Monitoring System of Biogas Production Volume and Digester Pressure Control

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Abstract: In this paper, an IoT-based biogas production volume monitoring system and digester pressure control have been developed. This system uses a fixed dome type digester with a semi-continuous filling method. A mixture of stale rice and water in a ratio of 1:2 was used as a substrate with a refill time of every 2 days. The pressure and volume of gas in the digester are measured using a pressure sensor and a flow sensor. In order to produce optimal gas volume, the pressure in the digester is controlled using the on-off method. The biogas pressure and volume data are displayed on the LCD screen and then sent to the IoT platform so that it can be monitored remotely via a smart phone. Pressure in the digester can be maintained between 0.326 psi to 0.652 psi. The system that has been designed can produce an average gas volume of 10.37 liters. Data transmission to the platform is carried out with an interval of 10 minutes with a delay in the travel time of sending data for one transmission of 8 seconds.

1 INTRODUCTION

Biogas is one of the alternative energies that can be used to help save petroleum energy use, because biogas processing comes from organic matter that does not take long to become available. Biogas is a gas produced from the process of decomposition of organic materials by the activity of microorganisms in the absence of oxygen or anaerobic condition (M. C. T. Atmodjo, 2018) Biogas formation process must take place in a place that is free of oxygen, called a digester. The shape and size of the digester can vary, according to the needs and available materials to make the digester (E. Randjawali and A. Waris, 2016). In general, biogas consists of methane (50-75%), carbon dioxide (25-50%), as well as small amounts of other gases such as nitrogen (0-10%), hydrogen (0-1%), hydrogen sulfide (0-3%), and oxygen (0-2%) (S. Ford, 2007). This gas mixture will be used as fuel.

The biogas production process involves four successive biological processes: hydrolysis, acidogenesis, acetogenesis and methanogenesis. If one of these processes is negatively affected in any way, it can affect the other process and the biogas production process can become unstable. Process monitoring can help to understand what's going on in biogas installations and help keep the process stable. The possible disadvantage is that if the biogas system is completely damaged, it may have to be emptied and replenished with a new substrate. This leads to time and financial losses (B. Drosg, 2013).

Some related studies that researched to sanitize the influence of pressure control on biogas production. The conclusion obtained that the production of gas produced with the largest amount is at a pressure range of 60% of the maximum pressure (F. R. Silmi et al., 2017). However, monitoring the parameters cannot be remotely, it can only be seen onsite on the LCD with volume measurements using no electronic instruments. Another study researched to incubation system to enhance biogas and methane production. The conclusion obtained that the filling time of the substrate is for two days(F. Liberi et al., 2019).

In an on-off control system, the control signal has only two specific positions, namely on and off or 1 and 0. On-off controllers are relatively simple and inexpensive, they are widely used in industrial and domestic systems (Y. Kanda, 1991). In this case, the actuator can produce a variable value or controlled magnitude in a state of full power or no power at all.

This research utilizes data from previous research and is integrated into a biogas volume monitoring and pressure control system produced on the digester by

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utilizing the IoT concept as the monitoring process. Measurement results by flow sensors and pressure sensors will be processed and then displayed on the LCD and delivered to the IoT platform so that gas production can be monitored through platforms or applications that have been connected to the system. The pressure control process uses the solenoid valve as an actuator with a specified pressure value range.

2 METHODOLOGY AND SYSTEM DESIGN

2.1 System Design

The system consists of three main components, namely digesters, panel boxes, and gas storage containers. Digesters are used in the form of containers with fixed dome and semicontinuous feeding types. This digester is equipped with an open-close valve that is above and on the bottom side, this valve is used for the entry and output of the substrate.

The panel box serves as a placement container of various system components. The biogas produced in the digester will be flowed to the panel box and measured in volume and pressure, as well as pressure control commands sourced from this panel box. After that, the biogas that has been measured will be flowed and stored in plastic containers.

