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Design of Gas Pressure and pH Pressure Monitoring and Control System using ESP32 on IoT-Based Biogas Digester

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KEYWORDS
Design, pressure, biogas

ABSTRACT
The design of the monitoring and control system used to support the biogas production process uses a control system with an ESP32 microcontroller and a gas pressure and pH monitoring and control system by installing a pressure sensor and a pH sensor that can monitor the condition of the digester based on the Internet of Things (IoT). The purpose of this research is to build a monitoring and control system based on the Internet of Things that allows checking gas pressure and pH in real-time. The devices used are BMT180 sensors and pH-4502C sensors as pressure and pH detectors. ESP32 microcontroller as a data processor so that the detection of BMT180 sensors and pH-4502C sensors can be displayed on the website. The application of the internet of things-based system to the monitoring and control system of gas pressure and pH can be accessed in real-time. The results obtained from this design are for the pressure monitoring system of the pressure process that fluctuates with ups and downs that form a regular wave indicating that the fermentation process is going well in biogas formation. Furthermore, for the pH of the graph that is read experiencing a stable pH ranging from 6-8 this shows that the biogas digester functions properly in microbial activity in the anaerobic process. The performance results show that the monitoring system design can work optimally and can be accessed as long as it is connected to the internet.

1. INTRODUCTION

The utilization of renewable energy is a promising approach for the development of various natural resources, one of which is biogas. Biogas is a renewable energy source produced through the fermentation of organic waste. It has become an increasingly important energy source in meeting the global demand for sustainable energy. The production of biogas is carried out using the anaerobic digester method, providing an effective solution for processing organic waste from household waste, agricultural residues, and industrial by-products into environmentally friendly energy. In this anaerobic process, decomposer microorganisms break down raw materials in an oxygen-free (sealed) environment, producing biogas, which mainly consists of methane (CH_4) and carbon dioxide (CO_2). According to Wahyuni (2015), typical biogas composition includes 50-70% methane (CH_4), 30-40% carbon dioxide (CO_2), 5-10% hydrogen (H_2), and small amounts of other gases.

To optimize biogas production, an effective monitoring and control system is essential. Therefore, it is crucial to develop an Internet of Things (IoT)-based biogas digester monitoring system. An IoT-based monitoring and control system for digesters is a significant step towards improving the efficiency of biogas systems by enabling real-time monitoring of gas pressure and concentration during the anaerobic digestion process. Such a system utilizes sensors as critical parameters for monitoring pressure, pH, and temperature in biogas production. This approach aligns with the research of Prasetya et al. (2022), who developed a smart biogas platform using IoT technology for biogas monitoring.

The design of the IoT-based digester monitoring and control system aims to optimize the biogas production process by automatically monitoring and regulating key parameters. This system is expected to improve biogas production efficiency, simplify maintenance, and support the development of more efficient renewable energy systems. The IoT-based monitoring and control system is anticipated to create a more reliable biogas production process, reducing the reliance on manual supervision, which is often prone to errors. Implementing this system can streamline the production process, making it more efficient. The objective of this research is to develop an IoT-based monitoring and control system that enables real-time gas pressure and pH monitoring.

2. METHOD

The research method used is problem identification and determining the importance of pressure and pH monitoring systems using a microcontroller (ESP32) on the digester. Design of an IoT-based digester design system, and an integration system.

Tools and materials

The tools used are electronic components in the form of two hardware and software components, both of these devices are intended to be used as devices that control and monitor pressure, pH, humidity, temperature and biogas formation in the digester.

Research procedures

The implementation of the research is divided into 3 stages, the first stage is hardware design, the second stage is software and the third stage is platform design . Can be seen in Figure 1.

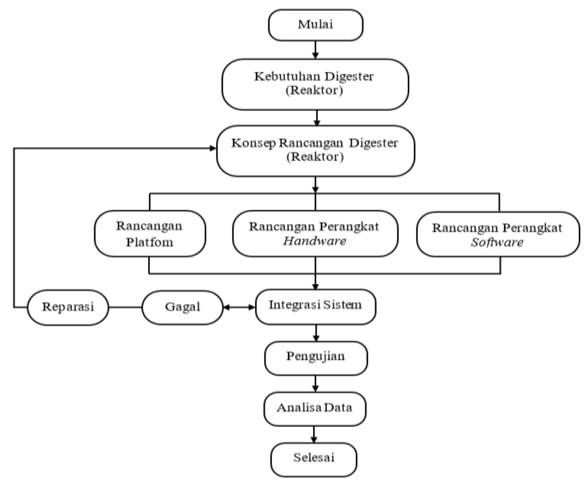


Figure 1. Research procedure

Hardware design stages

The design begins with identifying the material requirements used for the design of the biogas digester. In carrying out the hardware design and software design, the instrument design method is used to determine how the tools and sensors needed for monitoring and controlling the biogas digester work. Shown in Figure 2.

