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Implementation of Automatic Monitoring and Control System in Balloon Digester Type's Biogas Plant from Tofu Waste Using Ultrasonic Distance Sensor

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Abstract— **Biogas plant is a name often given to digesters that treat waste or sewage into biogas. The monitoring system is an important process to know the quality and quantity of gas produced and understand the processes inside the plant to achieve the optimum process. The monitoring process can be carried out by measuring the volume of biogas collected in the gas holder and the concentration of biogas produced (especially CH_4 gas). The manual method of monitoring and control system used a pressure gauge to estimate the volume of biogas. An automatic device was designed and tested for monitoring and controlling gasbag volume by using an ultrasonic sensor. This device measures the distance between the sensor to the surface of the gasbag and calculates it into volume. The sensors contained in this device had a good level of performance with a percentage error of 0.2% and a standard deviation of 0.32 cm. At the same time, the system design has a good level of performance to calculate the volume with a percentage value of 2.51% and a standard deviation of 0.18 cm. The designed system also has proper performance response, shown by the LED indicator turns off and the socket turns on when it reaches the setpoint. The results showed that the volume of the gasbag used in the plant had a maximum capacity of 102.984 kiloliters and a minimum capacity of 58.857 kiloliters, with a total filling time of 30.5 hours and a usage time of up to 12.5 hours.**

Keywords— **Monitoring; control system; automatic; biogas; balloon digester; distance sensor.**

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I. INTRODUCTION

The biogas plant is a name often given to digesters that treat waste or sewage into biogas. Biogas itself is a technology that utilizes biodegradable manure or waste that will be fermented from complex organic materials to simple materials through anaerobic processes [1], [2], [3], [4]. During the process, microorganisms convert biomass waste into biogas in the form of methane gas and several other gases such as carbon dioxide. In general, there are three types of digesters in biogas plants, i.e., fixed dome plant digester, floating dome plant digester, and balloon digester [5], [6], [7], [8]. The primary difference in digester type is the gas storage capacity and the construction of the digester itself [9], [10]. One example of a biogas plant is a biogas plant located in Giriharja subdisctrict, Sumedang, West Java, Indonesia. This biogas plant has a balloon digester type [11], [12]. In this plant, the tofu waste residue from Sumedang will be fermented into biogas for further distribution to resident's homes.

However, in practice, this plant has shortcomings in monitoring and controlling the volume of a gasbag (a type of gas holder) which is still done manually and not real-time, so the data is less accurate. These processes are essential to know the quality and quantity of the gas produced and to understand the processes inside the plant to achieve the optimum process [13]. In general, the monitoring process in a biogas plant is carried out by measuring the volume of biogas collected in the gas holder and measuring the concentration of biogas produced (mainly CH_4 and CO_2 gas) [14], [15], [16], [17]. Measurement of the volume of biogas itself can be done by measuring the change in the size of the gasholder [18], [19] or measure biogas flow in a pipe and measure biogas pressure in a gas holder to calculate the volume [18], [20].

The manual method of the gasbag monitoring system is done based on pressure gauge display to estimate biogas' volume. However, this method could not be done in real-time thus had a lack of data accuracy. This research used automatic monitoring and control system by using a device system with an ultrasonic distance sensor. It calculates gasbag volume changes and controls the compressor based on the distance of the sensor to the gasbag in real-time. A minimum limit of 6.269 kiloliters of gas will be turned on the compressor, while a maximum limit of 15.389 kiloliters will turn it off. This control prevents damage to the gasbag due to excess or lack volume [11]. Using this automatic device system is the measurement can be done in real-time and accurate.

II. Materials and Method

A. Plant Work System

This biogas plant utilizes Sumedang tofu waste to be fermented into gas utilized in residents' homes. Sumedang tofu waste residue from the home industry of tofu is collected in the sedimentation pool. Then these wastes are pumped into the reactant tank (digester) 8 times a day with a pump time of 15-time interval of each pump is 2 hours and 45 minutes. During this interval, the tofu waste is fermented in the reactant tank by microorganisms. This fermentation results in biogas (nearly 70% methane gas) entering the scrubber tank to be filtered if it still contains liquid.

This residual liquid was put into the remaining pool, which is put back into the sedimentation pool. Then the filtered biogas enters the gasbag-shaped tank to be collected first. This biogas was then pulled from the gasbag into the distribution tank by the compressor. The compressor works automatically when the pressure in the distribution tank is less than 800 millibars. The gas contained in the distribution tank is then distributed to 125 houses from 5 am until 7 pm.