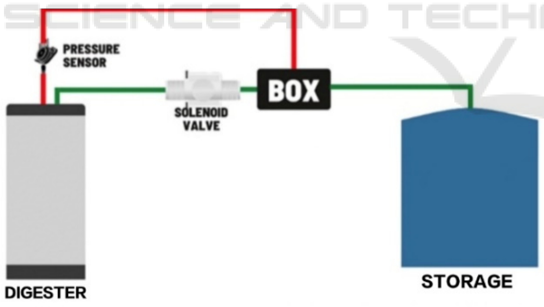

Figure 1: System Design.

2.2 Device Design

The hardware used to build biogas digesters includes a ±5 liters gallon with a tap that has been installed, a ¾ inch pipe, two ball valves. The installed pipe serves as the entrance of the substrate during the feeding process, while the two taps attached to the pipe are intended to hold the biogas formed in the digester so that it is not wasted into the air when the feeding process is carried out. The faucet that has been installed in the lower area of the gallon is the place where the substrate outputs.

Figure 2: Biogas Digester Design.

Electronic hardware stored in the panel box includes arduino uno+wifi R3, LCD, RTC, SD card module, relay, and sensor flow. While there is a pressure sensor and a solenoid valve that is installed outside the panel box because of its use that is closer to the biogas digester. For online monitoring, data processed in the microcontroller is sent to the ESP8266 chip via serial communication. This ESP8266 chip will read the data and then send the data to the IoT platform, Antares. The platform is integrated with android-based applications, so remote monitoring can be done on the Antares platform as well as android applications.

The program on Arduino IDE begins with the initialization of pins connected to various components and variables that will be processed later. After that it is continued with the value reading for the flow sensor and pressure sensor. For volume readings, the accumulation of readable volumes is carried out, while for pressure readings, accumulation is not carried out. For volume accumulation data and pressure values are displayed on the LCD in real time as an onsite monitor. Data is sent to an SD card every 20 seconds as a temporary data store, and then sent to the IoT platform every 10 minutes as an online monitor.

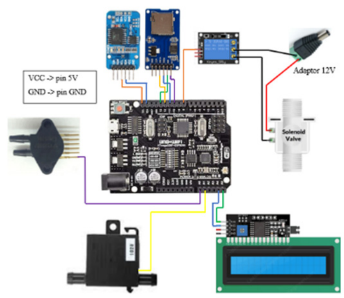

Figure 3: Schematic Electronics System.

The readable pressure value is seen as a movement parameter of the solenoid valve. Pressure control with set point at pressure 0.652 psi and reset point at pressure 0.326 psi, this value will be discussed in the next chapter. When the readable pressure is above 0.652 psi, the solenoid valve will open, when the readable pressure is below 0.326 psi, the solenoid valve will be closed. Meanwhile, if the pressure value is read between the two points, then the state of the solenoid valve depends on the previous condition. If the previous condition is open, it will remain open. And if the previous condition is closed, it will remain closed.

2.3 Software Design

The simple program flow of the system begins with the readings of the volume and pressure values of each sensor. Then the readings are distributed for onsite monitoring on LCD, online monitoring on The IoT platform, backup data storage on the SD card, and determining the control of the solenoid valve.

