Vol. 1, No. 2, 2023
ISSN: 2987-3932
https://pubs.ast-ptm.or.id/index.php/eat

Design Water Flow Measurement with Ultra Sonic Sensor

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ABSTRACT

Human life in the world cannot be separated from the need for water. This water utilization can be maximized by implementing water use management. To carry out water usage management, precise measuring instruments are needed and continuous and up-to-date observations are made. So the measurement of water discharge needs to be done carefully and automatically. In this system the flow meter readings use ultrasonic. The reading results are obtained on the microcontroller. The output of this microcontroller is displayed through a display that can be read directly. Besides that, the reading results are also sent via modbus to an android phone or other receiving system. To determine the precision of the measurement, it is necessary to compare it with a manual flow meter. The process of comparing the measurement results with ultrasonic with manual measurements is carried out by installing a series between ultrasonic and manual meters. After that, the remote delivery process is carried out using modbus. The measurement results of the comparison of ultrasonic and manual meters show an error value of 6.45%. This tool can be used as a means of controlling water consumption and the results can be transmitted over long distances.

KEYWORDS
Ulltrasonic
Flowmete
PDAM

1. Introduction

Human life cannot be separated from the need for water. Water is used for cooking, bathing and washing. The use of water in big cities uses clean water supply facilities. This clean water provider is provided by a government agency, namely the regional drinking water company (PDAM). From the PDAM's perspective, they often experience water loss or leaks. Usually referred to as Non Revenue Water (NRW) or called Unbilled Water (ATR) [1]. Meanwhile, from the customer side, there is a problem with the meter system installed, which has a problem if it is not water but air. The meter measuring instrument is currently still done manually [2][3]. By using a mechanical system. Namely using a wheel that is placed in a pipe through which water passes. So this results in not only liquid being detected, but air will also be detected. To overcome this, it is proposed to manufacture a water flow meter (Flowmeter) using an ultrasonic sensor device [3].

This sensor is equipped with a screen display that can be read directly by the customer and can be sent to the PDAM office using the Internet of Things facility. In addition to using microcontroller media and the internet of things, artificial intelligence technology is also used to more precisely input and output data. Artificial intelligence in question is the use of the Fuzzy Inference System in the analysis process. By using this tool, customers as consumers and PDAM as the party providing clean water will get the latest data on water usage. This is done to make the design of the installation of an ultrasonic meter measuring instrument. The third stage is designing ultrasonic microcontroller sensors and remote communication systems using the Internet of Things. The fourth stage is to enter the artificial intelligence system in the microcontroller software [4].

From the above background, the problem can be formulated: How to make a measuring instrument for the use of clean water that uses an electronic digital system with the following provisions:

1. The reading of the material in the pipe is water (not air), it can be read directly by the customer's usage value.
2. Can read up-to-date clean water usage data and can send usage data to the PDAM office.

3. Digital measuring instruments that are made later have long durability and are not easily affected by weather and piping conditions at the customer.

In the implementation of this research, the process carried out is conducting research preparation where at this time the design of tools and methods of making tools are carried out. This includes the manufacture of tools

Hardware and software, because the process of running the system also depends on the software that is loaded into the microcontroller. Some literature shows how the water flow discharge measurement system is carried out. Based on previous research that utilizes ultrasonic sensors used to measure the height of rainfall [5]. The use of ultrasonic sensors is used to measure the water level in the dam [4][6]. Manufacture of a water velocity measuring device in a pipe using two ultrasonic transducer sensors consisting of a transmitter and a receiver. Measurements were made by comparing the results of the water flow velocity on the Doppler effect method with the pressure transmitter on the flow process training system T3300/03. The results obtained have an average error of 5.22% and based on the optimal interval (measurement stability) it is obtained that it has an average error of 3.85% [7], and also monitoring the flow of water in the pipe has been carried out using the TUF UFM module. -2000M which is integrated with several electronic module devices. Some of these electronic modules are Arduino Mega2560, RS458 module, SIM800L modem, RTC module and also 20x4 LCD [8][6]. Then the sequence of the process of carrying out research activities is made.

2. Method

The detailed explanation of the implementation stages that have been carried out are as follows:

1. Preparation Phase: is to conduct a literature study on the plan of the tool to be made. An introduction to the tool's characteristics and how it works. Thus, there is an adjustment process between the literature and the tool. The design of the tool used in this study is as shown in Fig. 1.

