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Water Usage and Electrical Power Consumption Monitoring System Based on IoT

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***Abstract*—This research aims to design and evaluate the performance of an Internet of Things (IoT)-based monitoring system for water usage and electrical power consumption, integrating a YF-S201 flow meter sensor to measure water volume and a PZEM-004T V3.0 sensor to measure electrical parameters within a single integrated platform. The system was built using an ESP32 microcontroller as the main control unit, a solenoid valve controlled through a relay as the actuator for automatic water filling, Firebase Realtime Database for real-time data storage, and a Kodular-based Android application as the user interface. The research employed a Research and Development (R&D) method, in which the system was tested directly under real operational conditions. Test results show that the system was able to fill water according to target volumes (5L, 15L, and 19L) with average error percentages of 1.88%, 1.41%, and 5.12% respectively, resulting in an average system accuracy of 97.1%. The PZEM-004T sensor demonstrated high accuracy in voltage readings (average error -0.285%) but lower accuracy in current readings (average error -6.44%). The system also successfully calculated estimated electricity costs based on the R-1/1300VA electricity tariff.**

***Index Terms*—Internet of Things, flow meter, PZEM-004T, ESP32, Firebase Realtime Database, water and electricity monitoring.**

I. Introduction

Water and electrical energy are widely used resources for daily activities, so their usage needs to be monitored in order to obtain more measurable consumption information. Continuous monitoring can provide information on resource usage and support the evaluation of consumption patterns. The development of Internet of Things (IoT) technology provides an opportunity to develop monitoring systems capable of automatically acquiring and transmitting measurement data through the internet network. The application of this technology can help reduce dependence on conventional recording processes and provide resource usage information more quickly.

In water usage, conventional recording still has limitations because the measurement and recording process requires direct inspection. Latifah et al. showed that the use of conventional water meters for discharge calculation makes the recording process less effective, which led to the development of an automatic IoT-based water discharge calculation system that can provide water usage and billing information through an application [1]. This condition shows that automatic measurement of water usage is needed to obtain consumption information more easily and measurably. The use of flow sensors is one approach that can be used to obtain such data, since water discharge can be calculated based on the flow passing through the sensor.

The development of IoT-based water measurement systems has been carried out using various types of sensors and monitoring methods. Zaenurrohman et al. developed a water discharge monitoring system for pipes using an ultrasonic flowmeter connected to a webserver. The system was able to display discharge data as a real-time graph and store the data in a database for display in tables and graphs [2]. The use of a water flow sensor was also applied by Wahyuni et al. through the development of an IoT-based flow measurement instrument. That study used a Water Flow Sensor and obtained an RMSE of 0.31 L/minute, or a deviation of about 4.12%, while the data transmission success rate to the platform over 24 hours reached 98.1%. This shows that flow sensors can be used to obtain real-time water usage data while also supporting the monitoring process through the IoT network [3].

Water usage monitoring can also be carried out by integrating flow sensors with digital interfaces so that consumption information can be accessed by users. Novelliani and Wildian developed a PDAM water usage monitoring and notification system using a water flow sensor and Arduino that can display the amount of discharge and the cost of water usage in real time via Telegram, with an accuracy of 95.62% [4]. Meanwhile, Rosyady and Anugerah developed a household water consumption monitoring system using a YF-S201 waterflow sensor, an Arduino Uno, an ESP32, and a website. The system can display discharge, volume, and estimated water consumption cost information in real time on a website, with an average volume measurement error of 4.61% [5]. Yulianto and Kusban also developed an IoT-based water usage cost calculator using a flow sensor, which allows water usage data to be displayed directly on the device and sent to a Blynk server to be accessed through a real-time web dashboard [6]. These studies show that the use of flow meter sensors integrated with IoT can provide water usage information more easily, automatically, and sustainably.

In addition to water usage, electrical energy is also a resource that needs to be monitored, since the continuous use of electrical equipment can lead to energy consumption that is difficult to determine without direct measurement. Monitoring of electricity consumption is required to determine the amount of energy used and the resulting cost. Chairunnisa and Wildian developed a device to monitor the cost of electricity usage using a PZEM-

004T sensor and the Blynk application. The system was able to display electrical energy usage along with its cost in real time via an LCD and the Blynk application, with an error percentage of 0.1% for current and 0.004% for voltage [7].