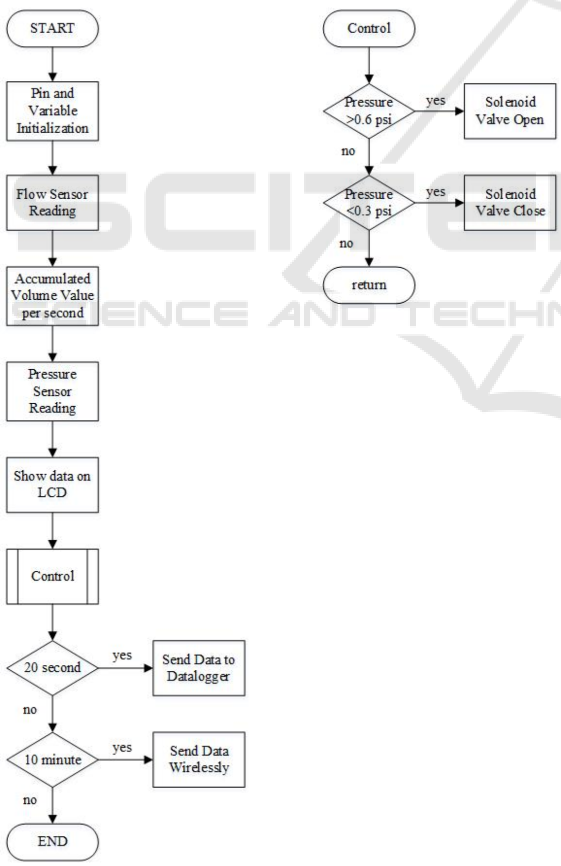

Figure 4: Flowchart Program of Monitoring and Controlling Biogas System.

As in Figure 4, the program begins with the initialization of pins connected with various components and variables that will be processed later. After that, it is continued with the value readings for the flow sensor and pressure sensor. For volume readings, the accumulation of readable volumes is carried out, while for pressure readings, accumulation is not carried out. For accumulated volume data and pressure values are displayed on the LCD in real time as an onsite monitor. Data is sent to an SD card once every 20 seconds as a temporary data store and sent to the IoT platform once every 10 minutes as an online monitor. The following image shows the system software flowchart.

The readable pressure value is seen as a movement parameter of the solenoid valve. Pressure control with a set point at a pressure of 0.652 psi and a reset point at a pressure of 0.326 psi, this value will be discussed in the next chapter. When the read pressure is above 0.652 psi, the solenoid valve will open, when the read pressure is below 0.326 psi, the solenoid valve will be closed. Meanwhile, if the pressure value is read between the two points, then the state of the solenoid valve depends on the previous conditions. If the previous condition was in an open state, it will remain open. And if the previous condition was in a closed state, it will remain closed.

3 RESULT AND DISCUSSION

The purpose of this study is to create a system that can measure, monitor, and control parameters in the biogas process with the help of IoT as its monitoring system and solenoid valve as a control actuator.

3.1 Sensor Testing

Calibration is performed to get an equation of the relationship between the voltage emitted by the sensor and the actual value. The readable voltage value in the microcontroller will be compared with the readable gas flow discharge value in the MF-5721 flowmeter. Also, when calibrating the pressure, the voltage read in the microcontroller will be compared with the readable pressure value in the pressure gauge. From the results of the comparison formed a graph and equation that states the relationship between the two. This equation will be included in the program in the microcontroller to calculate the appropriate physical magnitude.

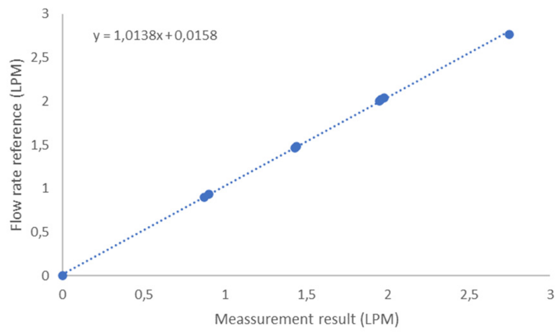

Figure 5: Relation Between Flow Measurement Value and Reference Value as Flow Sensor Validating.

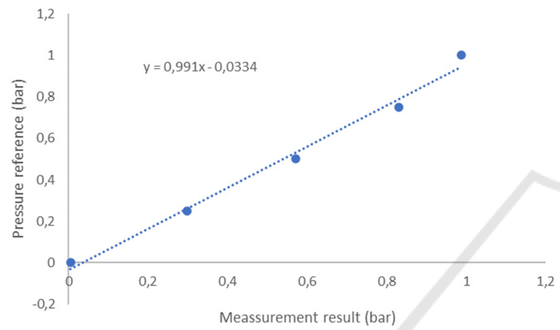

Figure 6: Relation Between Pressure Measurement Value and Reference Value as Pressure Sensor Validating.

Testing is done in the same scheme as when performing calibration. The difference is the parameters that will be compared in the actual form with those read on the microcontroller. A comparison of the two for sensor flow test results can be seen in Figure 5, while the comparison for the pressure sensor can be seen in Figure 6.

