Development of ECU (Electronic Control Unit) to Maintain Stability of Biogas Fuelled Generator

Totok Soehartanto[1], Dwi Nur Fitriyanah[1], Putri Yeni Aisyah[1]

***Abstract*— Biogas fueled generator has a unique character because the converter kit on the generator has the characteristic of absorbing the biogas supply. Therefore, in this study, biogas is accommodated in a plastic container equipped with a valve that can adjust the amount of biogas supply pressure. Combustion in the Genset combustion chamber will occur if the ratio of air supply and supply of biogas (AFR = Air to Fuel Ratio) meets the stoichiometric number. So a ratio control is needed on air supply and biogas supply, which can follow changes in biogas conditions in plastic bags and generator loads. For this reason, this paper presents an ECU (Electronic Control Unit) that can regulate the ratio of air supply to biogas supply by using a servo motor valve, which is commanded by a control signal from the ECU. The resulting ECU prototype is equipped with a multi-input connector (to receive the signal output of CH_4 methane gas sensor and the biogas supply pressure sensor), multi-output (control signal to the servo motor valve), and multi regulators to adjust the Set Point value for the methane gas content CH4, the value of the set point of the biogas supply pressure and to tune the value of the proportional gain control (KP). The results of the ECU performance test by trial and error by giving a dummy input signal (analogy to the signal output of methane gas sensor and the analog of the pressure sensor output signal in the form of an electric voltage generated from the signal generator) can drive the servo motor, valve air supply, and servo motor, valve supply biogas. Accordance with the gain control input from the regulator.**

***Keywords*—ECU, Biogas, Generator, Stability, Methane Gas**

I. INTRODUCTION

The biogas-fueled generator is equipped with an air supply converter kit and a biogas supply via carburetor modification, where the converter kit cannot accept pressurized biogas supply, this is because the converter kit tends to suck up the biogas supply [1]. Therefore, in this study, biogas is first accommodated in a plastic container equipped with a pressure regulating valve. So that operators have to arrange air supply and regulate biogas supply by trial and error, this is because the methane gas content of CH4 in biogas changes according to changes in the type of food and environmental conditions of the bioreactors used for biogas extraction from livestock manure [2]. This paper presents a microcontroller-based controller equipped with a multi-input connector (connector to the methane gas sensor and the biogas pressure supply sensor) and a multi-output connector to the multi servo motor valve regulating air supply and biogas supply. This microcontroller-based controller is hereinafter called the Electronic Control Unit (ECU) [3], this is because of its ability to process the sensor input signal into a control signal to manipulate the air supply and the biogas supply through the opening of the servo motor valve using the control mode in the form of proportional mode (P). The proportional control gain value can be adjusted through several regulators in the ECU to assist air supply and biogas supply according to the methane gas content in the biogas and generator load. The ECU is equipped with a methane gas sensor input data processing program following the range of methane gas content in the biogas and the biogas supply pressure range that the converter kit can still accept and a program to maintain the operational stability of the generator in case of changes in methane gas content and changes in biogas supply pressure through manipulation. servo motor air supply valve openings and biogas servo motor supply valve openings.

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II. METHOD OF RESEARCH

A. Designing a Microcontroller Based MIMO ECU

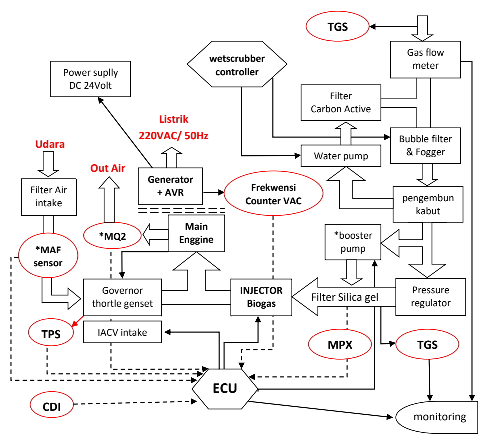

Figure 1. ECU (Electronic Control Unit) System

The microcontroller-based ECU is designed to receive multi-input signals from sensors and send multi-output signals to the final control element. The ECU is equipped with a proportional mode (P) to process the deviation that occurs between the process variable and its setpoint. Setting the proportional mode gain value can be done through the regulator provided in the ECU. So that the opening of servo motor valve supply air and servo motor valve supply biogas can meet the ratio control according to the AFR (Air To Fuel ratio) value [4].

