Smart Biogas Plant Monitoring System Using Internet of Things (IoT) Technology

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Keywords: Biogas, Digester, IoT, Biogas Sensor.

Abstract: Biogas is mixture of gases produced from fermentation process of organic matter derived from animal manure. To produce optimal biogas, it is necessary to have composition of raw materials and appropriate environmental conditions. This study used measurement system to maintain conditions in the biogas reactor. Two types of tanks are used, first the digester tank functions as an anaerobic biogas production process, and second storage tank functions to store biogas produced. Thermocouple sensor to detect temperature, MQ-4 sensor to detect methane gas, MG-811 sensor to detect carbon dioxide gas, and MQ-136 sensor to detect hydrogen sulfide. Data from the readings of all sensors will be processed first into microcontroller, Arduino Mega 2650, which will then be monitored via smartphone with the Android IoT platform in the form of Blynk. Sensor data can be displayed on the blynk platform using communication module. Based on the measurement results, it is known that the accuracy of measuring instrument is compared with secondary data, precision value of measuring instrument is analyzed based on the standard deviation with the results of all measuring instruments not more than 5.0, and the linearity value obtained from results of regression calculations with linearity results not more than 0.15%.

1 INTRODUCTION

To carry out economic activities in Indonesia,energy is needed for consumption and production activities in various economic fields. Currently in line with economic growth and increasing energy needs. During the 2010-2019 period, total final energy consumption (including biomass) increased from 777.3 million to 1.009 million BOE (Barrel Oil Equivalent). Indonesia is a country that has renewable and non-renewable resources. However, exploration of energy resources is more focused on the energy that is unrenewable resources. High dependence on fossil energy sources is still a significant problem in the national energy supply. In 2019 it was recorded that 90.7% of the national primary energy supply was met from coal, oil, and natural gas.

In 2017 the government issued the Rencana Umum Energi Nasional (RUEN), with one of the targets for developing bioenergy-based renewable energy is the use of biogas. Biogas is one of the environmentally friendly renewable energy, and its availability is abundant in Indonesia. Utilizing biogas is expected to reduce energy dependence on fossil fuels. Biogas is produced from the fermentation of organic materials by microorganisms under anaerobic conditions. Materials containing organic compounds can be used as biogas, be it organic waste, plantation waste, or livestock manure such as cow dung.

Biogas contains a relatively high proportion of methane (CH_4). The complete composition of the biogas content is as follows:

Table 1: Biogas Content Composition.

Gas Type	Amount (%)
Metana (CH_4)	50 - 70
Nitrogen (N_2)	0 - 0,3
Karbondioksida (CO_2)	25 - 45
Hidrogen (H_2)	1 - 5
Oksigen (O_2)	0,1 - 0,5
Hidrogen Sulfida (H_2S)	0 - 3

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To produce optimal biogas, it is necessary to havea composition of raw materials and appropriate environmental conditions. The changing environment will affect and can reduce the quality of biogas. Therefore, to maintain the conditions in the biogas reactor as desired, it is necessary to addmeasurements and monitoring in real-time. This study used the batch type for the biogas production process. The control system used is an ON-OFF control system, where when the methane content in the digester has reached 70%, the valve will open so that the biogas will enter the storage tank. Inside the digester tank, a stirrer will operate for one hour four times a day.

The gas content and temperature in the digester tank and storage tank will be measured using sensors and monitored via a smartphone using IoT software, namely Blynk. From this research, it is hoped that the conditions in the digester will be monitored according to the desired conditions, and the biogas yield can be more optimal.

2 FLOWCHART AND TOOL MAKING

2.1 Flowchart Monitoring Process

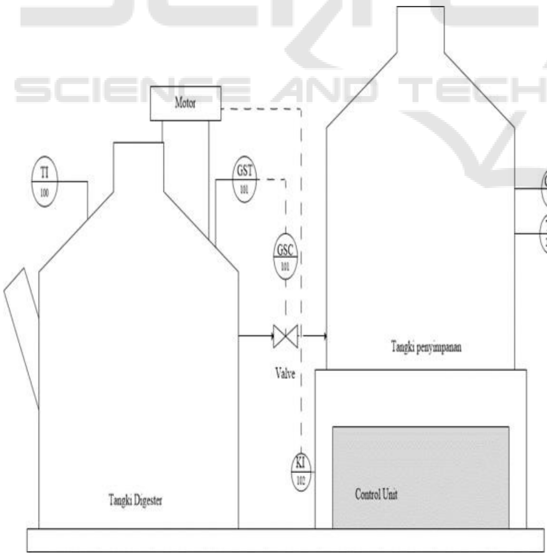

Figure 1: Schematic P&ID of the system on the digester.