The use of the PZEM-004T sensor also allows several electrical parameters to be obtained in a single measurement process. Adiwiranto et al. applied a PZEM-004T sensor, a NodeMCU, and the Ubidots platform to measure voltage, current, power, power factor, and electrical energy. The measurement results could be displayed through the Ubidots platform and an LCD, with test results showing a voltage accuracy of 98.94%, current accuracy of 99.18%, power accuracy of 98.87%, power-factor accuracy of 98.44%, and energy-consumption accuracy of 97.89% [8]. Nirwan and Hafidz also developed a PZEM-004T-based electrical energy consumption monitoring prototype capable of displaying real-time electricity consumption data, storing the measurement results in a database, and displaying graphs and cost estimates through a website [9]. Thus, the use of the PZEM-004T sensor can support the electricity consumption monitoring process by providing electrical data that can be displayed and stored digitally.

Based on the monitoring needs of these two resources, integrating water and electricity usage monitoring into a single system can provide more comprehensive information and reduce the need for separate monitoring systems. Sadida and Tukadi developed an IoT-based system for monitoring electrical power usage and water flow using a PZEM-004T as the power sensor and a water flow meter as the flow sensor. Test results showed an average error of 0.11% for the PZEM-004T and 0.46% for the water flow meter after the calibration process, with the system able to monitor electricity and water usage on a household scale [10]. These results indicate that the integration of a flow meter sensor and a PZEM-004T sensor within a single monitoring system can be applied to obtain water and electricity usage data simultaneously.

Although the integration of both sensors has been applied in previous studies, there is still room for development in the management and presentation of data so that water and electricity usage information can be monitored in a more structured and responsive manner within a single platform. Therefore, this research develops an IoT-based monitoring system that integrates a flow meter and a PZEM-004T within a single platform to monitor water and electricity usage in real time, and evaluates the system's performance under operational conditions. This research aims to design and develop an efficient and adaptive IoT-based monitoring system capable of integrating a flow meter sensor for water usage monitoring and a PZEM-004T sensor for electricity usage monitoring within a single platform, as well as to test the system's performance to ensure the effectiveness of water and electricity usage monitoring under real operational conditions.

II. METHOD

This research is a Research and Development (R&D) study. The developed system was directly installed and tested on an operating water filter installation, so testing was carried out under real environmental conditions. The research was conducted at Lab 405 and Jln. Pepaya VI No.19B, North Jakarta, over a period of three months.

A. Flowchart

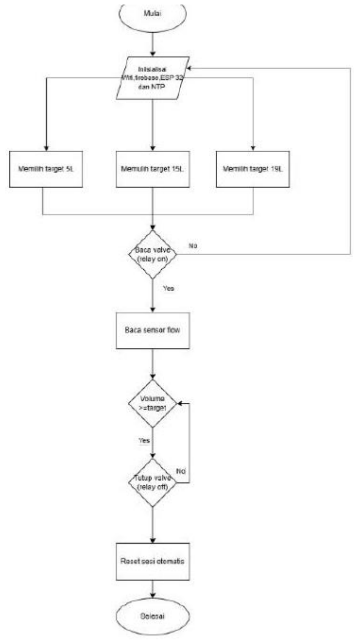

Fig. 1. System Flowchart

The flowchart in Fig. 1 shows the workflow of the IoT-based water usage monitoring system using an ESP32 microcontroller as the main controller. The process begins with system initialization, in which the ESP32 connects to the Wi-Fi network, links the system to the Firebase Realtime Database, and activates the Network Time Protocol (NTP) service for time synchronization. At this stage, all components such as the flow meter sensor, the relay, and the solenoid valve are also configured to be ready for use.

After initialization is complete, the user selects the target water volume through the Android application built using Kodular. The system provides three volume options: 5 liters, 15 liters, and 19 liters. The target value selected by the user is then sent to Firebase and read by the ESP32 as the reference (setpoint) value for the filling process.

Next, the ESP32 checks the status of the relay that controls the solenoid valve. If the relay is not yet active, the system remains in a waiting state until the user issues a command to start the filling process. Once the relay is active, the solenoid valve opens so that water begins to flow through the pipe and the flow meter sensor begins to detect the water flow rate.

