Design and Development of Water Distribution Monitoring System in Regional Drinking Water Companies (PDAM) Based On Internet Of Things

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Abstract. The purpose of this study is to create a prepaid PDAM clean water distribution system using a microcontroller based on the Internet of Things (IoT). The hardware used to realize the system consists of ultrasonic sensors, water flow sensors, relays, LCD buzzers and Arduino. ESP 8266 01 for delivery to the Thingspeak app. From the test results obtained HC-SR04 ultrasonic sensor reading error occurs when the water level is low and too high, the maximum measurable water level is 95%. When calculating the comparison between the water discharge that is read by the sensor and that measured by the measuring cup, the results are always not the same. The error when testing the water flow sensor at the water level is less than 49% this is influenced by the speed of the water fired by the pump, where the pump will be under low pressure when the water level is below that value. The system can monitor data readings from the water flow sensor using the ESP8266 monitored on the thinkspeak web server using a smartphone. Overall the tool can function well.

1. Introduction
Water is an essential compound for all forms of life. Humans are never separated from the use of water every day, both for consumption and for other daily uses. Clean water has become one of the basic needs for humans. Guaranteed water used by humans also affects health. Currently, the government distributes clean water through the Regional Drinking Water Company (PDAM). The distribution of PDAM water to the community is currently done on a postpaid basis. Where the community first uses PDAM water, then pays it once a month. The PDAM calculates the volume of water distributed using a water meter. The water meters currently in use require periodic calibration so that they are accurate in calculating the volume of water used by residents.

From the PDAM water distribution system, problems often occur including clean water from PDAM sometimes not flowing or dead, and frequent damage to residents’ water meters so that the increasing PDAM water bill costs are not in accordance with the use of water, calibrating water meters regularly so that the level of problems with the cause of the damage to the water meter is reduced, residents often forget that it is time to pay for PDAM water and result in fines because they have passed the payment due date. This makes consumers who use PDAM water feel disappointed and complain about it. Based on these problems, this study designed a monitoring tool for PDAM water usage that enters residents' homes so that it can be monitored directly (online) and can be monitored remotely using the internet.
network. The development of information technology has given birth to technological innovations such as the Internet of Things (IoT) [1]. Currently, IoT has been applied to agriculture [2], health [3], parking monitoring [4] and industry[5], IoT technology in basically used as control [6] and monitoring [7].

Research related to water distribution has been done previously. The study conducted by [8] proposed a web-based real-time water monitoring system. The MPX5700AP sensor is used to measure water pressure. The GSM/GPRS module functions for communication with the server via the GSM/GPRS network, the results of the study show that the system can measure water pressure and display graphs on the web. A study conducted by [9] proposed a water monitoring system using an IoT-based model. The prototype is made using an ultrasonic sensor to detect the water level, the GSM module will send a message when there is activity on the water pump. A study conducted by [10] realized an IoT-based Smart Water Level Controlling System [WLCS] to measure water levels and control the filling of water tanks. Similar research was also carried out by [11] to realize a tool that can monitor water levels automatically. The ultrasonic sensor HC-SR04 will detect the water level. If the water reservoir is full or reaches the 100% level, the sensor will detect the water level and the water supply pump will automatically turn off.

In this study, a system was created to monitor the volume of water quota with ESP8266 using Thingspeak. The system made is a prototype with simulation testing. The purpose of this study is to create a prepaid PDAM clean water distribution system using a microcontroller based on the Internet of Things (IoT).

2. Research Method

The design of this system consists of hardware design and software design. Figure 1 is a block diagram of a water distribution monitoring system design at a Regional Drinking Water Company (PDAM) based on the Internet of Things (IoT).

