidroponik adalah tidak terpantaunya pemakaian daya listrik dan kadar nutrisi yang telah digunakan. Pemantauan yang dilakukan pada penelitian ini bertujuan untuk mengetahui konsumsi energi listrik dan kadar nutrisi secara real-time. Metode yang digunakan adalah eksperimental dengan metode perancangan menggunakan prototipe. Sistem menggunakan delapan pompa air dengan hasil pengukuran daya 236 W, arus 2 A, dan tegangan 219 V. Beban (pompa air) yang terdapat pada hidroponik tersebut aktif selama 24 jam, dengan konsumsi energi listrik 5,66 kWh/hari. Biaya dari penggunaan daya listrik selama 24 jam adalah Rp 8.182,78, dan jika selama 30 hari mencapai Rp 245.483,00. Kadar nutrisi pada hidroponik tersebut dengan kapasitas 130 liter dan campuran nutrisi 1,2 liter adalah 363 PPM, dan pada kapasitas 100 liter dengan campuran nutrisi 1 liter mencapai 495 PPM. Alat ukur yang dirancang berfungsi dengan baik.

Kata kunci: Energi Listrik, Prototipe, Alat Ukur, Kepekatan Air, Hidroponik

Introduction

Based on research conducted by Rizki Afandi in 2019, titled "Hydroponic Plant Monitoring System Based on Arduino Microcontroller Using Android Smartphone," the researcher explained that growing plants using hydroponic methods requires more attention compared to soil cultivation. For instance, the concentration of nutrients in the water reservoir must be closely monitored. Using a hydroponic plant monitoring system equipped with a TDS meter sensor, this system can monitor the nutrient concentration in the water reservoir essential for hydroponic plants.

Additionally, in the research by Annisa Nurul Sholihah, Adnan Rafi Al Tahtawi, and Sarjono Wahyu Jadmiko in 2021, titled "TDS Control System for Deep Flow Technique Hydroponic Nutrients Using Fuzzy Logic," the findings indicated that the TDS control system for DFT (Deep Flow Technique) hydroponics using fuzzy logic was successfully designed and implemented, although there were some challenges during testing.

Furthermore, in the 2022 study by Ridyandhika Riza Ibrahim and Bekti Yulianti, S.T., M.T., titled "IoT-Based Monitoring System for PLN Electricity Usage," the results demonstrated the development of an IoT-based electricity usage monitoring device. Utilizing NodeMCU ESP 8266 as the controller, PZEM-004T as the sensor to measure voltage, current, power, and energy, an LCD for data display, and the Blynk application for smartphone monitoring, the testing of sensors with different loads and power levels yielded a relatively low error value, below the PZEM module's tolerance level of ±0.5.

In the 2022 research by Edi Kurniawan, Dwi Songgo Pangaudi, and Eko Nugroho Widjatmoko, titled "Design of an Android-Based Electrical Power Consumption Monitoring System," the testing results concluded that the PZEM-004T sensor used for monitoring electrical power consumption demonstrated high accuracy with a percentage of ±6%. The power error percentage exceeding 5% was attributed to the measuring instrument's lower precision compared to the PZEM-004T sensor.

Method

This study is an experimental research. The experiment was conducted by designing a prototype for measuring electrical energy consumption and a water sensitivity measuring device for hydroponic plants based on IoT. By experimenting with the design and development of the device, it is expected to obtain reliable testing results.

a. Prototype Method

The Prototype Method is a structured system development process comprising several stages that must be traversed during its creation. However, if the final stage determines that the system produced is not yet perfect or still has deficiencies, then the system will be re-evaluated and undergo a process from the beginning. The Prototype Approach is an iterative process involving close collaboration between designers and users. The objective of this prototype model is to evolve the initial software model into a final system.

b. Requirement

Defining all software components, identifying all requirements, and outlining the system to be developed. In order to design the measurement of electricity consumption and nutrient levels in hydroponics for this research, the necessary tools and materials can be found in the description below.

- NodeMCU ESP8266
- TDS Meter
- LCD 6 x 2
- I2C library
- PZEM-004T
- Kabel Jumper

- BLYNK app
- Arduino IDE app
- Fritzing app

c. Developing Prototypes

Developing prototypes involves creating preliminary designs focused on presenting to customers, such as designing input and output formats. After conducting a needs analysis for the device, it is necessary to design the arrangement of components based on the required features of the system so that the device can function as intended. The initial step before designing the system is to create a block diagram schematic of the system circuit, as illustrated in Figure 2. The block diagram schematic serves as a fundamental representation before proceeding with the device design.