During the filling process, the flow meter sensor generates pulses proportional to the amount of water flowing. These pulses are counted by the ESP32 to continuously obtain the water volume value. The sensor reading is then compared with the previously set target volume. If the measured volume is still smaller than the target, the system continues reading the sensor until the volume increases. Conversely, once the water volume reaches or exceeds the target, the ESP32 commands the relay to cut off the electrical supply to the solenoid valve. As a result, the solenoid valve automatically closes so that the water flow stops at the desired volume.

B. Schematic

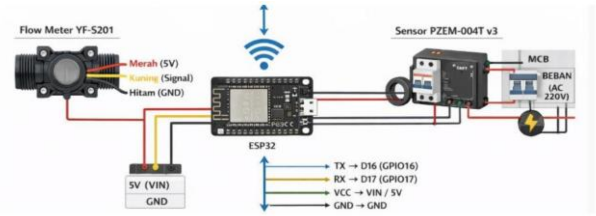

Fig. 2. System Schematic

The schematic in Fig. 2 shows the connections between the components used in the IoT-based water and electrical power usage monitoring system. The main component acting as the control center is the ESP32 microcontroller, which has Wi-Fi communication capability so that it can transmit sensor reading data to the Firebase Realtime Database in real time. The ESP32 receives data from two sensors: the YF-S201 flow meter, which measures the volume of flowing water, and the PZEM-004T V3 sensor, which measures electrical parameters. The data processed by the ESP32 is then sent through the internet network so that it can be displayed on the Android application developed using Kodular.

The YF-S201 flow meter sensor has three connection lines: a red cable as the 5V power supply (VIN), a black cable as ground (GND), and a yellow cable as the signal pin, connected to one of the ESP32's digital pins to read the pulses generated by the sensor. These pulses are counted by the ESP32 and converted into discharge and volume values for the water that has flowed through the pipe.

Meanwhile, the PZEM-004T V3 sensor is used to monitor electrical parameters including voltage, current, power, energy, frequency, and power factor on a 220V AC load. Communication between the ESP32 and the PZEM-004T uses a UART serial interface, in which the sensor's TX pin is connected to the ESP32's GPIO16 (RX2) pin and the sensor's RX pin is connected to the ESP32's GPIO17 (TX2) pin. In addition, the sensor's VCC pin is connected to a 5V power source (VIN) and its GND pin is connected to the ESP32's ground (GND). The PZEM-004T sensor is also connected to the electrical network via an MCB (Miniature Circuit Breaker) and the 220V AC load, enabling it to measure electrical parameters directly.

C. 3D Design

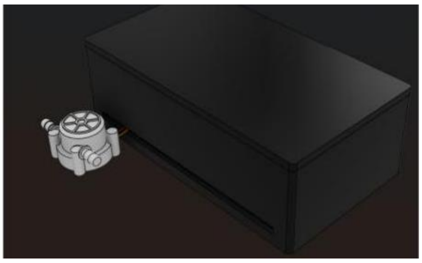

Fig. 3. Isometric view

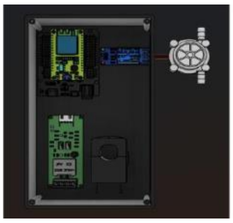

Fig. 4. Interior view

The hardware design in Fig. 3 and Fig. 4 shows the layout of the IoT-based monitoring system's components inside a panel box. The main components used include the ESP32 microcontroller as the control center, a relay module as the actuator controller, the PZEM-004T sensor for electrical parameter measurement, and the flow meter sensor, which is mounted outside the box so that it can be connected directly to the water flow line. The component layout was arranged neatly to facilitate assembly, maintenance, and wiring.

This design was created with consideration for safety and efficient use of space inside the panel. The ESP32 is placed at the top to facilitate access to the Wi-Fi connection, while the relay and the PZEM-004T sensor are positioned separately to minimize interference with the electrical system. The flow meter sensor is placed outside the box because it needs to detect water flow directly in the pipe. With this design, all components can work in an integrated manner, allowing the system to monitor water usage and electrical power consumption in real time, more reliably, and with easier installation and maintenance.

III. RESULTS AND DISCUSSION

The system was successfully implemented with the ESP32 as the main processing unit, integrating the flow meter sensor, the PZEM-004T sensor, a relay, and a solenoid valve within a single casing designed using Fusion 360. The Kodular application successfully displays current, voltage, power, energy (kWh), estimated cost, and real-time water flow rate, and provides buttons for selecting the target volume (5L, 15L, 19L) and for on/off valve control. The database structure on the Firebase Realtime Database was designed with three path groups: sensor data, system status data, and control data, as shown in Table 1.

