Micro-Controller Based Biogas Production Monitoring System

Mochammad Junus[1*], Akbar Dhea Rahman[2], Ridhofir Fikri Shodiq[3]
[123]Department of Electrical Engineering, State Polytechnic of Malang, Soekarno Hatta 9, Malang, 65141, Indonesia,
*mochammad.junus@polinema.ac.id; fikrishodiqridhofir@gmail.com

Abstract – Biogas still has limitations in monitoring gas quality parameters and mobility. This research aims to design an IoT-based mini biogas reactor equipped with a contaminant purification system, wheels for mobility, and a solenoid valve for automatic gas flow and integrated sensors to optimize biogas production and safety. The prototype is designed by integrating MQ-4 (CH_4), MQ-135 (CO_2), MPX5700AP (pressure), and DS18B20 (temperature) sensors connected to an Arduino nano. Sensor data is processed in real-time and displayed on a 20x4 LCD, while a SIM800L GSM module sends data via SMS periodically. The stepwise purification system using activated carbon successfully increased the purity of CH_4 from 55% to >70%. This research proves that IoT integration, automatic purification can be an innovative solution to improve production efficiency, safety, in rural and livestock environments.

Keywords: *Biogas, IoT, Arduino, Gas Purification Gas, Sensor Gas, Real Time.*

I. INTRODUCTION

Limited energy resources in Indonesia are one of the factors that hinder economic growth. This situation shows that energy resources play a vital role in national economic development. Although Indonesia is one of the leading producers of oil and gas, the decline in oil reserves, the elimination of subsidies resulting in an increase in oil prices, and the decline in environmental quality due to excessive use of fossil fuels are challenges that must be faced [1].

Biogas is a renewable energy source with great potential to fulfill fuel needs. The feedstock for this energy usually comes from non-fossilized livestock waste or manure, and its production is highly dependent on the availability of grass. The advantage of grass is that it can regrow continuously as long as it is well cared for. In comparison, natural gas, which is not categorized as renewable energy, is of fossil origin and takes millions of years to form [2].

Cow manure is a solid waste that has potential as an alternative energy source in the form of biogas. Organic matter contained in cow dung is converted by bacteria in the anaerobic fermentation process into biogas (methane gas, carbon dioxide). The fermentation process of cow dung into biogas can be done in a biodigester [3].

Biogas produced from the fermentation process of organic waste does not have a 100% combustible gas content. Biogas products consist of methane (CH_4) 55-75%, carbon dioxide (CO_2) 25-45%, nitrogen $N_2$0-0.3%, hydrogen H_2 1-5%, hydrogen sulfide (H_2S) 0-3%, oxygen O_2 0.1-0.5%, and water vapor [4]. Of all these elements that play a role in determining the quality of biogas, namely methane gas (CH_4) and carbon dioxide (CO_2). The purity of methane from the biogas is important because it will affect the heating value produced. If the CH_4 content is high, the biogas will have a high heating value. Conversely, if the CO_2 content is high, it will result in a low calorific value of the biogas [4].

Many studies have been conducted to measure and monitor biogas production. One of them is the research conducted by Ahmed and colleagues [5], where they monitored various parameters, such as temperature, pressure, and pH. The results of the monitoring are displayed on an LCD screen. In addition, another study conducted by Yang and team [5] focused on monitoring methane composition by utilizing an affordable microcontroller.

Existing monitoring systems are limited and manual, requiring constant supervision, and the biogas produced often still contains impurity gases such as carbon dioxide (CO_2) and hydrogen sulfide (H_2S), which reduce quality and heating value. The ideal condition is that cow dung waste can be maximally utilized to produce high-quality biogas, with the production process monitored automatically and in real-time, and biogas that has gone through a purification process to remove impurity gases.

This research develops a tool to ensure that biogas can be used optimally as an energy source, an effective monitoring system is needed. To measure methane levels, sensors (MQ-4), carbon dioxide (MQ-135), pressure (MPX5700AP), and temperature (DS18B20) are utilized. The collected data is processed by Arduino Nano and can be monitored through a 20x4 LCD display and SMS notification via SIM800L GSM module, so that users can monitor the reactor condition remotely easily.