System Diagram Design

The system design consists of both hardware and software components. In this study, the system is divided into several parts: the input system utilizes a TDS sensor to measure nutrient levels and a PZEM-004T for measuring electrical energy consumption; an ESP8266 microcontroller serves as the control system; and an LCD along with the Blynk application function as the output. The system implemented in this study is explained in detail below, and the flowchart of the device design is shown in Figure 1.

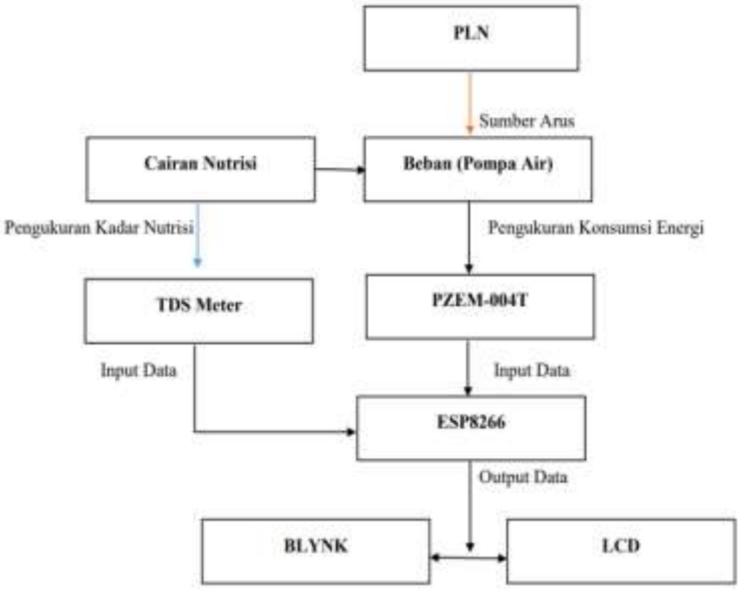

Figure 1. Block Diagram Schematic

The TDS Meter functions as an input to detect the PPM levels in the nutrients. The data collected by the TDS Meter is then processed by the ESP8266 Microcontroller. The PZEM-004T functions as an input to measure the electrical energy consumption in the hydroponic system. The ESP8266 processes the data detected by the TDS Meter and the PZEM-004T.The Blynk application and LCD display serve as outputs for the processed data.

Software Design

The circuit design for this system utilizes the Fritzing application. The detailed circuit design can be seen in Figure 3.

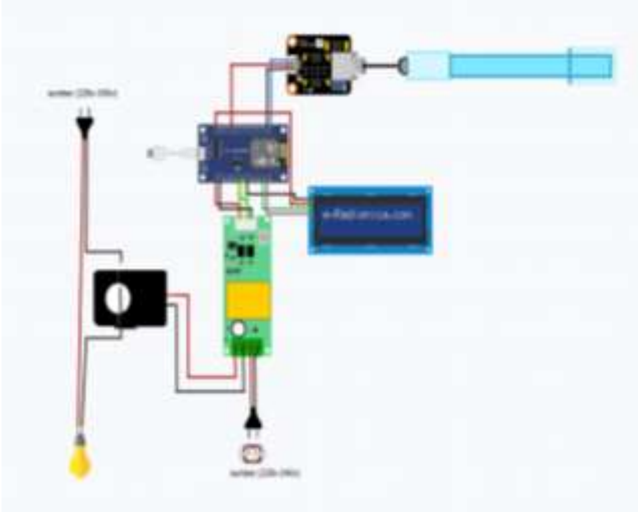

Figure 2 Circuit Design

The TDS sensor functions as a nutrient concentration meter, while the PZEM-004T is used for measuring electrical energy consumption. The ESP8266 microcontroller serves as the control system, and both an LCD display and the Blynk application are used as outputs.

Prototype Evaluation

This evaluation is conducted by the customer to determine if the built prototype meets their requirements. If it meets the requirements, proceed to step 4. If not, the prototype is revised by repeating steps 1, 2, and 3.

System Coding

In this stage, the agreed-upon prototype is translated into the appropriate programming language. The programming language used in this device design is C. Programming is performed using the Arduino IDE application, following the steps outlined below.