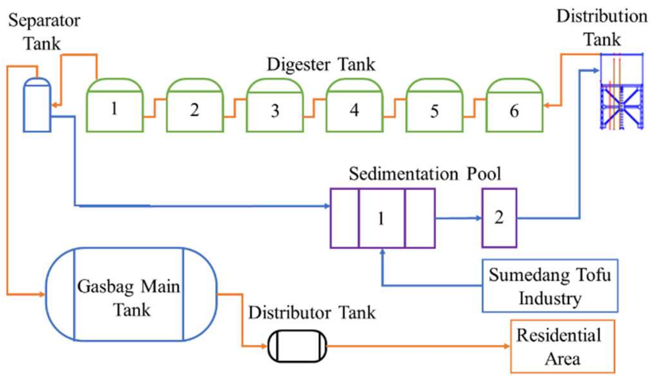

Fig. 1 Biogas plant diagram

Fig. 1 shows a diagram of a biogas plant. The largest canister is a gasbag monitored and controlled by volume, while small canisters are reactant tanks that produce biogas.

B. Tools and Materials

This study uses the Gasbag Main Tank in the biogas plant as the main object of biogas volume monitoring and control by placing a tool or system designed right above the tank. The components used to assemble the gasbag volume monitoring system at the biogas plant are the Arduino Uno R3 Microcontroller, the HC-SR04 ultrasonic proximity sensor, the 20x4 LCD module equipped with I2C and Relay. This system was connected to the compressor to control the volume of the gasbag to keep it safe. The block diagram design was created, as shown in Fig. 2.

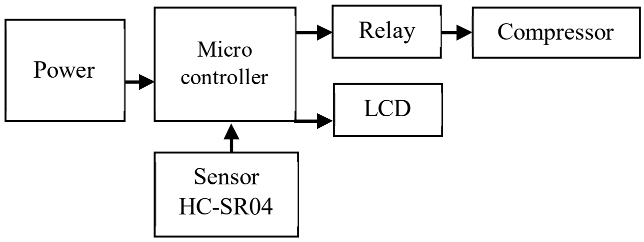

Fig. 2 Tool block diagram

The ultrasonic sensor in Fig. 3 measures the change of distance between the top of the tank and gasbag's surface. The microcontroller then calculates the volume of the gasbag using formula (1) – (6).

$$h = 2r - h2 \qquad (1)$$

$$\mathrm{Cos}\,\theta = \frac{r-h}{r} \qquad (2)$$

$$\theta = \arccos\frac{r-h}{r} \qquad (3)$$

$$\text{Tank Area} = \theta r^2 \qquad (4)$$

$$\text{Gasbag Area} = r^2\left(\theta - \frac{1}{2}\sin 2\theta\right) \qquad (5)$$

$$V = r^2\left(\theta - \frac{1}{2}\sin 2\theta\right) L \times 22 \qquad (6)$$

The distance measured by the tool is reduced by the tank height so that the actual gasbag height is obtained. From the height of the gasbag, the biogas volume value in the gasbag is calculated using equation (6).

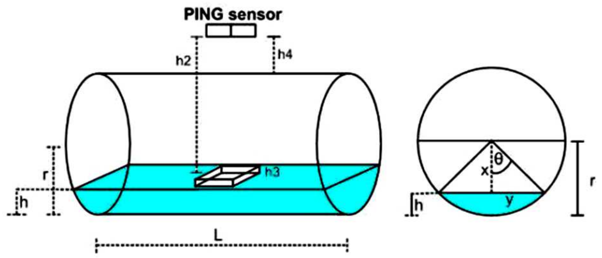

Fig. 3 Tool measurement system

If the calculated volume of the microcontroller has reached the minimum limit (known from the datasheet), the microcontroller gives the relay a command to deactivate the compressor.

III. Results and Discussion

A. Proximity Sensor Testing

Before measuring changes in gasbag size, the ultrasonic HC-SR04 sensor is tested first by placing the sensor and barrier at different distances. Sensor distance is also measured manually using a ruler. Proximity sensor testing is repeated 5 times for each distance measured. The results of this sensor test are in the form of percentage error and sensor deviation standard (showing sensor accuracy level).

Based on the test, it is known that the sensor's performance in measuring distances has met the design criteria and has good quality. The sensor can measure distance well and precisely from 20 cm until 500 cm, with an average percentage error of only 0.2%, while the average standard deviation is only 0.32 cm. This shows that the sensor has a good accuracy value and can detect the distance.