In Figure 1, the process begins with the raw materials being put in the digester tank, and then the stirrer will rotate according to the set timer. After themethane is formed, the sensor will detect the methanelevel and process it using a controller. When the methane content reaches 70%, the controller willinstruct the valve to open, and the biogas fills the storage tank. The entire process will be monitored ona smartphone using an IoT platform in the form of Blynk.

From the hardware design above, the methane content is obtained from the MQ-4 sensor, the carbon dioxide level from the MG-811 sensor, the hydrogen sulfide content from the MQ-136, and thetemperature from the K type thermocouple. The sensor will then be connected to the Arduino Mega microcontroller. 2560. Valves and agitation motors are also connected to the microcontroller. The outputis displayed on the smartphone on the IoT platform, namely Blynk. To be able to display the output on the Blynk, the microcontroller will be connected to a communication module in the form of an ESP8266.

2.2 Manufacturing Process

In this study, the process of making the tool follows the directions on the flowchart shown inFigure 3. The manufacture of hardware andsoftware is carried out in parallel by starting with hardware design by drawing the circuit schematic. After that, the schematic is checked and printed on the PCB using the help of the EAGLE software. Followed by laying the components on the PCB by soldering, the results of the hardware design can be seen in Figure 2.

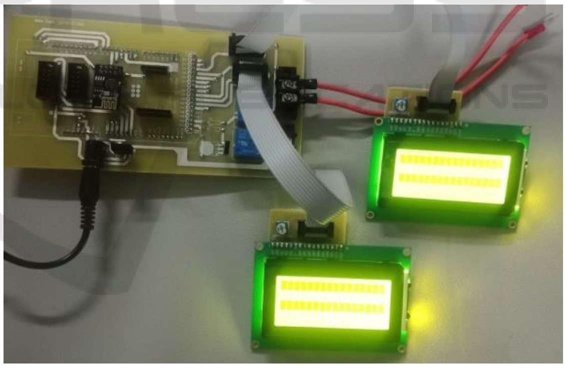

Figure 2: Hardware Tool Design.

The data that has been processed on the microcontroller will then be sent to the Blynk software via the internet network that the microcontroller requires a communication module so that the microcontroller can connect to the internet network. The communication module used is ESP826 Software development is done by programming each sensor and programming it for smartphone needs. The program is made with the help of Arduinosoftware. After that, check again to ensure the program is correct so it can be integrated. Followed by testing for the program as a whole. If successful, the program is uploaded to the assembled hardware. The communication module needs to be configured first with the microcontroller, Arduino Mega 2650.

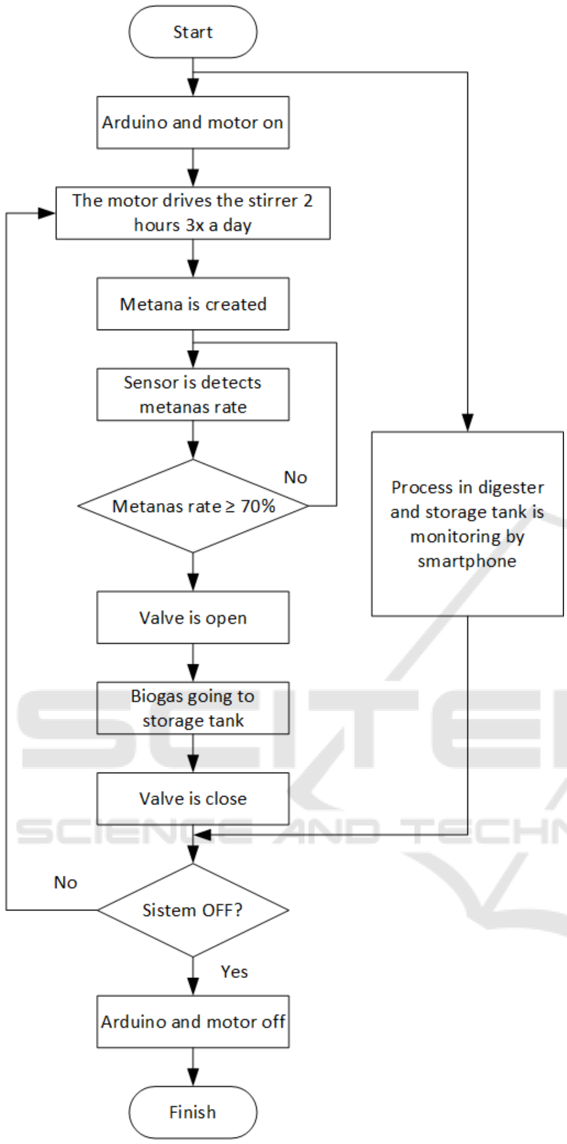

Figure 3: Tool making flowchart.