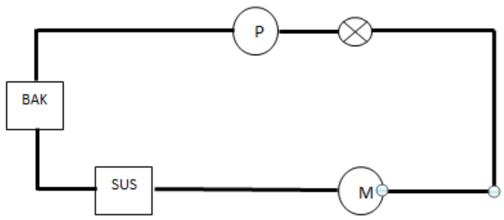

Fig. 1. Test Series

Caption :

P = Water Pump.

⊗ = Stop Valve.

M = Flow Meter Manual.

SUS = Flow Meter Ultrasonic.

BAK = Water tub.

Fig. 1 shows the circuit used to test the precision of the ultrasonic sensor in measuring the flow of water flowing in the system. Meanwhile, the tools used to transmit data are located separately from the above system.

2. The survey stage of the installation of the tool. At this stage a survey has been carried out on the plan to install tools on the pipe to the customer. The suitability of the installation of ultrasonic sensors and other electronic devices needs to be designed so that they do not require a large space. This survey has beencarried out by obtaining photo data of water meters to customers as shown in Fig. 2.

Fig. 2. PDAM Customer Water Meter (Regional Drinking Water Company)

Fig.2 shows the general design of the PDAM water customer meter where this installation uses a pipe with a diameter of dim[9][10]. There is a manual water meter that uses a pinwheel connection circuit between the water meter and the pipe along with a stop valve. With these conditions, the installation of ultrasonic equipment will be carried out on the secondary side after the water meter. If modifications are made to the secondary side after the water meter, then no permission is needed from the PDAM. Installation of the ultrasonic sensor requires a pipe length of approximately 20 cm. This measuring instrument is designed to be protected from water so that there is no short circuit. While the positioning of the control device is carried out close to the measuring instrument. This tool requires a direct current (DC) power supply and requires a Wifi network as a means to transmit data. Due to the need for these two systems, this problem must be conveyed in advance to both the customer and the PDAM.

3. Tool design stage. At this stage, the design of a clean water flow measuring instrument has been carried out using an ultrasonic sensor as shown in the block diagram in Fig. 3.
4. Tool making stage. Implementation of making tools with block diagrams as shown in Fig. 3.

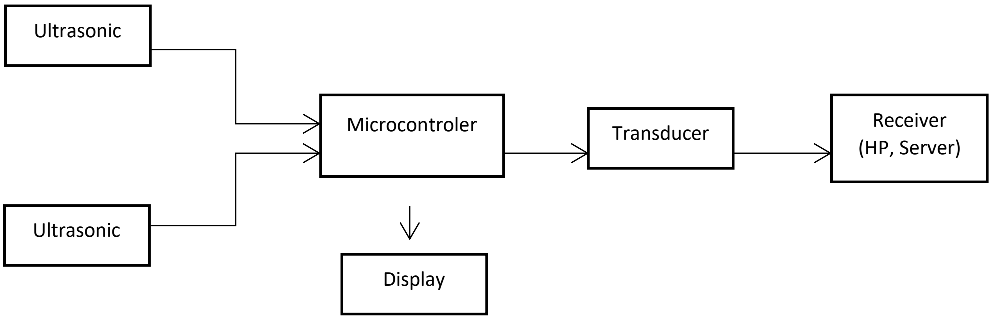

Fig. 3. Experimental Circuit Design

While the tools used are as shown in Fig. 4 until Fig. 8: The ultrasonic flow meter works based on speed, where ultrasonic waves are transmitted by the transducer which is passed by the flowing media so that the flow velocity is obtained by the ultrasonic transmitter. Ultrasonic flow transmitter will capture and process the signal from the sensor or transducer by providing the average flow velocity of the medium being measured. Ultrasonic flowmeters take advantage of the ultra sound vibrations generated by the transducer to measure the flow rate of liquids. There are two types of ultrasonic flowmeters, namely Doppler and Transit Time. Ultrasonic flow meters are ideal for measuring all types of fluids or fluids that are homogeneous and independent of the conductivity of the liquid.

