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DESIGN AND CONSTRUCTION OF INTERNET BASED MONITORING DEVICES *THINGS*(IOT) FOR MONITORING METHANE GAS IN MINES COAL USING MQ-4 SENSOR

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Abstract

Methane gas (CH_4) is a flammable gas and has the potential to cause an explosion if it accumulates in high concentrations. Therefore, an effective monitoring system is needed to detect the presence of methane gas to prevent the danger of gas leaks. This research aims to design and build a methane gas monitoring tool based on the MQ-4 sensor which is capable of detecting the presence of methane gas in real-time. This system uses a microcontroller as the main processing unit and is equipped with a wireless communication module for sending data to the monitoring platform. The MQ-4 sensor was chosen because of its high sensitivity to methane gas and its ability to measure gas concentrations in ppm (parts per million). Measurement data is displayed via a user interface that enables remote monitoring and provides early warning if gas levels exceed specified thresholds. Test results show that this system is able to detect methane gas with good accuracy and provides a fast response to changes in gas concentration. Thus, this tool can be used as an early warning system to improve safety in environments that are at high risk of methane gas leaks.

Keywords: ***Methane gas monitoring, MQ-4 sensor, microcontroller, early warning system, gas safety.***

INTRODUCTION

The coal mining industry is a vital sector that provides a large energy resource for global consumption. The coal mining sector presents significant occupational safety hazards primarily due to the potential accumulation of methane (CH4) gas in the mining environment. When methane gas reaches a certain concentration level in the atmosphere, it becomes highly explosive and flammable, making monitoring and controlling gas concentrations essential to prevent occupational accidents in mining areas. The evolution of technology through IoT applications has created new opportunities to improve the effectiveness and efficiency of workplace environmental monitoring systems, including toxic gas detection. The Internet of Things supports rapid data collection while enabling remote monitoring and providing faster and more precise data analysis. This technology enables significant prevention of methane gas leak accidents [1]. The MQ-4 sensor falls into the category of sensors designed to detect methane and other flammable gases. This sensor exhibits high sensitivity to methane gas while reacting quickly to changes in the concentration of the surrounding gas. Integrating the MQ-4 sensor with IoT technology enables real-time data transmission to the control center, enabling immediate response to potential threats from methane gas detection. Coal mining businesses require a reliable system to monitor methane gas to improve their occupational safety standards. IoT technology incorporating MQ-4 sensors to monitor methane gas promises an effective solution for early leak detection, real-time alerts, and fast and accurate emergency decision making [2]

LITERATURE REVIEW

Before conducting research, a review of previously conducted research is needed. Previous research is used as a means of searching for references around the problem topic that will be discussed in this research, namely Internet of Things (IoT)-based methane gas monitoring. Some previous studies used as the main reference in writing are as follows:

First, a study conducted by Dhamastya Adhi Putra, Taufik Rahmadani, Andika Dwi Wicaksono, and Aris Triwiyatno from Diponegoro University entitled "IoT-Based Methane Gas Level Detection System (CH_4) Using NodeMCU ESP8266 and MQ-5 Gas Sensor". This study aims to design and build an IoT-based methane gas monitoring system to minimize the potential dangers due to LPG gas leaks that often occur due to damage to cylinder accessories such as hoses and regulators. This system uses NodeMCU ESP8266 as the main microcontroller and the MQ-5 sensor to detect methane gas levels. Detection data is sent to the Thingspeak platform in real-time and can be monitored via the internet. Testing shows that within 15 minutes the average methane gas concentration detected was 201.4 ppm with a good level of accuracy, indicated by an error difference value of 2.14% compared to a gas chromatograph as a calibration tool. This study confirms that the use of IoT technology can increase the effectiveness of monitoring the presence of methane gas in risky environments [3].

Second, research conducted by Salma Osa Novantri and Unan Yusmaniar Oktiawati from Gadjah Mada University entitled "Design and Construction of Methane Gas Level Monitoring in Organic Waste Processing *IoT Based Using ESP32 Microcontroller"*. This research focuses on the processing of organic waste that can produce methane gas and has the potential to cause an explosion if not handled properly. The designed system utilizes the MQ-4 sensor to detect methane gas concentration and the DHT22 sensor to monitor temperature and humidity in the trash can. Data processing is carried out using the ESP32 microcontroller that supports IoT connectivity and displays monitoring results via website media. The main objective of this system is as a preventive effort against the dangers caused by the accumulation of methane gas in the management of household organic waste and to support the creation of a healthy and safe environment [4].

The main differences between the two studies lie in the location of the application and the type of sensors used. The first study focused more on detecting LPG gas leaks in household environments related to the use of gas cylinders, using an MQ-5 sensor that is sensitive to methane gas and other gases such as LPG and butane. Meanwhile, the second study focused more on monitoring methane gas produced from the decomposition of organic waste, using an MQ-4 sensor that is more specific to methane, and equipped with temperature and humidity sensors to provide additional information regarding the environmental conditions of the waste processing area. In addition, the use of microcontrollers is also different, namely the NodeMCU ESP8266 in the first study and the ESP32 in the second study which has higher performance and more complete features to support efficient IoT data processing.