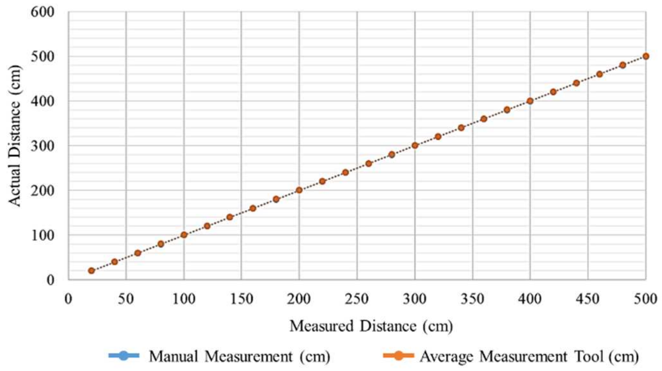

Fig. 4 Sensor testing

Fig. 4 shows the lines of manual measurement, and the measurement lines of the tools coincide. This shows the sensor has a very high level of accuracy and precision of distance measurement.

B. System Testing

Testing the system is conducted by measuring the volume compared to the container and observing the system's response when the setpoint volume has been reached with LED indicators and sockets. The final result of volume measurement is in the form of percentage error and standard deviation of the system designed. Here are the results of the volume measurement. It is known then that the designed system had met the design criteria and has good quality to calculate the volume. The system can measure volume well and is quite precise from 25 times of measurements. The average percentage of error obtained is 2.51%, while the average standard deviation is only 0.18 cm. This shows that the system can calculate the volume of the measured distance with precision and accuracy.

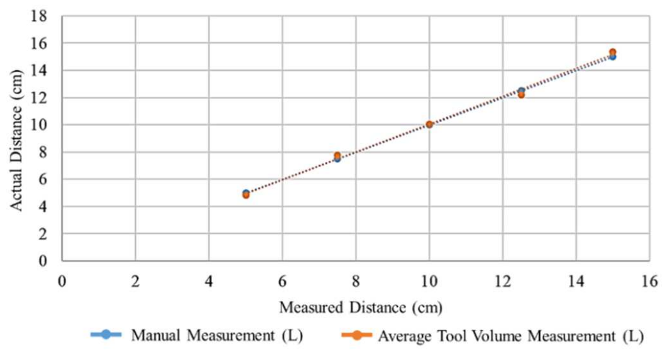

Fig. 5 Volume easurement

Fig. 5 shows a slight distance between the manual measurement line and the tool volume measurement line. This shows that the system designed still has a small error value. As for testing the sensor response, the setpoint volume value is 15 L, with the system response indicators are LED and socket. This test was carried out three times. The test result shows that the system is working correctly. The LED indicator lights, and the wall socket turn off if the setpoint volume (15 L) has not been reached. The LED indicator lights turn on when the measured volume has reached or exceeded the volume setpoint (15 L).

C. Gasbag Filling Data

The production of biogas filled in gasbag can be determined by measuring the change in the volume of the gasbag. It can be fully charged within 1830 minutes or 30.5 hours from the initial condition to the maximum gasbag condition. The maximum capacity of a gasbag filled with biogas in the field is 102.984 kiloliters and has a difference of 7.016 kiloliters from the gasbag specifications as 110 kiloliters. This is because when the gasbag volume has reached 102 kiloliters, the gasbag has expanded entirely, but the surface conditions have not been very harsh and require a long time to get these conditions. The maximum data obtained from this measurement then be used for the upper set point of the biogas volume control system designed.

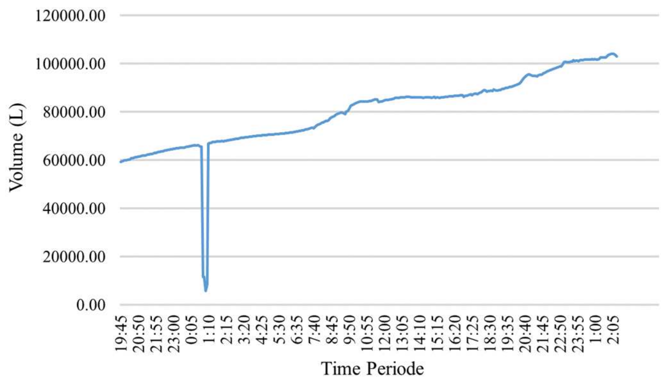

Fig. 6 Gasbag filling

Fig. 6 shows that the increase in the volume of biogas in the gasbag yield a constant rate. However, in the 325th minute, there was a very significant change in the data. This is due to interference that occurs in the ultrasonic sensor by a shock of the sensor.