![System Block Diagram](image)

From Figure 1, it can be explained that the input of clean water to residents' homes is carried out using a personal computer (PC) through a web page that is connected to a LAN (local area network). If the data has been inputted into the microcontroller then the water quota can be used. by pressing the push button on the house meter so that the pump and solenoid valve are active and water can flow into people's homes. The data from the push button is received by the microcontroller to activate the pump and solenoid valve. When the water quota is up, the solenoid valve will automatically close. When water flows into people's homes, the water will go through the water flow sensor. By using this water flow sensor, the volume of water entering the residents' homes is calculated whose sensor reading data is sent to the microcontroller and then displayed on the LCD. Monitoring via a smartphone on this device uses an ESP8266 with a Thinkspeak web server. By using Thinkspeak the amount of water that has been used can be continuously monitored as long as you have internet access. The reading data from the Water Flow sensor is displayed on Thinkspeak in the form of a graph. If the calculation has reached the quota from the purchase of water, the solenoid valve closes and turns on the buzzer at the residents' houses as a warning for water consumption per 1 liter and when the water quota has run out.
2.1 Hardware Design
To control the 12Vdc solenoid valve, a switching circuit is used which is connected to pin 6 and pin 5. When the pin on the Arduino Mega 2560 is HIGH, the solenoid valve will open (normally open) and when the pin on the Arduino Mega 2560 is LOW, the solenoid valve will be closed (normally closed). In this circuit using an LED connected to a switching transistor as an indication of whether the solenoid valve is active or not. To control the ON/OFF conditions on the 220Vac water pump, a relay driver circuit is used which is connected to pins 7 and 8. This circuit also uses an LED which functions as an indicator when the water pump is ON or OFF as shown in Figure 2.

![Figure 2. Overall Series of IoT-Based PDAM Water Distribution Monitoring](image)

The Water Flow G1/2 sensor is used to calculate the amount of water that has flowed in the residents' homes connected to pins 20 and 21 by calculating the speed of water emitted by the water pump. Ultrasonic sensor HC-SR04, the trigger pin is connected to pin 48 while the echo pin is connected to pin 46 of the microcontroller, it is used for reading water available in the main gallon. The data read is the water level in the main gallon whose reading results are displayed on a web page on a PC. The data that has been read by the G1/2 water flow sensor stored on the arduino mega 2560 is sent to the arduino uno R3 using serial communication using the TX pin and the Rx pin to be displayed on the arduino uno LCD and monitored with the thinkspeak account using the ESP8266.

This circuit 5Vdc buzzer connected to pin 6 arduino uno. When the pin on the Arduino Uno R3 is HIGH, the buzzer is on and when pin 6 is LOW, the buzzer will turn off. The series of push buttons on this tool are used to activate the water quota that has been inputted. When the push button is pressed after the water is input, the water can flow to the customer connected to pin 13. The ESP8266 circuit is a circuit made for communication with internet monitoring data that has been read by the sensor. In this circuit using a 3.3Vdc voltage which is connected to the 3.3V pin on the Arduino Uno. When this Arduino has a HIGH logic, the ESP8266 01 will be active and can send sensor data that is connected to the internet network. The mechanical design of the tool can be seen in Figure 3.

![Figure 3. Mechanical Design of IoT-Based PDAM Water Distribution Monitoring](image)
2.2 Software Design
The software design process starts from initialization, then the sensor will read the water level in the filling tank, if the water level is 90% then the water will be distributed and will display a web page for filling the water quota. After the water is distributed, the customer will press the push button. If the push button is HIGH then the solenoid valve is ON and the water flow sensor reading will be displayed on the LCD and the data is sent to the smartphone via ESP8266. If the water quota is the same as the water flow sensor reading, the buzzer is active and the solenoid valve is OFF, as shown in Figure 4.

3. Experiment Result
In this section, the system testing that has been created is carried out. The test was carried out in two stages. The first stage is hardware testing and software testing. The prototype of the tool can be seen in Figure 5.

3.1 Hardware Testing
3.1.1. HC-SR04 Ultrasonic Sensor Testing with Arduino Mega 2560
Tests carried out on the ultrasonic sensor HC-SR04 to determine the performance of the sensor when used to transmit water level data in large gallons in the form of a centimeter (cm) distance which will be calculated into the water level level on the microcontroller. The test carried out on this sensor is to measure the water level which is read by the ultrasonic sensor HC-SR04 and the sensor data is compared with the ruler and the data measured by the sensor will be converted into a water level level in the form of percent, the data can be seen in table 1. the data obtained in testing the ultrasonic sensor HC-SR04 can be made in a comparison graph between the water level and the water level read by the sensor, figure 6 graphs of the comparison of the data.