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <PZEM004Tv30.h>
#include <SoftwareSerial.h>
#include <ESP8266WiFi.h>
#include <BlynkSimpleEsp8266.h>
```

Programming utilizes several libraries on the Arduino and ESP8266 platforms. Here's an explanation:

- Wire.h: This library is used to access I2C, a communication protocol for devices within embedded systems.
- LiquidCrystal_I2C.h: This library is used to control the LCD module with I2C connection, simplifying pin layout.
- PZEM004Tv30.h: This library is likely related to the PZEM-004T v3.0 sensor, commonly used to measure electrical consumption and related parameters.
- SoftwareSerial.h: This library is used to create virtual serial ports on specific digital pins.

- ESP8266WiFi.h and BlynkSimpleEsp8266.h: These libraries are used to connect the ESP8266 device to a Wi-Fi network and utilize the Blynk platform for remote control and monitoring.

This programming is likely used for projects involving reading data from the PZEM-004T sensor, displaying information on the LCD, and sending data over Wi-Fi with the help of the Blynk platform.

The code snippet provided sends data including TDS, AC Voltage, AC Current, AC Power, and Total Energy to Blynk. Here's a brief explanation:

Blynk.virtualWrite(V4, tdsValue);

// Sends the TDS value to the Virtual Pin V4 on Blynk

Blynk.virtualWrite(V5, acVoltage);

//Sends the AC Voltage value to Virtual Pin V5 on Blynk.

Blynk.virtualWrite(V6, acCurrent);

//Sends the AC Current value to Virtual Pin V6 on Blynk.

Blynk.virtualWrite(V7, acPower);

//Sends the AC Power value to Virtual Pin V7 on Blynk.

Blynk.virtualWrite(V8, totalEnergy);

// Sends the Total Energy value to Virtual Pin V8 on Blynk.

Each Blynk.virtualWrite command sends data to the corresponding widget in the Blynk app, allowing you to monitor and analyze data from the device through the Blynk mobile app.

System Testing

Once the system has been developed into a ready-to-use software, it must be tested before deployment. This testing is conducted using Black Box testing methodology, performing various trial tests on the developed device.

System Evaluation

Evaluate whether the finalized system meets the expected requirements. If yes, proceed to step 7; if not, repeat steps 4 and 5.

System Utilization

The tested and requirement-compliant software is now ready for use. The design diagram can be viewed in Figure 3.

Data Analysis

In the analysis of data in this research, the data analysis technique is employed to measure factors that may affect the sustainability of a product's feasibility. One of the calculations performed is Error, Accuracy, and Precision.

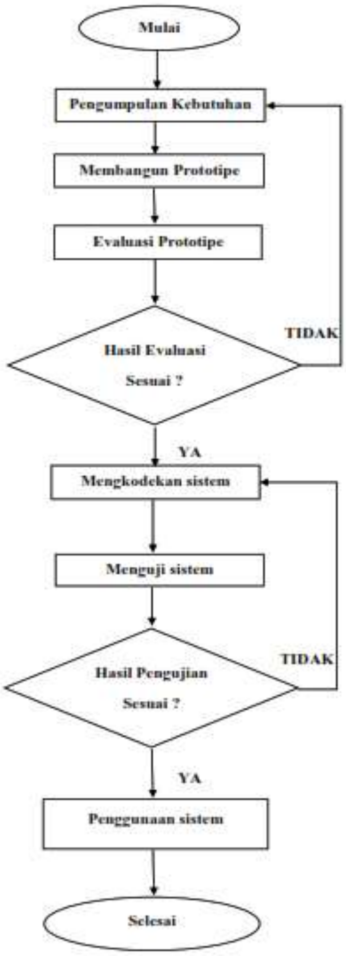

Figure 2 Planning flow chart

a. Error

Error, or deviation, represents the disparity between a measurement value and its true value, as articulated by Cohen (1998).

$$Error = |Yn - Xn|$$
$$Error\ (\%) = \frac{Yn - Xn}{Yn} \times 100\%$$

Where:

Error :Absolute Error

Yn :True Value

Xn :Measured Value

b. Accuracy

Accuracy is defined as the proximity of measurement results from a measuring instrument to an agreed-upon standard value or to a true value. To obtain the relative accuracy value, the following equation is utilized (Cohen, 1998):

$$A = 1 - \left|\frac{Yn - Xn}{Yn}\right|$$

Where:

Xn :Measured Value

Yn :True Value

A :Relative Accuracy

Accuracy can also be expressed as a percentage, calculated as follows:

Accuracy Percentage = 100% - Percentage Error

c. Precision

Precision refers to the closeness of repeated measurements to the average measurement (Cohen, 1998). The equation for precision value is as follows:

$$Persen\ Precision\ (\%) = 100\% - \left|\frac{Xn - \overline{Xn}}{\overline{Xn}}\right| x100\%$$