D. Biogas Usage Data in Gasbag

The community in residential homes uses the filling gasbag with biogas. This usage data is based on the time to fill the gasbag is fully charged until it reaches the minimum limit. The gasbag can be fully filled and be used up within 730 minutes or 12.5 hours from the initial condition. The maximum gasbag usage data in the field is 58.857 kiloliters and has a difference of 857 L from the gasbag specifications as 58 kiloliters. This is because the volume of biogas in the gasbag was controlled under 58 kiloliters, so the measurement must be stopped when it approached 58 kiloliters. The minimum data obtained from this measurement then be used for the lower setpoint of the volume control system biogas designed. Fig. 7 shows a decrease in the volume of biogas that is released for daily needs. Measurements were made at a gas output condition greater.

E. Daily Gasbag Volume at Normal Conditions

Gasbag volume measurements were carried out under normal plant conditions (no disturbances to the reactant tank and other plant components). There are two sessions in the daily requirements measure, i.e., the production session (18.00-06.00) and the distribution session (06.00-18.00).

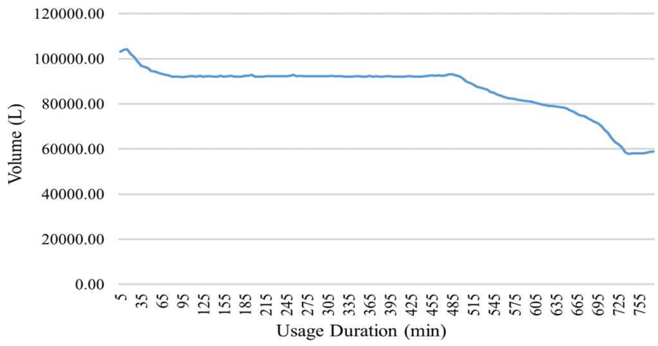

Fig. 7 Biogas usage

Fig 8 shows the highest and lowest volume of gasbag at normal daily conditions were reach neither minimum nor maximum value. Therefore, setpoint limits 58.857 kiloliters until 102.984 kiloliters were determined. So that for routine use with normal plant conditions, the plant can produce biogas to be distributed to 125 resident's homes.

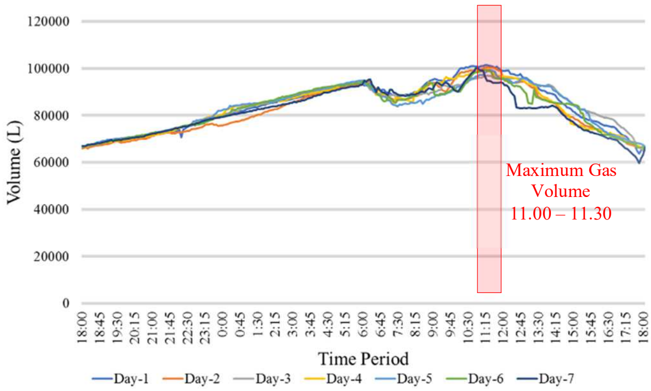

Fig. 8 Daily gasbag volume measurement

Fig.8 also shows that the gasbag volume monitor is quite volatile but still in the same pattern. It shows that from 18.00 to 6.00, the gasbag volume increased steadily because it was a production session, wherein this session the distribution flow path to the people's homes was closed so that the biogas was only stored in the gasbag. From 06.00 to 08.00, the volume of the gasbag has decreased due to the start of entering the distribution session. At 08.00-11.00, the use of biogas by residents is less than produced biogas, causing the volume of biogas to increase. At 11.00 to 18.00 is the peak time, where the amount of biogas used by residents is more than that produced by the plant.

IV. Conclusion

It has been designed and tested for automatic monitoring and controlling gasbag volume. The device designed can measure the distance between the sensor and the surface of the gasbag and calculate it into volume. This device also able to control the compressor by setting the setpoint, which is determined from the lowest and highest measured volume of the gasbag. The sensors contained in the device designed have a good level of performance with a percentage error of 0.2% and a standard deviation of 0.32 cm. While the system design has a good level of performance to calculate the volume with a percentage value of 2.51% and a standard deviation of 0.18 cm. The system response that is designed has the proper performance response, shown by the LED indicator turns off and the socket turns on when it reaches the setpoint.

The results of gasbag monitoring in the field indicate that the gasbag has a maximum capacity of 102.984 kiloliters, a difference of 7.016 kiloliters with the maximum capacity contained in the specifications. Gasbags can be fully charged for 30.5 hours. While the minimum gasbag capacity in the field is 58.857 kiloliters, the difference is 857.09 L, with the minimum capacity contained in the specifications. Gasbags can reach a minimum capacity within 12.5 hours. While from the monitoring of gasbag volume in daily conditions, it is known that the highest volume value is at 11.00 – 11.30 and the lowest volume is at 17.30 - 18.05 while the peak time for using biogas occurs at 11.00 to 18.00, where the amount of biogas used by residents is greater than that produced by plants.

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