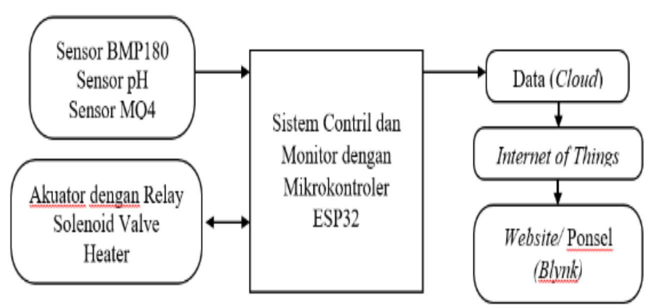


Figure 2 Hardware Design (*Hadware*)

Hardware designer (*Had ware*) designing this device uses the Arduino Uno program as a programming application connected to the BLNYK server. This circuit system uses the ESP32 microcontroller as a control and monitoring system connected to sensors to the IoT prog Software design stages

The hardware design process is integrated with sensors, BMP180 sensors, MQ-4 sensors, and pH sensors, which will be connected as a control and monitoring system using ESP32. This design will take measurements according to the sensors used in a system using ESP32 as a controller. The input obtained from all sensors is forwarded to the web and then processed, while the output is the sensor sending data to the Arduino IDE which aims to monitor gas pressure, humidity, pH, and temperature detected by the sensor. The system design process that has been integrated will then be implemented in the biogas digester. Hardware design can be seen in the system design flow diagram in Figure 3.

Software design flow diagram

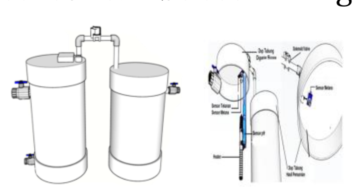
The software designer of this device design uses the Arduino IDE program as a programming application connected to the *BLNYK server* . This circuit system uses the ESP32 microcontroller as a control and monitoring system connected to sensors to the IoT program.

The design begins by initializing the ports on the microcontroller. then determine the input and output of data. *Input* input in the form of sensors and *outputs* in the form of actuators from relays connected to *the heater* and *solenoid valve* . *The sketch data* is processed using Arduino IDE. The syntax on the Arduino IDE is compiled and processed to produce output on the serial monitor.

The data that read is also sent to the cloud *database* . The *Blynk application* then connected to *the database* and displayed via serial monitor and can accessed via mobile phone or laptop online . After having a *blynk account* , the first step is to create a project and template to get the token code. The token code is entered into the Arduino IDE syntax and then run so that it can be connected via IoT. Set *the datastream* to determine the parameters and data that will be displayed and controlled via *blynk* . Set the *web display dashboard* so that data can be read via *the Blynk website* or application. After that, run the *blynk application* until it is connected so that it can control and access the data display on the biogas reactor system. In addition, *blynk* can be used to automatically adjust the actuator . Data monitoring on each sensor will be transmitted wirelessly *to* the *server* and then displayed via *Blynk* in *real-time* .

Plate design stages from

The platform design is done using PVC pipes and the materials used are sensors. The design of this platform consists of two tubes consisting of a raw material processing tube and a biogas storage tube. The design of the biogas digester (reactor) and sensors are designed using the *SketchUp* pro 2021 application. Figure a. Tube design and Figure b. is the layout of the tool, and the sensor can be seen in Figure 4.



(a) (b)

Figure 4. Design of biogas reactor (a), layout of sensors on the digester (b).

The platform design is finished being assembled then designing the layout of the sensors, after that the digester is connected to the actuator in the form of a relay that is connected to the heater and soenoid valve to regulate the conditions in the tube to remain stable. The sensors will read the condition of the tube in real-time.