II. LITERATURE

Biogas

Biogas is a type of gas that can be burned, which is produced through the process of anaerobic fermentation of organic materials such as livestock and human waste, agricultural waste biomass or a mixture of both, in a digester. The composition of biogas produced from the fermentation is mostly Methan gas (CH_4) and carbon dioxide gas (CO_2) [6].

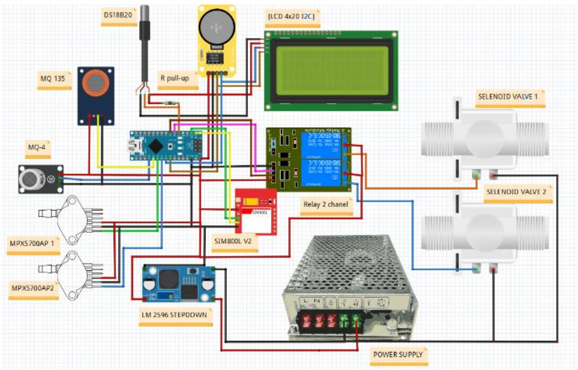


Figure 1. Schematic Diagram Micro-Controller Based Biogas Production Monitoring System

Monitoring System

A system is a unit consisting of two or more subsystem components that interact with each other to achieve certain goals. Meanwhile, monitoring is a routine process of collecting data and measuring certain objects. Thus, a monitoring system can be understood as an integrated device that functions as a monitoring tool [6].

Real-Time System

Real time systems are also called real-time systems. A system that must produce an appropriate response within a predetermined time limit. If the computer response exceeds the time limit, performance degradation or system failure occurs. A real time system is a system whose correctness is logically based on the correctness of the system's output results and the timeliness of those results. Applications of using such a system are to monitor and control equipment such as motors, assembly lines, telescopes, or other instruments. Telecommunication equipment and computer networks usually also require real-time control. Based on the time limitations it has, this real-time system is divided into several types. Among them are hard real time system, soft real time system [6].

Purification

Purification is a process of separating a certain thing from other unwanted things so as to get a purity. Biogas has several contents, namely CH_4, (CO_2, N_2, H_2 and H_2S, while of all these elements, methane gas (CH_4) and carbon dioxide (CO_2) are the elements that most greatly affect the heating value produced [6].

Biodigester

Biodigester is an anaerobic reactor used to manage the fermentation process of organic materials so that it can produce biogas optimally. Biodigester performance is influenced by several factors, such as temperature, pH, material residence time, and stirring system [7], a stable temperature setting between 30-35°C is an ideal condition for methanogen microorganisms to produce methane gas with high efficiency. In addition, a good biodigester design also supports an increase in biogas production in a sustainable manner [7].

III. METHODS

System Design

The following is a schematic of the biogas production system that includes the various components used and the connections for each pin. This design is designed to ensure effective integration between the physical and electronic components, thereby supporting optimal monitoring and control of biogas production.

Diagram Block System

The system consists of MQ-4 sensors to detect methane (CH_4), MQ-135 for carbon dioxide (CO_2), MPX5700AP to measure pressure, DS18B20 to monitor fermentation temperature, and RTC for real-time time recording. Data from the sensors is processed by Arduino Nano as the control center, then activates the actuator in the form of a solenoid valve to regulate the flow of biogas based on the threshold value of pressure and gas content.

The ppm detection range of the MQ-4 sensor is 300 - 10,000 ppm. This indicates the minimum value that the sensor is capable of detecting is 300 ppm. If it is less than this value, then the sensor cannot detect the presence of gas. While the maximum value that can be measured is 10,000 ppm. If it is more than this value, the sensor will not be able to display the correct value [3]. Thus, the sensor concentration range can be calculated as follows:

$$\text{Range} = \text{maximum value} - \text{minimum value}$$
$$= 9.700 \text{ ppm}$$