TABEL 1. FIREBASE REALTIME DATABASE PATH STRUCTURE

Path	Data Type	Function
sensor/flow/rate	Number (float)	Real-time water flow rate (L/min)
sensor/pzem/1/voltage	Number (float)	Measured voltage (V)
sensor/pzem/1/current	Number (float)	Measured current (A)
status/total_liter	Number (float)	Cumulative water volume
kontrol1/valve	Boolean	Valve open/close command
kontrol1/target_liter	Number (int)	Target fill volume (5/15/19 L)

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Fig. 5. Realized Device

The figure shows the realization of the IoT-based water and electrical energy usage monitoring device that was successfully designed and implemented. The device consists of a water storage container, a flow meter as the discharge and volume measurement sensor, a PZEM sensor to measure electrical parameters, the ESP32 as the main microcontroller, a relay, and a solenoid valve that automatically regulates the water flow. All components are integrated so that the device can monitor water and electricity usage in real time, send data to Firebase, and display information through the Kodular application. The assembly results show that the system functions according to the design, with the solenoid valve able to open and close automatically based on the target water volume set through the application.

Accuracy testing of the system against three fill-volume targets was carried out in five trials for each target, using a measuring cup as the comparison instrument. A summary of the test results is shown in Table 2.

TABEL 2. SUMMARY OF WATER VOLUME MEASUREMENT ACCURACY

Target (L)	Average Sensor Reading (L)	Average Error (%)	Accuracy (%)
5	4.988	1.88	98.12
15	15.18	1.41	98.59
19	19.97	5.12	94.88

The overall average error percentage across all targets was 2.80%, resulting in an average system accuracy of 97.1%. The largest error occurred at the 19-liter target, caused by the solenoid valve's response delay, the water-hammer effect when the valve closes abruptly, and variations in water source pressure that affect the number of pulses read by the flow meter sensor. Nevertheless, all test results remained within the sensor's accuracy tolerance based on its datasheet (approximately ±10%), so the sensor is considered suitable for use as a water usage monitoring device in the developed IoT system.

Testing of the PZEM-004T sensor was carried out on several types of loads (a single-phase motor, a laptop charger, and a phone charger) by comparing the voltage and current readings against an AVO meter and a clamp meter. The test results are shown in Table 3.

TABEL 3. PZEM-004T SENSOR MEASUREMENT RESULTS

Load	AVO Voltage (V)	PZEM Voltage (V)	Error V (%)	Reference Current (A)	PZEM Current (A)	Error I (%)
Single-phase motor	229.0	228.4	-0.262	0.024	0.023	-4.17
Single-phase motor	228.3	227.6	-0.307	0.023	0.021	-8.70
Laptop charger	228.8	228.2	-0.262	0.296	0.302	-2.03
Laptop charger	228.5	227.9	-0.262	0.301	0.306	-1.66
Phone charger	228.7	228.1	-0.262	0.089	0.091	-2.25

Based on Table 3, the PZEM-004T sensor shows high accuracy in voltage readings, with an average error of -0.285%, but much lower accuracy in current readings, with an average error of -6.44%. The consistently negative error direction (undershoot) for both parameters indicates a systematic bias rather than random error. The low accuracy of the current readings is caused by the characteristics of the current-transformer (CT) sensor, which is less precise at small current ranges (tens of milliamperes), given that the PZEM-004T is designed for a current range of up to 100A and therefore operates at the lower end of its working range in this test.

The measured voltage and current data were converted into power values (P = V × I) to calculate the estimated electricity cost based on the R-1/1300VA electricity tariff of Rp1,444.70/kWh. The calculation results show that the single-phase motor had the largest estimated electricity cost (around Rp129.37–Rp129.57) due to its higher energy consumption compared with the other loads, followed by the laptop charger (around Rp99.56–Rp100.75) and the phone charger with the lowest energy consumption (around Rp30.00).

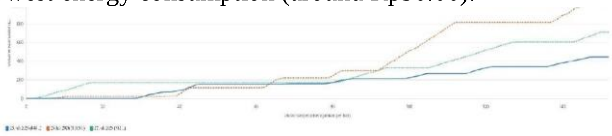

Fig. 6. Cumulative Water Volume Integral Curve — 25, 26, and 27 July 2026

The shape of the integral curve in Fig. 6 shows a step-like pattern, where the cumulative volume remains constant during periods without water flow and increases sharply during periods when the system is actively flowing water. This pattern is consistent with the system's on-demand working mechanism, which only actively flows water when a filling command is issued by the user through the Kodular application.