3 CHARACTERISTICS STATIC MEASUREMENT SYSTEM

3.1 Accuracy

Accuracy is the accuracy of measuring instruments in providing readings (Gunterus, 1994). Measurement accuracy is how close the measured value of a quantity is to the actual value. This quantity indicates the number of deviations that occur in a measuring device or system. There are several ways to express accuracy.

3.1.1 On the Measurement Variable

For example, a thermometer with a scale of O`F - 1OO'F is said to have an accuracy of 1'F. If the thermometer shows a temperature of 40'F, then the actual temperature is between 39'F and 41'F

3.1.2 In Percentage Span

A pressure transmitter has a of 100-400 psi rangeand span accuracy. In other words, every signal that comes to the transmitter can deviate as muchas 0.5% x 300 psi = 1.5 psi. For example, if the transmitter emits 250 psi, the actual pressure willbe between 248.5 psi and 251.5 psi.

3.1.3 In Percentage to the Maximum Scale

The term maximum scale is usually called full scale (FS). Thus a voltmeter is said to have an accuracy of 1% FS, which means that if the meter is set to a maximum reading scale of 300 volts, theaccuracy in that range is ±3 volts.

3.1.4 In Percentage of Reading

In this case, the accuracy depends on the value ofthe reading measured. A level transmitter is said to have an accurate output of 0.5%. The transmitter range is 0-100 cm. If the transmitter time shows the signal at 60cm, then the actual level range is 59.7 - 60.3cm.

3.2 Precision

Precision is the ability to produce the same valuefrom identical and repeated measurement results (measurement points and relative time) (Obstfeld & Taylor, 1997). The smaller the difference between repeated measurements, the better the instrument's performance. This can be seen from the standard deviation obtained from the measurement.

The standard deviation is a statistic used to determine how spread out the sample data is and how close each point is to the mean. If the variance from the mean is very large, the value of the σx will be large, but if the variance of the data from the mean is very small, then the value of σx will also be small.

This helps to determine whether the sample data collected is representative of the population. Higher precision means a smaller standard deviation. The standard deviation can be calculated according to the formula:

$$\sigma x = \frac{\sum_{i=1}^{n}(x_i - \bar{x})}{(n-1)} \quad (1)$$

3.3 Linearity

An element can be said to be linear if its input and output curves form a straight line. However, finding a graph with an ideal linear form is very rare. There will be indentations that are usually slightly curved or tortuous. However, in an ideal straight line, there is still a nonlinearity called linearity (Gunterus, 1994).

A linearity test is needed to find out whether two variables have a linear relationship or not. The measuring instrument can be said to have a linearity level of 1% if the results of the input-output ratio curve are still winding, but the difference in curvature that is produced is still in the range of ± 1%. The approach to a non-linear curve by cutting the curve into smaller parts is called piecewise linear. The non-linear shapes can be a parabola, serpentine, or curved. The regression method is used to determine linearity. Simple regression analysis is the relationship between two variables: the independent variable and the dependent variable. Multiple regression analysis is the relationship between three or more variables, with at least two independent variables and one dependent variable. The purpose of regression is to estimate the value of a variable when its value is related to another specified variable. There are two types of regression used: linear regression and quadratic regression.

3.4 Linier Regression

Linear regression determines the effect between one independent variable and one dependent variable. The linear regression equation for a population based on Yusuf (2009) is shown in the equation below:

$$y' = a_0 + a_1 x \quad (2)$$

3.5 Quadratic Regression

Quadratic regression is when the value of the independent variable increases or decreases linearly, or the form is displayed in a parabola if the data results are formed in a scatter plot (the relationship between the dependent and independent variables is squared) and is a nonlinear regression method (Wibisono, 2005). The mathematical model for quadratic regression is:

$$y' = a_0 + a_1 x + a_2 x^2 \quad (3)$$

4 RESULTS AND DISCUSSION

Accuracy is the precision of a measuring instrument in providing readings (Gunterus, 1994). To determine the accuracy of the measuring instrument, calibration of the measuring instrument must be carried out. Calibration is essential to determine the conventional correctness of the designation value of measuring instruments and measuring materials by comparing traceable measuring standards to national standards for units ofmeasure. As explained in Chapter 2, there are three types of measuring standards in calibrating. In this study, the data produced by MQ-4 (methane sensor),MG-811 (carbon dioxide sensor), and MQ-136 (sulfide acid sensor) are compared with measurement standards in the form of data from Slamet's research, 2017. In comparison, the data generated by the K- Type Thermocouple is compared to NTC.