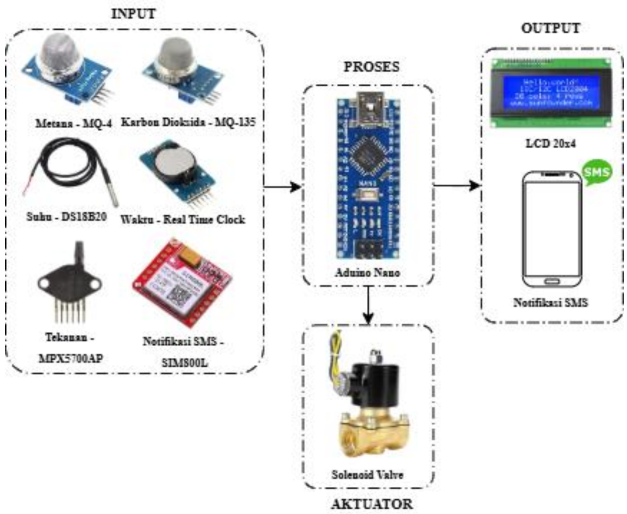


Figure 2. Hardware Design Micro-Controller Based Biogas Production Monitoring System

Data processing results are displayed locally via a 20x4 LCD and sent via a SIM800L GPRS module in the form of SMS notifications. This system enables remote monitoring and automatic control of biogas production. The following is the block diagram of the biogas production system:

Hardware Design

The following is the design of the biogas production monitoring prototype.

The system consists of two 60-liter iron drums that serve as fermentation reactors and gas reservoirs, equipped with plywood to cover the frame and wheels to facilitate mobility. The system is also equipped with a gas distribution hose to distribute the produced gas, as well as a ball valve for the disposal of fermentation waste.

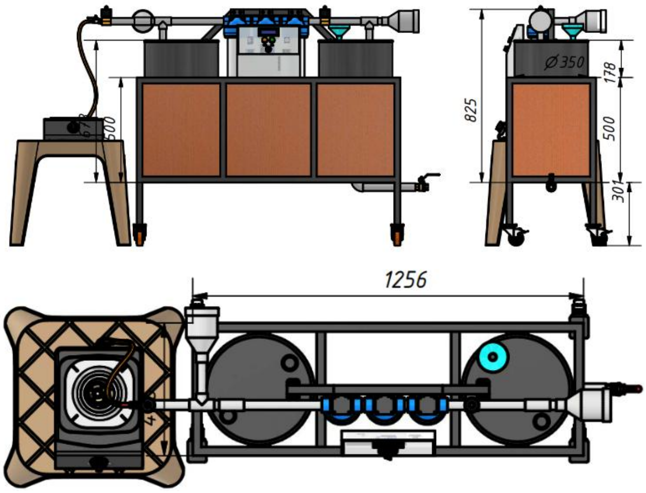
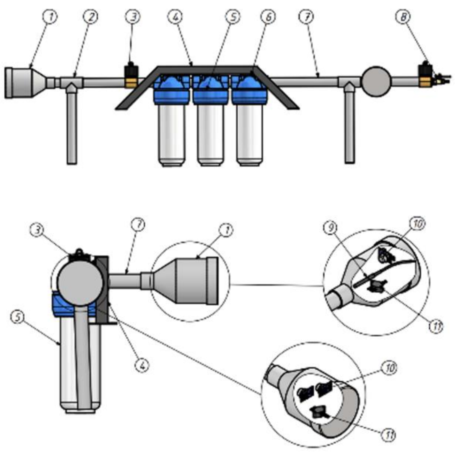


Figure 3. Mechanical Design



ITEM	PART NUMBER	DESCRIPTION	QTY
1	Vlok Sock		2
2	Tee Pipe		2
3	Selenoid Valve		2
4	Frame Filter		1
5	Water Filter		3
6	Breaket Filter		3
7	Pipe		1
8	Valve		1
9	Sensor Suhu		1
10	Sensor Gas		3
11	Sensor Tekanan		2

Figure 4. Purification and Sensor System

The picture above is the distribution path of fermentation gas to the gas storage area. Fermented gas is flowed through the pipe to the solenoid valve. In this design, the minimum set point limit is 230 mV, or equivalent to a pressure of 5.111 kPa [8].