Where:

Xn :Measured Value

Xn :Average Measured Value

Result and Discussion

a. Measurement of Electrical Energy Consumption

The measurement results for 8 loads (water pumps) can be seen in Figure 4.

Figure 4: Measurement of 8 Loads (Water Pumps)

From the conducted measurements, it was observed that there are several water pumps with the same brand but different types, hence their specifications differ. It can be concluded from the measurement results that the system is functioning properly. The measured results can be comprehensively understood through Table 1.

From the overall measurement results of the 8 loads (water pumps), it was found that the power consumption was 236 W, current was 2.05 A, and voltage was 219 V. These measurements were conducted over a period of 1 hour. Since the loads operate for 24 hours, the electrical energy consumption in the hydroponic system is 5.66 kWh per day. The measurement results can also be seen in Figure 5.

Table 1. Measurement Results of Electrical Energy Consumption in Hydroponic Plants

Number of load	Power (W)	Current (A)	Voltage (V)
1	20	0,18	215
2	49	0,23	214
3	94	0,45	223
6	128	1,70	220
8	236	2,05	219

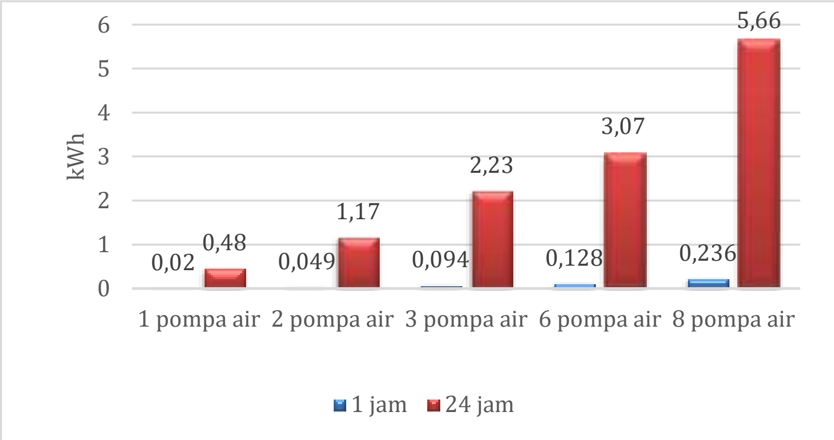

Figure 5: Measurement of energy

In this study, the electrical power used corresponds to the household customer group with a power of 1,300 VA. Therefore, the tariff for this group is Rp 1,444.70/kWh. The cost calculation of using electrical power in the hydroponic system, which employs water pumps as loads.

b. Measurement of Water Concentration (Nutrient) in Hydroponics

This measurement is conducted to determine the nutrient concentration (PPM). The TDS Meter sensor can measure the concentration of nutrients in the water used for hydroponic plants, specifically with AB Mix nutrients. In the first measurement, with a water capacity of 130 liters and nutrient mixture of 1.2 liters, the result was 363 PPM as can be seen in Figure 6 . The second measurement, with a water capacity of 100 liters and nutrient mixture of 1 liter, yielded 495 PPM. The ideal nutrient concentration for lettuce hydroponic plants ranges from 560 to 840 PPM. Exceeding this range can disrupt the water absorption by the plants, affecting the photosynthesis process.

c. Testing of PZEM-004T Sensor

Testing the device is crucial to assess the performance of the device and its components. Several tests were conducted on the PZEM-004T sensor:

Voltage Testing

The average voltage measurement on the PZEM-004T compared to a multimeter resulted in an average voltage of 223.8 V, with an error of 0.25%, accuracy of 99.74%, and precision of 99.82%.

Current Testing

The average current measurement on the PZEM-004T compared to a multimeter resulted in an average current of 2.44 A, with an error of 0.60%, accuracy of 99.39%, and precision of 99.70%.

Figure 6. Nutrient measurement

Power Testing

The average power measurement on the PZEM-004T compared to a multimeter resulted in an average power of 223.8 V, with an error of 0.25%, accuracy of 99.74%, and precision of 99.82%.

Conclusion

Based on the measurement of electrical energy consumption in hydroponic plants using 8 water pumps, it was found that the daily consumption is 5.66 kWh. The cost of using electrical power for 1 hour is Rp 340.94, for 24 hours it is Rp 8,182.78, and for 30 days it is Rp 245,483.00. The testing of the PZEM-004T sensor resulted in an average error of voltage of 0.25%, accuracy of 99.74%, and precision of 99.83%. For current, the average error was 0.60%, accuracy was 99.39%, and precision was 99.79%. Finally, the average error for power was 0.66%, with an accuracy of 99.34%.

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