Water discharge monitoring is carried out automatically and continuously, with discharge data recorded every second and sent to Firebase as a permanent archive. Monitoring tests over three observation days (25, 26, and 27 July 2026) showed that the highest cumulative volume occurred on 26 July 2026, at 1,114.73 liters, consistent with the longest observation duration on that day. The cumulative volume was calculated using the trapezoidal-rule numerical integration method applied to the continuously recorded discharge data (L/minute), producing a step-like curve pattern consistent with the system's on-demand working mechanism.

Because the system uses a Firebase polling method with a 3-second interval, the theoretical maximum response time between a user command and its execution by the ESP32 is 3 seconds. The non-blocking mechanism based on the millis() function proved effective in maintaining system stability, since the sensor-reading process, data writing to Firebase, and valve control can run in parallel without interfering with one another, allowing the monitoring system to operate consistently throughout the testing period.

IV. Conclusion

Based on the design, implementation, and testing carried out, it can be concluded that the IoT-based water and electrical power usage monitoring system, using an ESP32, a YF-S201 flow meter sensor, a PZEM-004T V3.0 sensor, and a solenoid valve, was successfully designed and implemented with on/off control through the Firebase Realtime Database and the Kodular application. The system is able to fill water according to the target (5L/15L/19L) with an average accuracy of 97.1%, with a tendency toward larger errors at higher volume targets due to solenoid valve response delay and water source pressure variation. On the electrical power monitoring side, the PZEM-004T sensor produced very good voltage measurement accuracy (average error -0.285%) compared with current measurement (average error -6.44%), caused by the characteristics of the current-transformer sensor, which is less precise at low current ranges. The system also successfully calculated the estimated electricity cost based on the R-1/1300VA electricity tariff, demonstrating that it can operate optimally as a real-time IoT-based medium for monitoring water and electrical energy usage.

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References

[1] A. Latifah, Y. Septiana, and A. A. Nurhakim, “Perancangan Sistem Perhitungan Debit Air Otomatis Berbasis Internet of Things pada PDM Tirta Garut,” in Jurnal Sistem Cerdas, APIC, 2021.

[2] Zaenurrohman, R. P. Dewi, and F. Hazrina, “Monitoring Debit Air Pada Pipa Menggunakan Ultrasonic Flowmeter Berbasis Internet of Things (IoT),” TEKNO Jurnal Teknologi Elektro dan Kejuruan, vol. 30, 2020.

[3] M. I. Wahyuni, H. A. Kusuma, and S. Nugraha, “Pengembangan Instrumen Pengukuran Aliran Air Berbasis Internet of Things,” 2021.

[4] J. Novelliani and Wildian, “Sistem Monitoring dan Notifikasi Penggunaan Air PDAM Berbasis Arduino dan Telegram,” Jurnal Fisika Unand (JFU), vol. 10, no. 2, pp. 219–224, 2021.

[5] P. A. Rosyady and P. A. Anugerah, “Sistem Monitoring Konsumsi Air Rumah Tangga Berbasis Website,” Jurnal Teknologi Elektro, vol. 14, no. 2, p. 62, 2023.

[6] K. A. Yulianto and M. Kusban, “Alat Penghitung Biaya Pemakaian Air Berbasis IOT,” Emitor: Jurnal Teknik Elektro, vol. 22, no. 2, pp. 133–138, 2023.

[7] I. Chairunnisa and 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, 2022.

[8] M. N. Adiwiranto, C. B. Waluyo, and B. Sudibya, “Prototipe Sistem Monitoring Konsumsi Energi Listrik serta Estimasi Biaya pada Peralatan Rumah Tangga Berbasis Internet of Things,” 2022.

[9] S. Nirwan and Hafidz MS, “Prototipe Sistem Monitoring Konsumsi Energi Listrik Berbasis Internet of Things,” 2020.

[10] E. R. Sadida and Tukadi, “Rancang Bangun Sistem Monitoring Penggunaan Daya Listrik dan Aliran Air Berbasis IoT (Internet of Things),” JREEC Journal of Renewable Energy, Electronics and Control, 2024.