System integration

The system integration process is the process of combining sub-systems so that into one system, this is done to obtain combined results overall design. This stage is carried out by integrating *hardware* design , and *software design* . Integration in each sub-system will be combined to become one unit and designed to become one system. The next stage is the design stage of the digester which is integrated with the BMP18 0 pressure sensor , pH-4502C sensor. Stages integration a system is a combination of several separate components into a single whole to perform a specific function. The performance of integration system involving sensor pH-4502C, BMP180, MQ-4. Testing is carried out to determine the output results of the system and the performance of the tools built . Figure 5 is a system integration

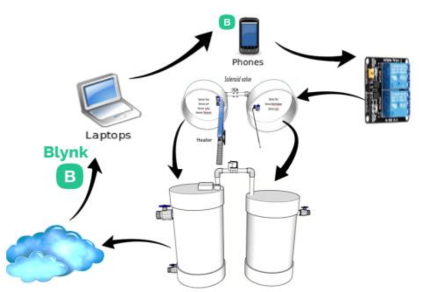


Figure 5 Integration of design systems

3. RESULT AND DISCUSSION

Hardware design (Hardware)
hardware system is a series of sensors (PH-4502C, BMP180, MQ-4) and integrated with a microcontroller (ESP32) as a control and monitor system. The design of the hardware system , starting from the microcontroller as a programming driver tool in this hardware system , there are input, processor and output devices. The processing device consists of Ardiuno IDE and ESP32, while the output is to get a database (cloud) that is integrated into the internet of things . Several studies have shown the successful implementation of IoT systems for monitoring various parameters in biogas systems, which are critical for the efficiency and safety of digester operations. According to research conducted by (Haryanto et al ., 2018) monitoring the biogas system can increase productivity by observing parameters such as pH and pressure. The advancement of IoT technology allows real-time data collection and remote control, which can be applied to the operation of biogas digesters to ensure optimal conditions for biogas production . (Apriandi et al ., 2023). Shows that proper hydraulic retention time (HRT) settings can improve the quality of the biogas produced, with pH and HRT serving as the main indicators in the anaerobic decomposition process .

Software includes all applications, information, and instructions that manage the operation of a computer system. Software consists of code written in various programming languages, including C++, Java, and Python, among others. Software is essential for the operation of a computer system. Software allows users to interact with the hardware and perform specified functions. A computer would not function without software, making the hardware ineffective.

The implementation of sensors for pH and pressure measurements is also an important aspect in designing this system. The pH sensor and pressure sensor can be connected to the ESP32 microcontroller, and through an IoT-based application , data from both sensors can be accessed directly by users via smartphone devices. Research by (Wei et al ., 2023). explains that the use of microcontrollers and sensors for monitoring and controlling environmental aspects can provide the possibility of managing resources efficiently and developing systems that are responsive to changes in environmental conditions.

The selection of sensors and microcontrollers for biogas monitoring is considered based on literature studies in previous studies. Previous research by Marbouki et al. (2021) discussed monitoring many levels in biogas using the MQ-4 sensor (4) and the MQ-7 sensor (CO 2) with Arduino Uno R3 assisted by the ESP8266 WiFi module. Research on biogas monitoring in portable digesters was also conducted by Soebagia et al. (2021) using the MQ-4 and DHT-11 sensors with the ESP-12E Node MCU. The use of the MQ-4 sensor is needed in this study because is an electro-chemical sensor that detects various types of gas combinations such as methane, propane and butane (Harjanto et al. 2022).

The results of the instrumentation system design show that each sensor... successfully read the data and surrounding conditions. The MQ4 sensor successfully read the surrounding conditions but the effect Temperature and humidity will affect the sensitivity level of the sensor. The pH-4502C sensor successfully reads in about 1 minute to detect the degree acidity. The BMP180 sensor reading results can read well and used as a treeshold . Actuator test results with relay work according to the set treeshold limits. The heater and solenoid valve will turns on and off according to the specified conditions . The results of the design system of the instrumentation system can be seen in Figure 6.

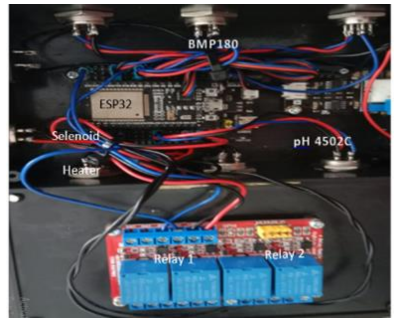


Figure 6 Hardware design results

Software design

The software design in this system design uses Ardiuno IDE as a programming application where this application provides commands to monitor all sensors used in addition there is a thingspeak platform as a cloud in storing data as a result of reading each sensor used then it will be sent by ardiuno IDE and monitored data via smartphone and website using the blynk application . Software design is a program that uses a microcontroller (ESP32) as a control and monitor system .