Figure 4. IoT-Based PDAM Water Distribution Monitoring Flowchart
Ultrasonic sensors are sensors that work on the principle of ultrasonic waves. To get a distance measurement on the ultrasonic sensor, the trigger pin is first triggered so that it can emit ultrasonic waves which will be reflected by the water object and received by the echo pin on the ultrasonic sensor. The time difference between transmitting ultrasonic waves until it is received back by the ultrasonic receiver is a pulse that will be converted by Arduino to produce data from the amount of water capacity. The formula used in the program to convert the pulses captured by the echo is \( \text{cm} = \frac{\text{duration} \times 0.034}{2} \). Duration is the time span of pulse transmission from transmitter to receiver, and 0.034 is the speed of sound in microseconds. The error data contained in the table of experimental results is caused by the reflected plane of the signal from the transmitter to the receiver being different from the other data. The water storage tube is not cylindrical so that when the transmitter signal the field the reflection obtained is not from the surface of the water but from a concave wall. So based on the workings of the ultrasonic sensor where the time difference between the transmitter signal and the receiver signal becomes shorter. When the length of time is converted to distance, the value becomes smaller than the value of the
measuring instrument. The shorter time causes the existing distance data to be small. Errors do not occur when the reading is in the middle of the tube, this proves the curvature at the bottom and top that affects the reading.

When the sensor reading remains 2 cm even though the distance obtained on the measuring instrument is already smaller than 2 cm, this is due to the ability of the ultrasonic sensor based on the data sheet which explains that the minimum distance of the ultrasonic sensor to read is 2 cm, after that the sensor cannot read anymore. The error value obtained based on the bottom reading of the tube proves that the more concave a field is, the faster the signal bounces then over time the concave plane returns to linear, this can be seen based on the smaller error value. The largest error value is when the sensor's minimum capability is so that the error becomes 100.

The water level is the reciprocal of the distance measured by the sensor, the smaller the sensor distance, the greater the water level, and vice versa. This value indicates that if the water approaches the ultrasonic sensor which is above the gallon, then the distance of the measured water is getting closer to the sensor or the water in gallons is higher. Therefore, the water level is getting bigger. The water level cannot reach 100 percent due to the sensor performance. Increase the water level level with a different sensor distance, where the sensor distance range is 2 cm while the water level increase range is 5 and 6 cm.

3.1.2. Testing the Water flow Sensor Circuit
Water flow sensor testing is done to determine how the performance of the water flow sensor in measuring water flow. To find out the time needed to reach the input quota, use a stopwatch. The quotas distributed to households are 1 liter, 2 liter, and 3 liter. The water flow sensor when the data pin is fed by water has a voltage of about 3.5 to 3.9 V but when it is not flowing water the voltage measured at the data pin is 0.08 V. So this sensor sends a voltage to the Arduino pin used by the sensor. The test results for the 1 liter quota can be seen in table 2.

| Input (Liter) | Water level | Time (s) | Measuring glass (mL) | Water Discharge Measured By Sensor (mL) | Error (%) |
|--------------|-------------|----------|----------------------|-----------------------------------------|-----------|
| 1 Liter      | 95          | 12,66    | 1000                 | 1034                                    | 3,29      |
|              | 90          | 12,55    | 970                  | 994                                     | 2,41      |
|              | 87          | 12,51    | 1000                 | 1022                                    | 2,15      |
|              | 82          | 12,45    | 1000                 | 1025                                    | 2,44      |
|              | 76          | 13,06    | 1050                 | 1067                                    | 1,59      |
|              | 71          | 12,72    | 1000                 | 1043                                    | 4,12      |
|              | 65          | 13,06    | 1000                 | 1058                                    | 5,48      |
|              | 60          | 13,26    | 950                  | 1014                                    | 6,31      |
|              | 52          | 13,01    | 1000                 | 1041                                    | 3,94      |
|              | 49          | 12,5     | 950                  | 981                                     | 3,16      |
|              | 25          | 14,59    | 960                  | 993                                     | 3,32      |
|              | 19          | 13,98    | 940                  | 971                                     | 3,19      |
|              | 9           | 13,89    | 925                  | 970                                     | 4,64      |