- Determination of the upper limit of the ON-OFF controller

  $ADC = \frac{VIN \ x \ 1024}{VREF}$
  ADC = 56,66 bit ≈ 57 bit

- Determination of the lower limit of the ON-OFF controller

  $ADC = \frac{VIN \ x \ 1024}{VREF}$
  ADC = 46,66 bit ≈ 46 bit

The 57 bit and 47 bit values are later used as the upper and lower limits of the ON-OF controller setpoint programmed in the microcontroller. There is a gas purification consisting of 3 water filters with filter frames and filter brackets, which function to filter gas. Each sensor is placed on a sock block connected to the panel control box. The output of each sensor is displayed in real-time via LCD and sent in the form of SMS notification. The figure below is the design of the biogas production system control panel box.

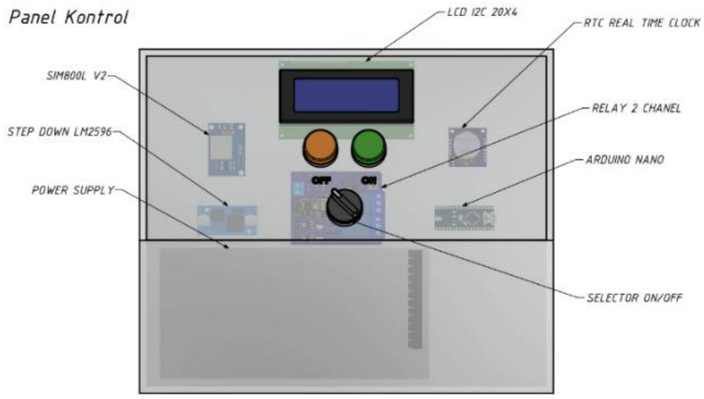


Figure 5. Design of Control Panel

Biogas Production Flowchart

The following is a flowchart of biogas production, this flowchart explains the stages of the process starting from the preparation of raw materials (organic waste), to the purification and storage of biogas produced.

Flowchart Monitoring

The following is a flowchart for monitoring biogas production: This flowchart illustrates the stages of collecting data from sensors, analyzing important parameters (such as pressure, temperature, and gas concentration), and making automatic decisions by the system to maintain the stability of the biogas production process. If parameters exceed normal limits, the system will activate actuators (such as pumps or heaters) to adjust the reactor conditions, while monitoring data is recorded in real-time for further evaluation and optimization.