The initial step in the design involves setting up ports on the microcontroller, followed by identifying data for input and output. Input data is collected from sensors, while output data is sent through actuators connected to relays that control heaters and solenoid valves. Sketch data is handled through the Arduino IDE. This environment compiles and processes the syntax to produce output that is displayed on the serial monitor. Additionally, the collected data is sent to a cloud database . Next, the blynk application connects to the database, displaying information through the serial monitor, which can be accessed via a smartphone or laptop online. The goal of blynk is to facilitate remote data monitoring and system control by leveraging IoT technology .

the software design include interface displays and commands. programming input using the

Arduino IDE program. Different with previous research such as by Ramadhane et al. (2024) which designing systems using ThinkSpeak or Marbouki et al. (2021) which utilizes SMS as a gateway to the Global System for Mobile module (GSM) to the computer, programming on this device is connected to blynk. The data that is read is sent via the server by utilizing ESP32 WiFi module. Data read by the sensor is displayed via Blynk in real-time . The syntax for initializing ports , variables, and sensor libraries can be seen in Figure 7.

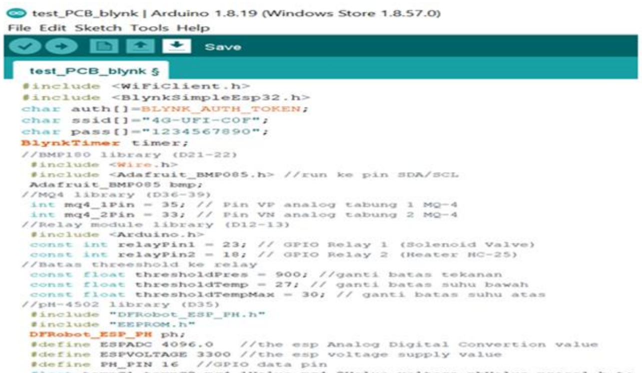


Figure 7 *Syntax* initialization *Library* and Variables

Initialization of variables and *libraries* aims to indicate variables which is used to determine the reference port to connect the pins to. GPIO to the sensors used to be read. Ports are used to determine the output source connected to the microcontroller so that information and data can be obtained. According to Dharmawan (2017), The #define function is a command to define or express a variable, the #include function is used to include *a library* or file so that it can be included in the source syntax. The integer function is used for declare a constant variable that has a decimal number. The float function is used for fractional numbers and number operations. produces numbers in decimal form. *The source code* used to read the MQ-4 sensor uses analogRead(), TempC() is used for find out the temperature read by the bmp. ReadPressure () used to determine the pressure read by the BMP180, ph. Read PH() used to read the acidity level from the PH-4502C sensor, while *blynk* .run() and timer.run() are used to run the program to get the results. Sensor data is sent continuously with IoT in *real-time* . Acquisition variables on the sensor are used to run each programming command. Programming *syntax* for acquiring and initializing variables for each sensor can be seen in Figure 8.

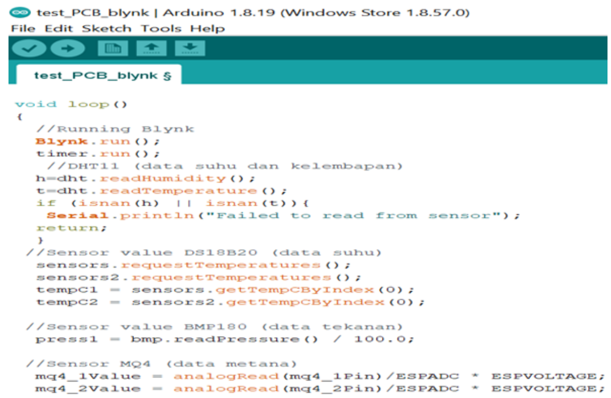


Figure 8 Acquisition And Initialization Sensor Variables

running program will then be displayed on Arduino IDE and blynk serial monitor . Display output data from serial The monitor on the Arduino IDE contains information about the condition of each sensor on each tube and relay conditions that display the state and condition solenoid valve and heater . Data output display data via serial monitor can be seen in Figure 9.

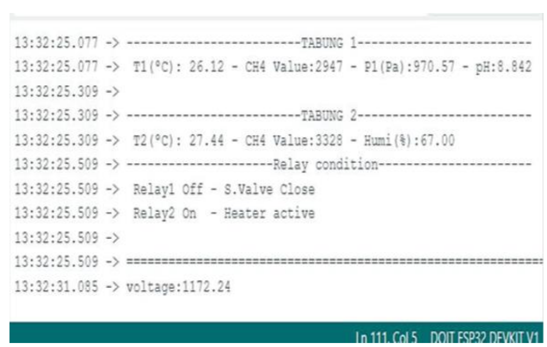


Figure 9 Display of data output on serial monitor

Then the data output on Blynk is received via the server automatically. Internet of Things (IoT) . The results of the Blynk website display can be seen via the dashboard in Figure 10.

Figure 10 View data output on *blynk website*

The results of data display via the *Blynk application* on a cellphone are seen in Figure 11.