B. Designing Ratio Control with Proportional Mode

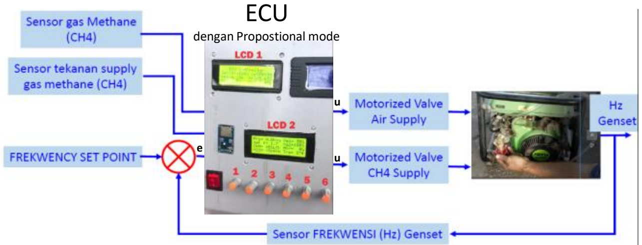

Figure 2. ECU-Based Ratio Control

Ratio control is used to adjust the ratio of air supply and biogas supply to a biogas-fueled generator converter kit, where the air supply flow rate and the biogas supply discharge volume have been set according to a certain AFR value. The proportional mode is the most suitable control mode to be applied to ratio control so that the control signal to the servo motor valve supply air and the servo motor valve supply biogas is regulated via gain control [5]:

$$u = k_p * e \qquad (1)$$

where :

-u = control signal (ECU output to servo motor valve)

-k_p = gain proportional control

-e = signal error (deviation process variable)

$$k_p = 100/PB \qquad (2)$$

where :

-PB = proportional band (gain)

The PB value is regulated through a regulator made of Op-Amp so that it can provide gain proportional to the regulator rotation.

C. Creating Servo Motor, Valve, Supply Air, and Biogas

The servo motor valve functions to regulate the air supply and biogas supply to the biogas-fueled generator converter kit. The opening air supply valve and the biogas supply valve opening regulated by the control signal generated by the ECU using a mode proportional.

(a) (b)

Figure 3. (a) Servo Motor Air Supply Valve and (b) Servo Motor Valve Supply Biogas

The control signal sent by the ECU represents the valve opening and proportional to the control signal so that the air supply or biogas supply matches the ratio control setting.

D. Creating Input Of A Methane Gas Sensor And A Biogas Supply Pressure Sensor

The ECU is used to control the operation of a biogas-fueled generator (maintaining stability) by manipulating the air supply and the supply of biogas to the converter kit so that the generator set produces electricity with a frequency according to the set point [6]. The operation of a biogas-fueled generator is strongly influenced by the quality of the biogas used (methane gas content CH_4) [7] and the supply of biogas supply pressure to the converter kit. So that the ECU must be able to receive input signals from methane gas sensors and pressure sensor input signals, which are very weak and corrosive.

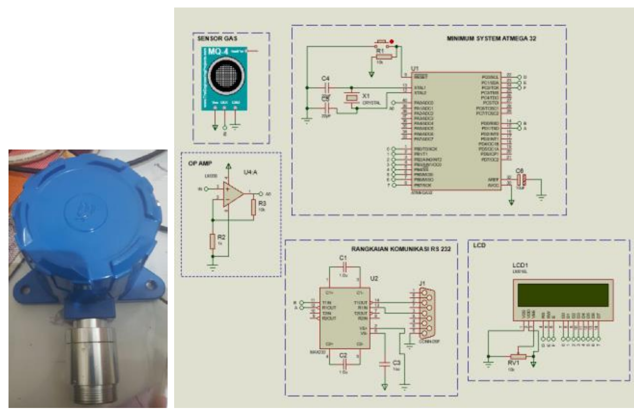

Figure 4. CH_4 Methane Gas Sensor Design

Biogas contains impurity gases such as CO_2 gas and H_2S gas, which are corrosive, so the methane gas sensor must be placed in a corrosion-resistant probe [8]. Its placement in the biogas supply line must be arranged in such a way as to be sensitive and accurate in measuring the methane gas content in biogas.