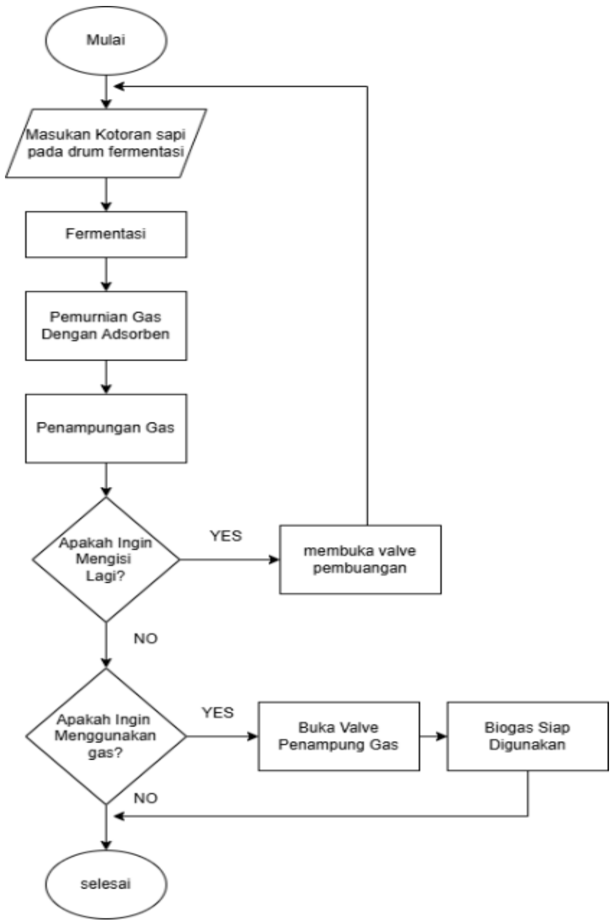


Figure 6. Flowchart Biogas Production

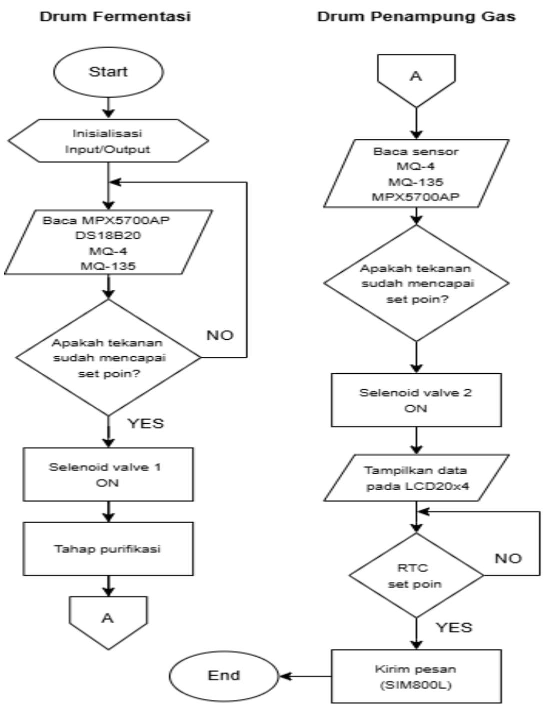


Figure 7. Flowchart Monitoring

The biogas monitoring system starts with input/output initialization on the fermentation drum. The microcontroller reads the MQ-4, MQ-135, DS18B20, and MPX5700AP sensors, if the pressure reaches the set point, solenoid valve I will open to drain the gas to the purification stage. The purification process removes impurity gases such as CO_2 and H_2S to improve the quality of biogas. Next, the microcontroller reads the data from the sensors, and if the pressure at MPX5700AP II reaches the set point, solenoid valve II opens to continue the gas flow to the gas hose and stove.

The sensor reading data is displayed on the 20x4 LCD, while the real-time time is monitored using the RTC sensor. If the time is within the set point, the SIM800L module sends the data to the user. This process repeats continuously, ensuring automatic and real-time monitoring and reporting of biogas conditions.

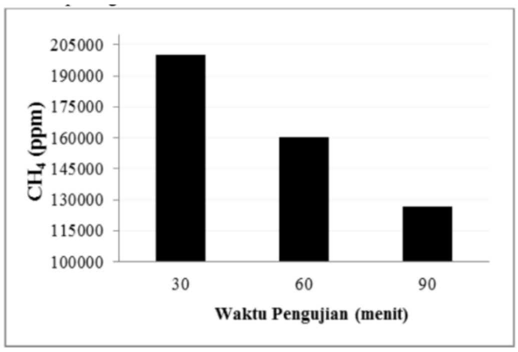


Figure 8. Methane Gas Testing Graph with Purification

IV. RESULT AND DISCUSSION

Pressure Value Data on Biogas Fermentation and Storage Drums

Table 1. Pressure Value on Fermentation Drum

Day-	Tube Pressure (PSI)	
	Fermentation	Shelter
0	0.00	0.00
2	0.09	0.00
4	0.15	0.00
6	0.29	0.00
8	0.47	0.00
10	0.89	0.00
12	1.18	0.00
14	3.51	0.00
16	5.53	0.00
18	12.00	0.00
20	21.03	0.00
22	25.19	0.00
24	8.22	6.55
26	8.22	6.59
28	9.31	7.01
30	10.09	7.50

The test was carried out for approximately 1 month. The pressure in the fermentation tube reaches the maximum value on the 22nd day. When the pressure detected in the tube has reached the maximum value, the valve on the fermentation tube will be active (open) automatically and will flow the fermented gas to the purification tube for the purification process. After that, the gas will be channeled to the storage drum [9].

Data of Average Value of CH_4 Content

Methane gas content decreased every measurement time, this is due to one of the adsorbents used, namely silica gel, has not been activated. The activation process of silica gel is at a temperature of 150 °C for 5 hours [10]. At working temperature silica gel will disappear and cause the adsorption ability to disappear, so the ability to absorb impurity gases is still not optimal. The decrease in methane gas content is also caused by the purifier installation that is used poorly, causing the purification to be less than optimal.