Figure 11 Display of data output in the *Blynk application*

The results of the data output display on the cellphone via the *Blynk application* can be monitored through *the dashboard*. The performance of The software successfully shows the graphs and monitored conditions. through installed sensors.

Platform Design

The design of the platform that has been designed according to the design that has been assembled. The layout of each sensor is designed according to the layout of this platform in line with the research of Soebagio *et al* ., (2021) who designed a portable digester using one tube with a smaller volume. Then for the layout design by Ramadhane *et al* ., (2024). Designing three portable tubes) where the three tubes have their respective roles, the first tube is a pre-treatment tube , the second tube as a digester tube and the third tube as a gas storage tube.

The digester design from the design results has two tubes, the first tube as a digester tube, this tube functions as a tube for processing seaweed and cow rumin raw materials and the second tube as a tube for storing biogas production results. The layout design of the sensors used can be seen in Figure 12.

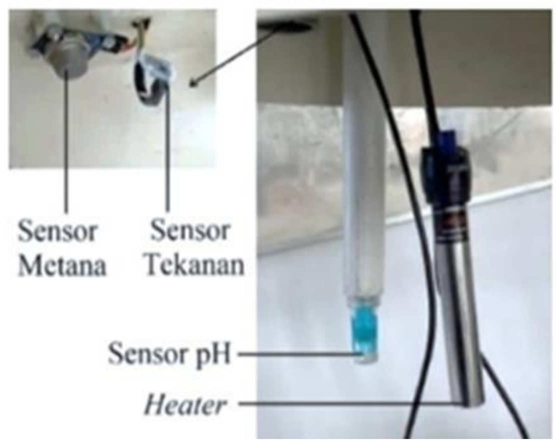


Figure 12. Layout of pH sensor, pressure sensor and MQ4 sensor

System Integration

The integration system of pH, pressure and MQ4 sensors in a system that functions to monitor and control the fermentation process effectively. The pressure sensor can be shown in Figure 13.

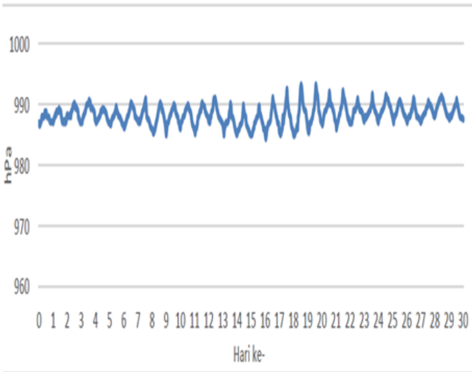


Figure 13 Gas pressure output results

Pressure sensors are used to monitor the level of gas production in the digester. Sensors that have high pressure indicate that the sensor is able to produce gas well so that the fermentation process can occur optimally. Conversely, sensors that have low pressure indicate that the sensor is not producing gas well, causing the fermentation process to be suboptimal. This is supported by the results of the study that high pressure sensors.

Based on pressure graph (Figure 13) experienced changes in increase and decrease, these changes occurred due to fluctuations with a regular wave-like pattern. This shows that the ongoing fermentation process has increased due to the formation of biogas, these fluctuations are caused by several factors such as temperature, raw material composition and microbial activity.

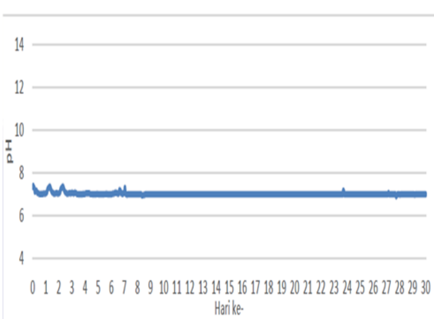


Figure 14 pH output results

pH is an important factor in the digestion process because it affects microbial activity. From the graph it can be seen that the pH is mostly stable around 6-8. This is common for a well-functioning biogas digester, because the optimal pH range of 6.5 to 8.5 is ideal for microbial activity in the anaerobic process.

4. CONCLUSION

Components needed for the design of the monitoring and control system are the BMP180 sensor and the pH-4502 C sensor based on the Internet of Things by using the ESP32 microcontroller which processes data to produce gas pressure and pH output. The system pressure and pH monitoring can operate properly based on test results. Monitoring data with the Internet of Things (IoT) system using Blynk and accessed in real-time. Performance results show that tools and systems can work optimally and can be accessed as long as they are connected to the internet. research and provide recommendations for the use of pressure and pH sensors as one of the monitoring and control tools with the Internet of Things system (IoT) in real-time properly.

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