Table 2: Clean Air Composition.

No	Gas Type	Formula	Concentration (%)	Concentration (ppm)
1	Nitrogen	N_2	78,09	780.900
2	Oxygen	O_2	20,95	209.500
3	Argon	Ar	0,934	9.340
4	Carbon dioxide	CO_2	0,032	320
5	Neon	Ne	$1{,}8 \times 10^{-3}$	18
6	Helium	He	$5{,}2 \times 10^{-4}$	5,2
7	Methane	CH_4	$1{,}5 \times 10^{-4}$	1,5
8	Krypton	Kr	$1{,}0 \times 10^{-4}$	1
9	Hydrogen	H_2	$5{,}0 \times 10^{-4}$	0,5
10	Water	H_2O	$2{,}0 \times 10^{-5}$	0,2
11	Carbon monoxide	CO	$1{,}0 \times 10^{-5}$	0,1
12	Xenon	Xe	$1{,}0 \times 10^{-6}$	0,08
13	Ozone	O_3	$2{,}0 \times 10^{-6}$	0,02
14	Ammonia	NH_3	$6{,}0 \times 10^{-7}$	0,006
15	Nitogen dioxide	NO_2	1,0 x 10-7	0,001
16	Nitrogen monoxide	NO	6,0 x 10-8	0,0006
17	Sulfur dioxxide	SO_2	2,0 x 10-8	0,0002

In this study, calibration was carried out three times before the sensor was installed on the tank to conduct the experiment. The results of sensor readings on calibration are as follows:

Table 4: Digester Tank Readings.

Sensor	Calibration to -		
	1	2	3
MQ-4 (ppm)	1,85	2,3	1,9
MG-811 (ppm)	315	324	366
MQ-136 (ppm)	0,00054	0,00098	0,00237
Thermocouple Type K	27,5°C	28 °C	27,5 °C

Table 5: Storage Tank Readings.

Calibration to -	NTC	Thermocouple type-K (Digester Tank)	Thermocouple type-K (Storage Tank)
1	27,8	27,5	27,5
2	28,3	28	27,5
3	27,6	27,5	27,75

Table 6: Temperature Readings.

Calibration to -	NTC	Thermocouple type-K (Digester Tank)	Thermocouple type-K (Storage Tank)
1	27,8	27,5	27,5
2	28,3	28	27,5
3	27,6	27,5	27,75

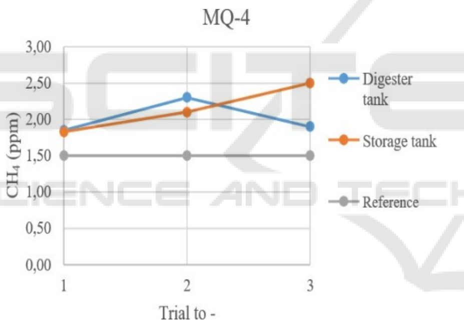

Figure 4: Calibration of the MQ-4 Sensor.

In the first calibration, the results of the MQ-4 sensor on the digester tank and storage tank showed a difference of 0.35 ppm by reference. In the second calibration, the difference in the readings of the MQ-4 sensor increased. The sensor on the digester tank shows a difference of 0.8 ppm, while in the storage tank, it is 0.6 ppm. The increase in the second experiment was due to the onset of rust on the sensor. The higher the difference between the reading and the reference, the accuracy of the measuring instrument decreases, so maintenance must be carried out in the form of a large enough sensor cleaning so that the sensor is better replaced with a new sensor. After the MQ-4 sensor attached to the digester tank was replaced with a new sensor, the reading difference dropped to 0.4 ppm. Meanwhile, in storage tanks, the difference is higher than before, which is 1.0 ppm.

There are differences in the sensors attached to the digester tank and the storage tank. This is due to the sensor attached to the digester tank being replaced with a new one, while the sensor on the storage tank is only cleaned if the reading still shows the difference.