Methane Gas Composition Based on Temperature

The following table shows the effect of temperature on methane gas

Table 2. Effect of Temperature on Methane Gas

Temperature (°C)	CH_4 m (%)
26-27	12,74
27-28	12,21
28-29	12,77
29-30	12,05
30-31	13,06
31-32	12,93
32-33	13,71
33-34	13,77
34-35	13,87
35-36	13,89

The value of methane gas volume in the biogas content against ambient temperature is measured to be stable around 31-36 °C with a volume of 12-93-13.89%, then with a difference of 0.96% at a temperature of 5°C, the average methane gas volume increase value per degree of temperature is 0.19%. The good temperature for the decomposition process is 30-35 °C [11].

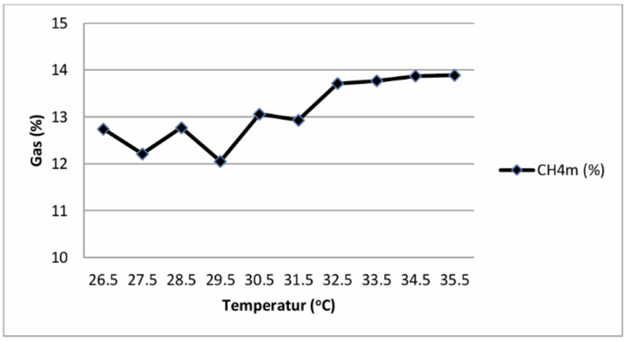


Figure 9. Effect of Temperature on Methane Gas

The average morning temperatures of P1, P2, P3 and the control were 30.7°C, 28.6°C, 28.6°C, 28.8°C and the ambient temperature was 26.4°C, respectively. In the afternoon and evening the temperature increased as shown in Figure 6 [12]. Based on the temperature, anaerobic processes can be grouped into mesophilic in the temperature range of 25-40°C, and thermophilic at temperatures greater than 40°C. The high temperature in the digester is due to anaerobic activity by bacteria which causes an increase in temperature in the digester. Digester conditions that are directly exposed to sunlight also have a relatively higher temperature during the day [12].

Temperature in the Digester

The following is a graph of the average temperature

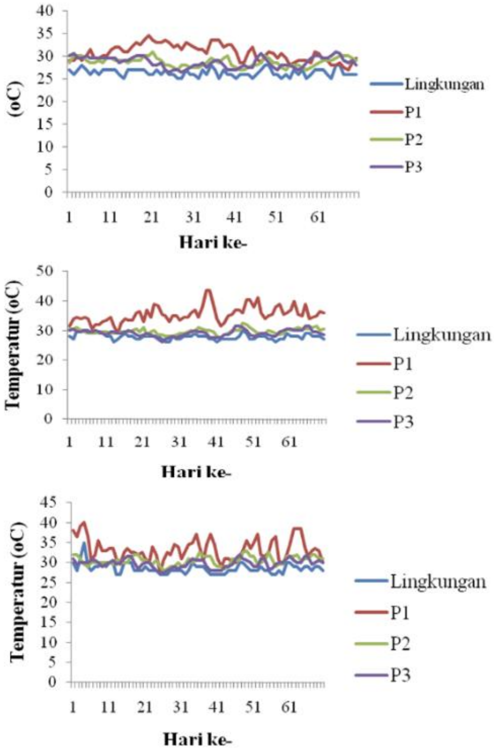


Figure 10. Average Temperature Chart

Comparison of CH_4 Concentration with Purification

The control sample (without purification) had a CH concentration of 514,537.99 ppm and the purified sample was 162,456.61. The purity of methane from the biogas is important because it will affect the heating value produced [10]. The control sample (without purification) had a CH_4 concentration of 514,537.99 ppm and the purified sample was 162,456.61. The purity of methane from the biogas is important because it will affect the heating value produced [10].