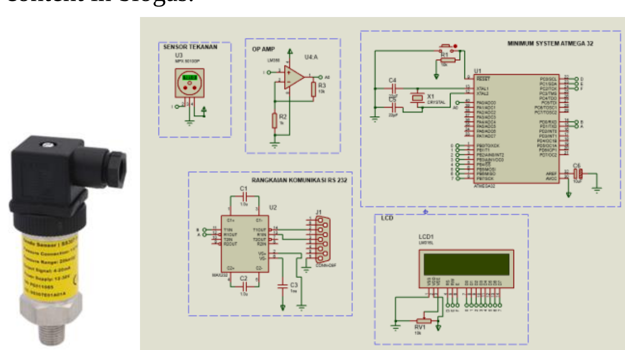

Figure 5. Biogas Supply Pressure Sensor Design

The biogas supply pressure to the converter kit is very weak because the converter kit cannot be supplied with pressurized biogas. The pressure sensor must be able to measure the biogas supply pressure, which is very weak and sensitive to changes in pressure values [9]. The pressure sensor output signal needs to be conditioned to produce an accurate measurement.

E. MIMO ECU performance testing

The performance of the ECU prototype that will be implemented in a biogas-fueled generator is tested by providing a dummy test signal in the form of an analog voltage with the output signal of methane CH_4 gas sensor and the pressure sensor, and observing the opening servo motor valve air supply and opening servo motor valve supply biogas.

III. RESULTS AND DISCUSSION

The performance of the prototype ECU is tested from its ability to read data from the methane gas sensor input and display it on the LCD screen on the ECU.

A. ECU Performance Test Reading Sensor Input

- *Test The Methane Gas Sensor Input Reading CH4*

The methane CH_4 gas sensor used has the following specifications:

TABLE 1.
SPECIFICATIONS OF THE CH_4 METHANE GAS SENSOR

Information	Specification
Sensor	CH_4
Brand	Bosean BH-60
Output	4-20ma
Range	0-100% LEL
Calibrated	Internal from factory
T working	-20 s/d 55 celcius
Protection	IP65

The performance test of the ECU in reading the input signal from the CH_4 methane gas sensor is carried out by giving a dummy signal, which is the electric voltage obtained from the methane gas sensor output voltage measurement when used to measure the methane gas content in biogas. The test is carried out by injecting an input voltage which is analogous to the value of methane gas levels in biogas, the reading results are displayed on the ECU LCD screen in the form of a voltage along with an analogy of the value of methane gas content CH_4. The test is carried out by inputting the biogas value with the lowest methane gas content (analogous to a certain voltage value) on the ECU, and the value displayed on the ECU LCD screen is compared with the input value given.

TABLE 2.
DATA ON THE RESULTS OF THE METHANE GAS READING TEST

Current (mA)	Voltage (V)	Data (10 bit)	Display (V)	(CH_4) &LEL	Error (%)
4	0,88	180	0,88	0,00	0,11
5	1,10	226	1,11	6,25	0,40
6	1,33	271	1,33	12,50	0,14
7	1,55	316	1,55	18,75	0,22
8	1,77	361	1,77	25,00	0,16
9	1,99	406	1,99	31,25	0,12
10	2,21	451	2,21	37,50	0,09
11	2,43	496	2,43	43,75	0,10
12	2,65	541	2,65	50,00	0,07
13	2,87	586	2,87	56,25	0,05
14	3,09	631	3,09	62,50	0,06
15	3,31	676	3,31	68,75	0,04
16	3,53	721	3,53	75,00	0,03
17	3,75	766	3,75	81,25	0,01
18	3,97	812	3,98	87,50	0,12
19	4,19	856	4,19	93,75	0,01
20	4,42	902	4,42	100,00	0,11

The test results show that the ECU can read the 10-bit analog input signal with the methane gas content value CH_4 as shown in the histogram of Figure 6 (changes in the value of data bits are proportional to changes in the value of methane gas content CH_4).

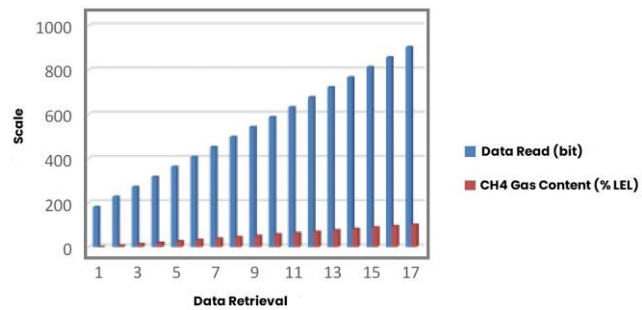

Figure 6. Histogram of Readable Data Relationship (10 Bits) with Analogy Data For Methane Gas Content

The read data bits are converted to an electric voltage which is analogous to the methane gas content value CH_4 as shown in the histogram of Figure 7 (the change in the value of the electric voltage is proportional to the change in the methane gas content value.