Fig. 4. Sensor Ultrasonic Flowmeter

Fig. 5. Ultrasonic Sensor Reader

Ultrasonic Doppler Flow Meters measure the frequency shift, which is directly proportional to the flow rate. This value is multiplied by the internal cross-sectional area of the pipe to obtain the volumetric flow as shown below:

$\Delta f = 2fT \sin\theta \bullet VF/VS$

$VF = \Delta f/fT \bullet VT/\sin\theta T = K\Delta f$

Where

VT = Sound Velocity dari material yang mengalir

θT = Angle of transmitter beam

K = Calibration factor

VF = Flow velocity

Δf = Doppler frequency shift

VS = Sonic velocity of fluid

fT = Transmitter frequency

θ = Angle of fT entry into liquid

Volumetric flow rate = K • VF • D2

K = Constant

D = Inner diameter of the pipe

The type of Doppler operation depends on the particles flowing in the liquid, therefore care needs to be taken to minimize the concentration and size of the solids or bubbles contained in the liquid. Likewise, to maintain the continuity of the suspended solid the liquid must flow at a sufficiently high rate[7].

Fig. 6. Arduino

Basically, Arduino is an electronic instrument board that can function as an electronic component controller because it contains an Arduino Image microcontroller chip as shown in Fig. 6. The chip consists of a processor, memory, Arduino input output devices, as well as several additional supporting components. For several types of Arduino, most use the Atmega328 series microcontroller chip. While other types use a variety of microcontroller series. The role of the microcontroller on the Arduino is very important because it helps the process of automating commands based on program instructions. So it is very suitable for the process of making automated system projects, monitoring, and control systems. The working principle of Arduino can be described as shown in Fig. 7[11].

Fig. 7. Arduino Workflow

Data reading by input component > data is sent to input pin > data goes to the microcontroller > data is processed > data comes out of Arduino > data is sent to the output pin > data is forwarded to the output component.

Fig. 8. Display

In this study, the data transmission process is carried out using the modbus protocol. The Modbus protocol was created by a PLC company called Modicon in 1979 and until now it has become one of the standard communication protocols used in Automating Building management, Industrial Processes, etc. Several Types of Modbus:

1. Modbus Serial (RTU & ASCII)
2. Modbus TCP/IP
3. Modbus +

The Modbus Serial communication protocol regulates the ways and formats of serial communication (rs232 or rs485) between the master and the Slave (master or slave can be a PLC, microcontroller, smart device, etc.). The Modbus network consists of a Master and several Slaves, the Master taking the initiative to initiate communication including writing data, reading data, and knowing the status of SLAVE. The master request is also known as a request or query. Slave is only passive/waiting or in other words the Slave only responds if there is a request/query from the Master. The number of Slaves in the Modbus protocol can be as many as 247 slaves. Slave can be PLC, electronic equipment, controller, sensor etc. The modbus transaction is shown by the scheme as shown in Fig. 9.

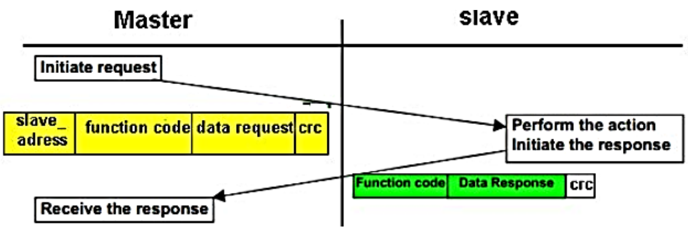

Fig. 9. Modbus Transaction Error

Storage In the modbus protocol there are 4 types of data storage with a length of 16 bits each.

1. Coil, Initially this type of data was used to activate the relay coil. the value of this data type is ON or OFF. Coil has a length of 16 bits, so to activate / ON by giving the value FF00H and 0000H for OFF. data FF00 and 00 are stored in registers 00000 to 09999.
2. Relay input / binary input / digital input / discrete input. In contrast to the coil, the relay input is used to determine whether the relay is ON or OFF. The relay input is read only for the master and can only be changed by the slave. The data is stored in registers 10001 to 19999.
3. Input Register, Input Regsiter is used to store analog data with a value range of 0 ~ 65535. The input register is read only for the master. This data is stored in registers numbered 30001 to 39999.
4. Holding Register, Holding register is used to store values in the range 0~65535. This register has register address 40001 to 49999, register address on modbus and function code used to access it.

3. Results and Discussion

By doing the experiment as in the block diagram of Fig. 3. Then the results of the test are obtained. In testing the ultrasonic sensor readings, what is carried out is to measure the water discharge (Flow). Some component settings are required by entering the value of the pipe material and pipe diameter. In the test, the data can be obtained as in table: 1 and table 2. With the graph as in Fig. 10.