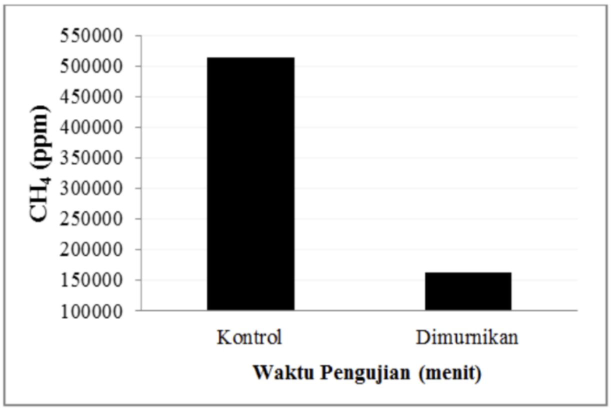


Figure 11. Comparison of CH_4 With Purification

Solenoid Valve Condition Switching Time Response

From the table it can be seen that the longest response time for the solenoid valve to change its condition is 0.55 seconds and the average value is 0.336 seconds for the solenoid valve to change its state from the on condition.

This value is qualified enough to be used as an actuator of the biogas production control system. This time response will show the time response rate of the solenoid valve when connected to the control system [13].

Table 3. Solenoid valve Condition Switching Time Response

No	Delay (s)
1.	0.55
2.	0.32
3.	0.27
4.	0.31
5.	0.24
6.	0.31
7.	0.40
8.	0.20
9.	0.36
10.	0.40
Average	0.33

Time Response Results

From the table below it can be seen that the response to the control system from changing conditions either from on-off conditions or off-on conditions has a fast response time of about 2.5 ms, this shows that the control amperage that has been made is in accordance with what is desired.

Table 4. Time Response on Solenoid Valve

Respon kendali	Waktu
Kondisi off-on	2.5 ms
Kondisi on-off	2.5 ms

Flame Test Results

The flame test aims to determine the quality of biogas produced. In the research conducted, the results of testing the length of the flame on the biogas stove with a trial of cooking eggs until cooked obtained a time of 9 minutes with a temperature of 97.8 °C, an oil temperature of 99.1 °C, a pan temperature of 86.9 °C, and a fire temperature of 152.7 °C. In this case the length of time the fire burns based on the amount of methane gas content that is collected. The flame test produced through the anaerobic fermentation process is one way to determine the presence or absence of methane gas in the gas [10].

This study was conducted when biogas was taken from the digester through a hose and produced a flame. From the results of the study that the color of the visible fire is bluish, this indicates the presence of methane gas. Based on the results of the fire color test can be seen in the picture.

Figure 12. Stove Flame Test

Calorific Value

The heating value of biogas depends on the composition of methane (CH_4) and carbon dioxide (CO_2) and the water content in the gas. Gas containing a lot of water content in the material can evaporate and mix with methane. If the CH_4 content is high, the biogas will have a high heating value. Conversely, if the CO_2 content is high, it will result in a low calorific value of the biogas. In biogas with a normal range of 60-70% methane and 30-40% carbon dioxide, the heating value is between 20-26 J/cm [10].

V. CONCLUSION

This research successfully developed an IoT-based mini biogas reactor with an automatic control system using a solenoid valve. The solenoid valve responds to a pressure rise >1.5 bar in ≤5 seconds, keeping the pressure stable at 1-1.5 bar and preventing the risk of explosion. The prototype integrates MQ-4 (±2% accuracy), MQ-135 (±3%), and MPX5700AP (±1.5%) sensors for real-time monitoring of CH_4, CO_2, and pressure. The activated carbon-CaO stepwise purification increased CH_4 purity from 55% to 72% and decreased H_2S from 200 ppm to <10 ppm. Biogas production efficiency reached 0.35 m^3/kg cow dung in 30 days, with SMS notifications sent in ≤10 seconds when parameters were abnormal. User satisfaction rate reached 90% thanks to automatic control and portable design.