This water flow sensor generates a frequency when the hall effect detects the magnetic field from the rotor, which generates a frequency pulse. The frequency pulse that will be calculated in the program to calculate the speed of the water flow, from the flow velocity can be used to calculate the water discharge. Based on the data that has been obtained, the resulting water discharge will be influenced by the level of the water level. The height of the water level is the pressure for the product of the rate at which water is fired at the pump. Based on table 2, it can be seen that when the water level starts to get low, the
resulting water discharge will decrease from the quota, and the time required exceeds the average of 1 second. The formula used to obtain this flow rate is as follows:

\[\text{flowRate} = \frac{(1000.0 \div (\text{millis()} - \text{oldTime})) \times \text{pulseCount}}{\text{calibrationFactor}};\]

Since the water flow calculation is iterative, therefore by calculating the number of milliseconds that have elapsed since the last execution and using it to develop the sensor output results. The program formula also applies calibration to develop results based on the number of waves per second per unit of measure (liters/minute in this case) coming from the sensor, this calibration aims to get the number of pulses per second for the size per liter of water according to the speed of the water. This calibration is done by entering a value to get the output of the water discharge according to the readings from the program calculations. After getting the flow rate in liters per minute, this flow rate will be converted into milliliters per second using the formula:

\[\text{flowMilliLitres} = \left(\text{flowRate} / 60\right) \times 1000;\]

Based on this formula, divide the flow rate by 60 seconds and multiply by 1000 mL. After getting the flow rate data in mL per second, this data is always added to get the water flow sensor reading data, using the program instructions:

\[\text{totalMilliLitres} += \text{flowMilliLitres};\]

From these data, it has been obtained the water discharge from the speed of the water. So the water discharge counter sensor used in this tool will not always fit from the data, because the addition of total MilliLitres of water to achieve the desired data will not always be the same.

3.2 Software Testing
This test aims to determine the performance of ethernet shield and esp8266 on this prepaid PDAM tool. The Ethernet shield functions as a web server. Network programming using HTML programmed in arduino. Testing the Arduino web server is done by connecting the Arduino web server to a personal computer using a UTP cable. Then the IP address of the computer is configured so that it can connect to the arduino web server. The results of the quota input test and monitoring using a smartphone can be seen in Figure 7.

![Figure 7](image)

**Figure 7.** The results of the quota input test and monitoring using a smartphone

This prototype system uses a computer network to connect to devices that function to monitor water levels and transmit data via PC devices. If the system is connected to the internet network, the information and data can be accessed from anywhere as long as the device used to control it is also connected to the internet network, but this system is only based on a LAN network. Arduino functions as a webserver, where HTML programs are located on Arduino which does not require a database. That is, it only displays the sensor data that we want to display on the web page according to the html program created, namely with the client.print(sensor data) program instructions. But to send data using the
program instruction if(Readstring.indexOf(the page to be read by Arduino)) after that the action that will be carried out by Arduino, for example inputting 1 liter of water quota and the action performed on the program by providing 1000 data, then The data will be processed by Arduino according to the program that has been made.

4. Conclusion
Based on the design of the prepaid PDAM system that has been made, it can be concluded that (1) HC-SR04 ultrasonic sensor reading error occurs when the water level is low and too high, because the minimum reading of the HC-SR04 ultrasonic sensor is 2 cm. So the maximum measurable water level is 95%. (2) When calculating the comparison between the water discharge read by the sensor and that measured by the measuring cup, the results are always not the same. This error is influenced by the speed of the water fired by the pump, where the pump will be under low pressure when the water level is less than 49%. (3) The system can monitor data reading from the water flow sensor using the ESP8266 monitored on the thinkspeak web server using a smartphone.

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