From the data on Figure 5. can be calculated average error value of the sensor to be used 2.768%. From the data on Figure 6., this sensor has an average error value of 11.342%.

3.2 Communication Module Testing

Communication module testing aims to see the required data transmission time. The test was conducted at the Telkom University Faculty of Electrical Engineering Building room P117 on Monday, November 22, 2021, at 12:47:35 to 17:59:27 WIB. Data is transmitted with an esp8266 chip that has been integrated on a microcontroller board and will be sent to the IoT platform, Antares. Data transmission is programmed with an interval of one second each data. Data delivery testing can be viewed on Figure 7.

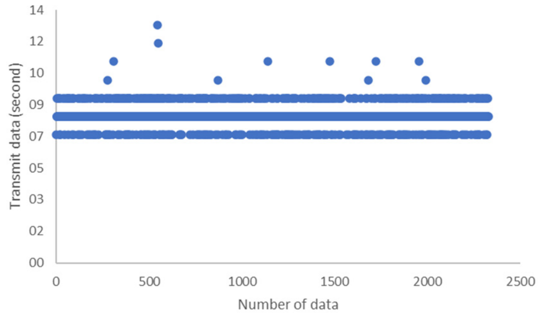

Figure 7: Relation Between Number of Data and Time Transmit Data as Communication Module Testing.

On Figure 7. data that can be sent as much as 2328 data. From this data obtained the average travel time of data transmission from device to IoT platform is eight seconds.

3.3 Device Profile

Most components are included in the 80x180x70 mm panel box to protect against environmental disturbances thereby reducing the risk of interference during the reading process. Some components are not included in the panel box because of their function and placement more with the digester.

Figure 8: Biogas Digester and Panel Box of Electronics System.

Measurements are carried out on biogas digesters with a continuous filling scheme carried out in Tegalluar Village, Bojongsoang District, Bandung Regency. The digester used is ±5 liters that are equipped with a faucet. The gas produced in the biogas digester is flowed to the sensor flow sensor to read the flow value of the gas passing through the sensor. Then the gas is flowed to a container in the form of plastic measuring 50x120 cm with a thickness of 0.8 micrometers as a biogas storage area.

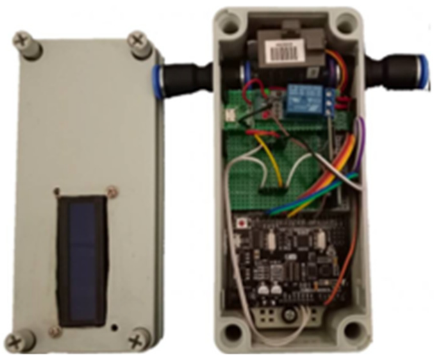

Figure 9: Panel Box of Electronics System.

3.4 Measurement Result

Measurements were taken for 20 days from February 19, 2022, to March 10, 2022, with the initial seven days used to determine the set point and reset point that will be the pressure limit set on the digester. For the first seven days there is no pressure control, with the valve constantly closed. The pressure generated during the first seven days can be seen in figure 10.

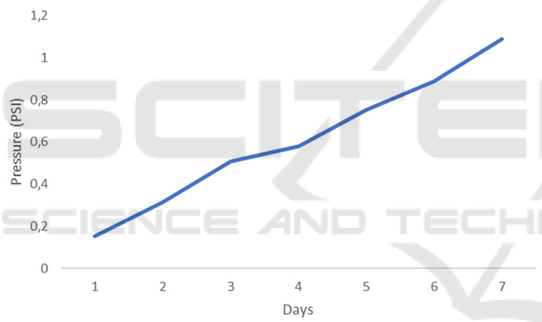

Figure 10: Average Pressure per Day as Deadband Value Determination.

On Figure 10. The highest pressure for the first seven days was 1,087. determination of the pressure value left on the digester is 30% to 60% of the highest pressure. Then obtained the reset point value at a pressure of 0.3261 psi and a set point value at a pressure of 0.6522 psi.