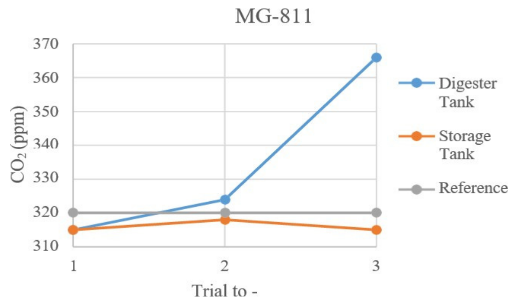

Figure 5: Calibration of the MG-811 Sensor.

From the graph in Figure 5, the readings of the MG-811 sensor on the digester tank and the storage tank are very different. In the first calibration, the readings on the two tanks are the same at 315 ppm, a difference of 5 ppm from the reference. For the second calibration, the sensor readings are equal to the increase. The sensor on the digester tank shows a difference of 4 ppm, while the digester tank shows a difference of 2 ppm. There is an increase in graphics, and this is due to the onset of rust on the sensors. In the third calibration, the sensor on the digester tank has increased significantly enough to produce a difference of 46 ppm, while in the storage tank, the sensor shows a difference of 5 ppm. In the third calibration, the sensor located on the digester tank experienced a considerable increase in difference;this is due to the sensor located in the digester tank being exposed to the gas produced by the biogas longer than the sensor located in the storage tank.

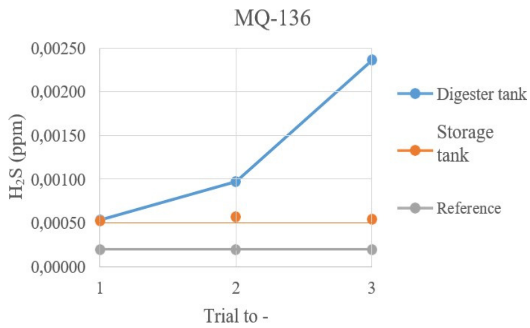

Figure 6: Calibration of the MQ-136 Sensor.

Figure 6 shows the calibration graph on the MQ- 136 sensor. It can be seen in the picture that the sensor readings on the storage tank tend to be constant, while in the digester tank, it is constantly increasing. In thefirst calibration, the magnitude of the difference in readings with a reference of 0.00034 ppm for the digester tank and 0.00033 ppm for the storage tank. In the second calibration, the difference in readings is 0.00078 ppm in the digester tank and 0.00038 ppm in the storage tank. In the third calibration, the MQ-136 sensor readings on the digester tank experienced a high enough increase to produce a difference of 0.00217 ppm, while the sensors on the storage tank showed a difference of 0.00035 ppm. The existence of considerable differences between the two sensors can be caused by the environmental conditions in the tank where the sensor is installed. The sensor attached to the digester tank is longer exposed to the gases produced by the biogas, so the sensor undergoes more ratification than the sensor on the storage tank.

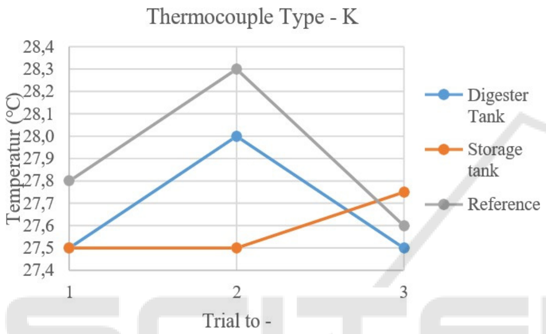

Figure 7: Calibration of K-Type Thermocouple.

Figure 7 is a calibration chart on the K-Type Thermocouple. Unlike the previous sensors, the thermocouple reading results are not compared with secondary data but rather with NTC. In the first calibration, the thermocouples on the digester tank and the storage tank showed the same result, so it is known that the difference is 0.3ºC. In the second calibration, the digester tank shows a difference of 0.3ºC and in the storage tank 0.8ºC. In the third calibration, the reading difference between the sensor and the NTC is 0.1ºC for the digester tank and 0.15ºC for the storage tank.

5 CONCLUSION

Based on the results of the analysis of the measurement system in the biogas reactor, it can be concluded that the measurement results are analyzed based on the static characteristics of the measuring instrument, namely accuracy, precision, and linearity. It is known that the accuracy of the measuring instrument is compared to secondary data with a not-so-significant difference; the precision value of the measuring instrument is analyzed based on the standard deviation with the results of all measuring instruments not more than 5.0 so that it can be concluded that the precision measuring instrument and linearity value are obtained from the results of regression calculations with linearity results are not more than 0.15%, which means that the sensor reading output shows a deviation of 0.15%

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