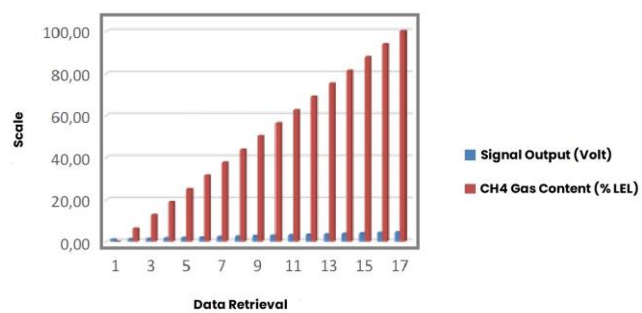

Figure 7. Histogram of Electric Voltage (Volts) Relationship with Analogy Data Of Methane Gas Content

- *Test the reading of the supply pressure sensor input*

The air supply and biogas supply pressure sensors used have the following specifications:

TABLE 3.
SPECIFICATIONS OF THE SUPPLY PRESSURE SENSOR

Information	Specification
Sensor	Pressure
Brand	Mpx5010dp
Output	0,2 s/d 4,7 Volt
Range	0 s/d 10Kpa
Body	Thermoplastic
Respon time	Up to 1ms
Initial run	20 ms
Max pressure	40 Kpa

The test is carried out by using the pressure generated by a pump equipped with a resulting pressure display, where this pressure is transferred to a pipe that resembles a biogas supply line to the generator converter. The test results show that the ECU can read changes in supply pressure (kPa) into data bits (10 bits), where this value is converted into an electric voltage to be verified by the value of the voltage generated by the pressure sensor which will be used to measure air supply pressure and supply pressure. biogas.

TABLE 4.
DATA FROM THE TEST RESULTS OF THE SUPPLY PRESSURE READING

Pressure (kPa)	Voltage (V)	Data (10 bit)	Display (V)
0	0,20	41	0
1	0,65	133	1
2	1,10	225	2
3	1,55	317	3
4	2,00	409	4
5	2,45	500	5
6	2,90	592	6
7	3,35	684	7
8	3,80	776	8
9	4,25	868	9
10	4,70	960	10

The test results show that the ECU is able to read the pressure input signal which is analogous to the voltage value generated from the pressure sensor output signal.

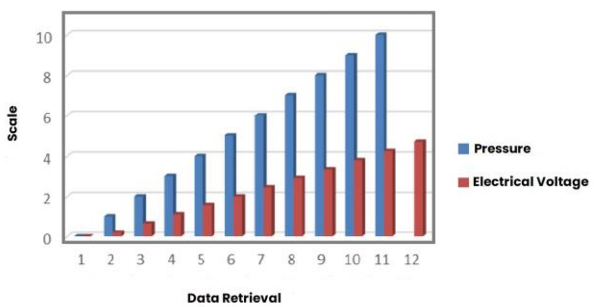

Figure 8. Histogram of Voltage (Volt) Relationship with Analogy Data of Methane Gas Content

B. *ECU Performance Test Adjusts Servo Motor Valve Opening*

The performance of the ECU prototype apart from being tested to read input data from the sensor, the ECU was also tested for its performance in regulating servo motor valve openings to regulate air supply and biogas supply to the converter kit. - Respond opening servo motor air supply valve test The servo motor valve used to regulate air supply has the following specifications:

TABLE 5.
SPECIFICATIONS OF SERVO MOTOR AIR SUPPLY VALVE

Information	Specification
Actuator	Servo valve
Gear box	1: 2,7
Servo range	0 - 300 degree
Protection	IP65
	25KG.CM
Torque	
Valve range	4 turn
Valve type	Globe valve
Diameter	1/2 inch
Valve material	SS316

The test is carried out by adjusting the gain proportional mode through the regulator in the ECU to be able to process the error signal with a specified percentage range (% range), and the servo motor valve rotation angle is observed. The angle of rotation of the servo motor valve will produce a mass flow rate of air supply that is proportional to the AFR (Air To Fuel Ratio) value.