The control program is used after entering the set point value and reset point that has been obtained. The measurement process with control is carried out by continuously replenishing the substrate for two days. The pressure obtained until the 20th day can be seen in Fig. 11.

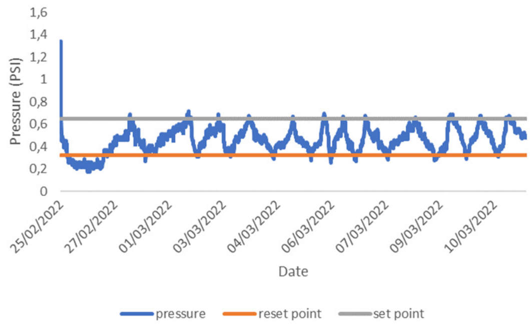

Figure 11: Result of Pressure Control.

Viewed on Figure 11. When the pressure has reached the set point value, the pressure will decrease again. This is due to the condition of the solenoid valve that changes. This pressure control system produces an average error of 4.875%.

When the condition of the solenoid valve opens, biogas will be released and passed through the flow sensor and then measured the volume value. The measured daily volume value of biogas can be seen in figure 12.

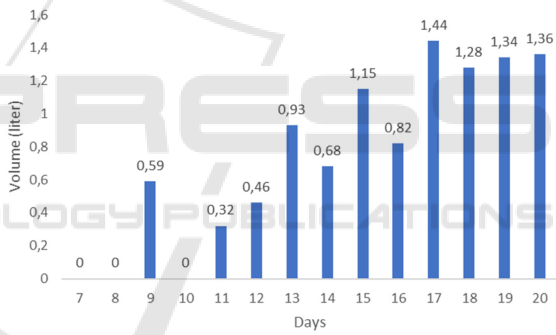

Figure 12: Volume Biogas Obtained During Pressure Control per Day.

Based on Figure 12, the volume of biogas produced tends to increase. The accumulated value of biogas volume produced during the control process is as much as 10.37 liters.

3.5 Presentation of Information

Data information can be viewed or monitored directly in real time on the LCD that has been installed panel box such as figure 13. It can also be viewed or monitored remotely on android-based mobile applications or directly on the IoT platform used, namely Antares as in Figure 14. The data displayed online is updated every 10 minutes.

Figure 13: Onsite Monitoring View on LCD.

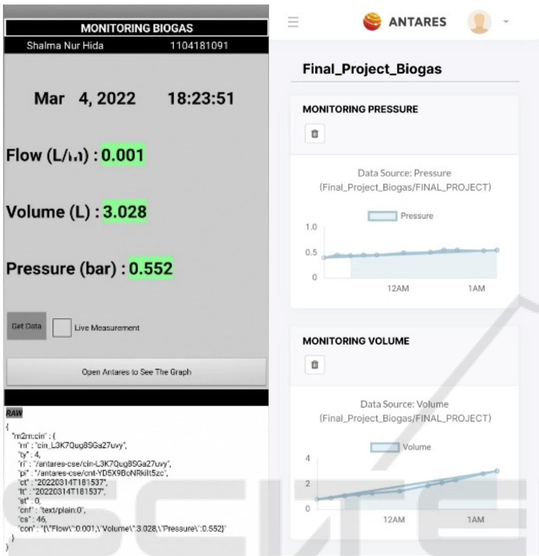

Figure 14: Online Monitoring View on Android.

4 CONCLUSION

In this research, a system that can measure and monitor the yield volume and biogas pressure has been created in the digester. The experiment was carried out using a digester measuring ±5 liters and the substrate was a mixture of stale rice and water with a ratio of 1: 2. Substrate filling was carried out continuously every two days. The parameters measured were volume and pressure with an average error value of 2.768% and 11.342% for each sensor. The volume of gas produced and the pressure in the digester can be monitored on the LCD screen and on the Android application and the Antares IoT platform with data transmission times of 10 minutes. Pressure control is carried out at the reset point and setpoint at values of 0.326 and 0.652 psi, this pressure control system produces an average error of 4.875%. The total volume of gas produced for 20 days is 10.37 liters.

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