ACKNOWLEDGMENT

The author would like to thank all those who have provided support in the implementation of this research. Thank you to the institution, supervisors, colleagues, and all those who have helped both directly and indirectly. Moral and material support provided

REFERENCES

[1] T. Lestari, J. Kartahadimaja, and N. A. Hakim, "Analisis Strategi Pengembangan Biogas Sebagai Energi Alternatif Rumah Tangga Dengan Memanfaatkan Limbah Ternak Kotoran Sapi," Jurnal Penelitian Pertanian Terapan, vol. 17, no. 3, p. 165, Jan. 2018, doi: 10.25181/jppt.v17i3.298.

[2] Penelitian, "BIOGAS: Limbah Peternakan Yang Menjadi Sumber Energi Alternatif Tuti Haryati."

[3] A. Setiawati, G. Mahardhian, D. Putra, and K. W. Sugandi, "Uji Kinerja Sistem Pemantauan Volume Biogas Berbasis Mikrokontroler Arduino Pada Biodigester Tipe Floating Drum Test Performance of Monitoring System Based on Arduino Microcontroller in Floating Drum Type Biodigester," 2017.

[4] O. C. Kandungan Metana, B. Kotoran Sapi Menggunakan Berbagai Jenis Adsorben Abdul Mukhlis Ritonga, and A. Mukhlis Ritonga, "Optimization Of Methana Content (CH4) Biogas of Cow Dug Using Various Types of Adsorben," vol. 10, no. 2, p. 2017, [Online]. Available: http://www.jurnal.unsyiah.ac.id/RTP

[5] H. Abdurrahman, M. R. Kirom, and A. Suhendi, "Biogas Production Volume Measurement and Internet of Things based Monitoring System," in 2020 IEEE International Conference on Communication, Networks and Satellite, Comnetsat 2020 - Proceedings, Institute of Electrical and Electronics Engineers Inc., Dec. 2020, pp. 213–217. doi: 10.1109/Comnetsat50391.2020.9328948.

[6] R. Alfanz, A. Nurhadi, and J. A. Laksmono, "Perancangan dan Implementasi Sistem Monitoring Produksi Biogas pada Biodigester," Jurnal Nasional Teknik Elektro, vol. 5, no. 1, p. 128, Mar. 2016, doi: 10.25077/jnte.v5n1.216.2016.

[7] Muhammad Zhaky, Dinda Asyifa, Eko Supriadi, and Oktrison Oktrison, "Prototype Biodigester Biogas dengan Sistem Monitoring Berbasis Internet of Things (IoT)," Jurnal Universal Technic, vol. 4, no. 1, pp. 32–39, Mar. 2025, doi: 10.58192/unitech.v4i1.3112.

[8] IE Yudaningtyas"Sistem Kontrol Produk Gas Metana pada Digester Tipe Fixed Dome," 2013.

[9] Roja and P. Studi Teknologi Rekayasa Instrumentasi dan Kontrol Jurusan Teknik Elektro Politeknik Negeri Lhokseumawe, "Rancang Bangun Sistem Kendali Proses Produksi Biogas."

[10] Mukhlis Ritonga and R. Pramesti Kusmayadi, "Pemurnian Biogas Metode Adsorpsi Menggunakan Down-Up Purifier dengan Arang Aktif dan Silika Gel sebagai Adsorben," 2020.

[11] N. Caturwati, J. Teknik Mesin, and J. Teknik Elektro Fakultas Teknik Universitas Sultan Ageng Tirtayasa Jl Jenderal Sudirman Km, "Uji Kualitas Biogas Hasil Landfill Pada Tempat Pembuangan Akhir Bagedung."

[12] Afrian, A. Haryanto, U. Hasanudin, and I. Zulkarnain, "Produksi Biogas Dari Campuran Kotoran Sapi Dengan Rumput Gajah (Pennisetum Purpureum) [Production Of Biogas From A Mixture Of Cowdung And Elephant Grass (Pennisetum purpureum)]," Jun. 2017.

[13] Arifin1, S. Baqaruzi2, and R. Zoro, "Analisis Sistem Kendali Dua Posisi Pada Solenoid Valve Untuk Produk Biogas Control And Monitoring (Common-Bigot) From Animal Waste," Indonesian Journal of Mechanical Engineering, vol. 1, 2021, [Online]. Available: https://politap.ac.id/journal/index.php/injectio