TABLE 6.
DATA ON THE RESULTS OF TESTING THE PERFORMANCE OF THE AIR SUPPLY VALVE SERVO MOTOR

% Range	Servo (Degree)	% Value
0	0	25,00
10	30	30,70
20	60	36,30
30	90	41,90
40	120	47,50
50	150	53,20
60	180	58,80
70	240	70,00
80	240	70,00
90	270	75,70
100	300	81,30

The test results show that the ECU can adjust the servo motor opening of the air supply valve to produce air supply following the deviation percentage of the process variable which is stated in% range.

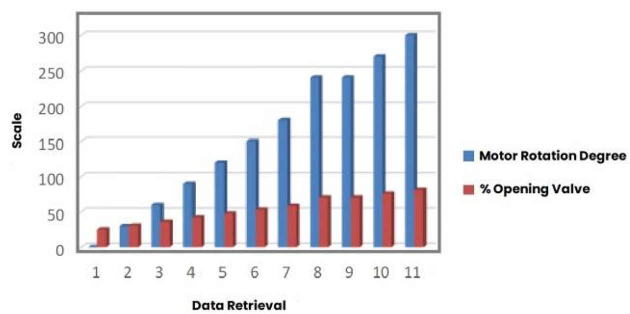

Figure 9. Histogram of The Relationship Between The Servo Motor Valve Rotation Angle and The % Supply Airflow

- *Respond to Open Servo Motor Valve Supply Biogas Test*

The servo motor valve used to regulate the biogas supply has the following specifications:

TABLE 7.
SPECIFICATIONS OF THE BIOGAS SERVO MOTOR VALVE SUPPLY

Information	Specification
Actuator	Servo valve
Gear box	2: 5
Servo range	0 - 300 degree
Protection	IP65
Torque	25KG.CM
Valve range	7 turn
Valve type	Globe valve
Diameter	1/4 inch
Valve material	SS316

The test is carried out by adjusting the gain proportional mode through the regulator in the ECU to be able to process the error signal with a specified percentage range (% range), and the servo motor valve rotation angle is observed. The servo motor valve rotating angle will produce a mass flow rate of biogas supply that is proportional to the AFR (Air To Fuel Ratio) value, in this case the fuel supply ratio is smaller than the air supply ratio to produce combustion according to the AFR value.

TABLE 8.
DATA ON THE RESULTS OF TESTING THE PERFORMANCE OF THE BIOGAS SERVO MOTOR VALVE SUPPLY

% Range	Servo (Degree)	% Value
0	0	0,00
10	30	3,00
20	60	5,90
30	90	8,80
40	120	11,70
50	150	14,60
60	180	17,50
70	240	23,40
80	240	23,40
90	270	26,30
100	300	29,20

The test results show that the ECU can adjust the servo motor opening of the biogas supply valve to produce a biogas supply following the percentage deviation of the process variable expressed in% range.

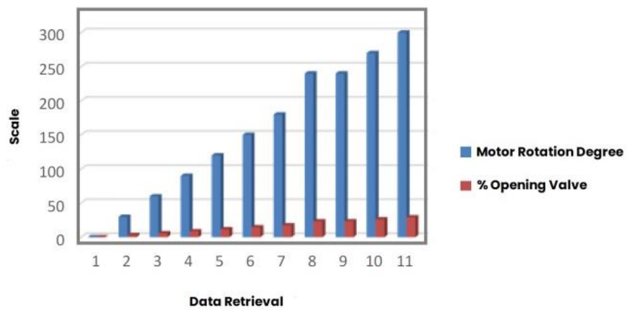

Figure 10. Histogram of The Opening Valve Supply Biogas Degree to The % Opening Valve

IV. CONCLUSIONS

A microcontroller-based ECU (Electronic Control Unit) prototype equipped with multi-input sensors and multi-output connectors to the actuator (final control element) has been produced to be applied to regulate the operational stability of a biogas-fueled generator by adjusting the ratio of air supply and biogas supply. The test results show that the ECU can read the input data from the methane gas content sensor CH4 and the air supply pressure sensor input, and the biogas supply that is displayed on the ECU LCD screen. The ECU is also able to adjust the air supply ratio and the biogas supply to the biogas-fueled generator converter kit through the opening percentage of each servo motor valve according to the AFR (Air To Fuel Ratio) value.

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