Table 1. Comparison of Ultrasonic and Manual Flow

TIME	Flow	
Minute	**ultrasonic**	**manual**
1	40.88	1.00
2	41.92	2.10
3	42.87	3.00
4	43.89	4.05
5	44.90	5.00
6	45.75	5.90
7	46.93	7.00
8	47.92	7.90
9	48.89	8.80
10	49.91	9.90

In table 1 it appears that the results of ultrasonic measurements and manual measurements have almost the same results. This shows that the measurement of water discharge using ultrasonic has a fairly good accuracy. The flow rate for each measurement when using ultrasonic measurements starts at 40.88, this is because at that number measurements are started. Manual flow measurement using a manual water meter with a mechanical system. The manual flow meter shows the number starting at 1 and increasing per unit of time.

Table 2. Comparison of Ultrasonic and Manual Discharge Movements

TIME	Debit		deviasi	error
Minute	**ultrasonic**	**manual**		
1	1.04	1.10	0.06	5.45
2	0.95	0.90	0.05	5.56
3	1.02	1.05	0.03	2.86
4	1.01	0.95	0.06	6.32
5	0.85	0.90	0.05	5.56
6	1.18	1.10	0.08	7.27
7	0.99	0.90	0.09	10.00
8	0.97	0.90	0.07	7.78
9	1.02	1.10	0.08	7.27
			Sum	58.06
			Average	6.45

Table 2 shows that the numbers in columns 2 and 3 indicate the amount of water flowing. Measurements using ultrasonic and using a manual meter. How to calculate it, namely the designation of the flow rate in each minute minus the measurements in the previous minute. From the calculation results, the average error rate is 6.45%. This number is quite good at a certain level of error.

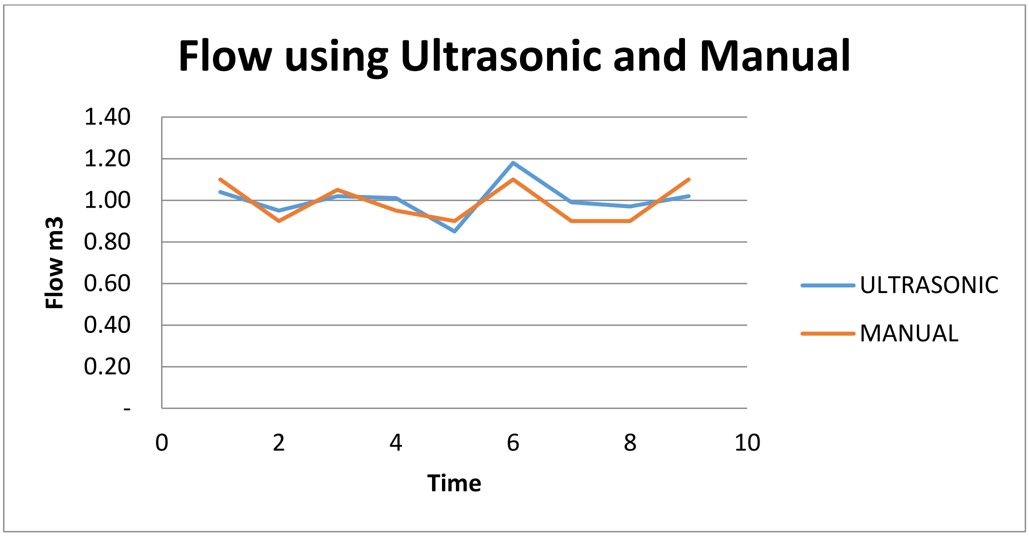

Fig. 10. Flow using Ultrasonic and Manual

In Fig. 10 it can be seen that there are differences in measurements using ultrasonic and manual, but they are not far apart. It can be seen in the graph that there are several increases in flow, this occurs due to the influence of the water discharge used. The second cause is the performance of the water pump used.

4. Conclusion

From the research above, it can be concluded that the measurement of water flow using ultrasonic has an error that is not high, namely: 6.45%. Therefore, ultrasonic flow measurement is an alternative that can be used to measure the flow of water discharge even though it uses a large pipe diameter. In addition, by using ultra sonic, this tool can be integrated with other tools, such as microcontrollers, tools for data transitions or other control tools.

Acknowledgements

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