From the current research compared to the two previous studies lies in the improvement of system specifications, monitoring accuracy, and real-time data integration capabilities with a more responsive early warning system. This study not only relies on the MQ-4 sensor which is sensitive to methane gas, but also optimizes data processing using a microcontroller that supports multi-tasking, so that it can handle more sensors simultaneously. In addition, this system is designed to have a more interactive user interface and supports automatic notification features through communication platforms such as Telegram or other IoT applications, so that it can provide a quick response to dangerous situations. This shows an improvement from previous studies which only display data on a web server without an active real-time warning system, and makes this tool more applicable for use in high-risk domestic and industrial environments.

METHOD

Research Framework

In Figure 1 below is a methodological framework containing stages to facilitate the implementation of research in order to achieve results that are in accordance with the wishes. This research framework is made in the form of a flow chart that describes the stages of the process that will be carried out during the research.

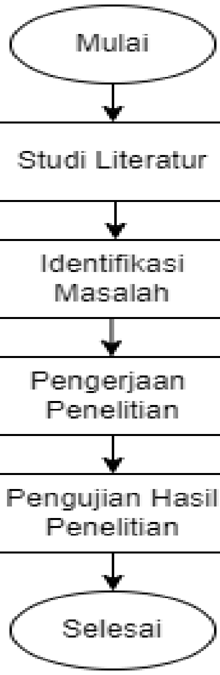

Figure 1 Research Framework Flowchart

The research begins with a literature study that is useful for collecting various sources of literature that support research references with discussion topics that are relevant to the research being conducted, this literature study is obtained through books, journals, articles, and research reports from various sources. These literature sources will be used as references and material references in the writing process. After conducting a literature study, the next step is The next step is to find the problems in the journals and articles reviewed. In this study, the problem raised is to determine the level of methane gas in the coal mining industry work area. The next step is the research process where in this process the Internet Of Things model will be designed to detect methane gas levels and the design of tools that will be useful for testing methane gas monitoring. After the model has been designed, testing will be carried out on the model. In this process, an evaluation of the performance of the tool is carried out. From this evaluation, it will be assessed if there are still errors or deficiencies so that it can be more efficient in detecting methane gas.

The initial stage of this final project is data collection and processing. Data collection and processing is a process carried out to ensure that the data obtained is related to the title of the final project and provides relevant information in the process of working on and writing the final project paper. At this stage, there are two methods of data collection carried out, namely direct data collection (primary) by conducting interviews with PT Pama Persada Nusantara, and indirect data collection (secondary) obtained from book and journal references that are still directly related to the final project, for example the type of sensor to be used. After the data is collected, a processing process is carried out to produce new references and ideas that are relevant in making the final project. At this stage it is done to see whether the automated system and IoT applications that have been created can work according to the desired procedure. Testing of the automated system is done by looking. Then for testing the IoT application, what will be tested is the application's ability to be able to display sensor reading data, and to be able to monitor via smartphone.

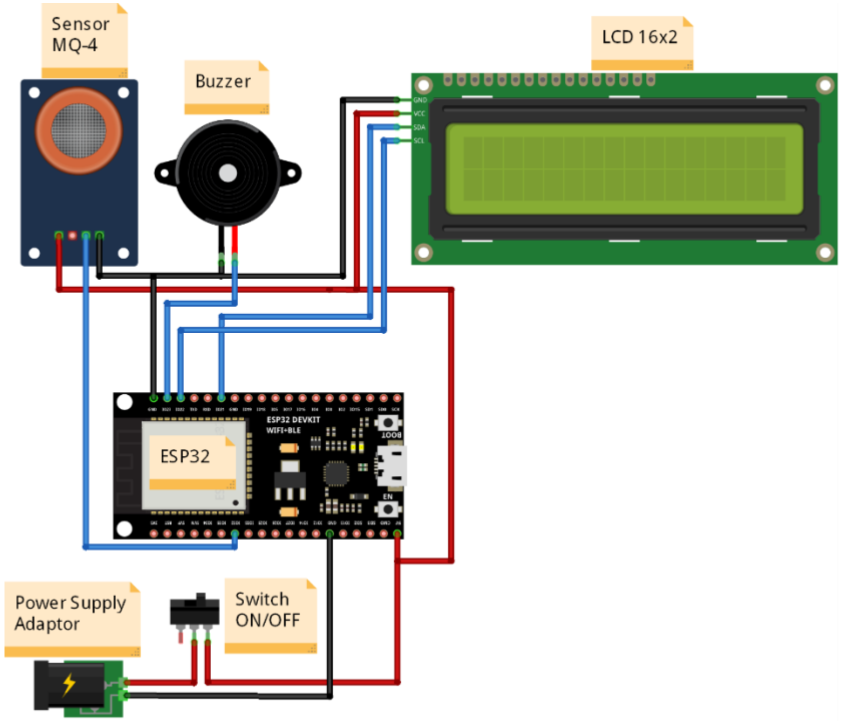

Figure 2 Circuit Schematic

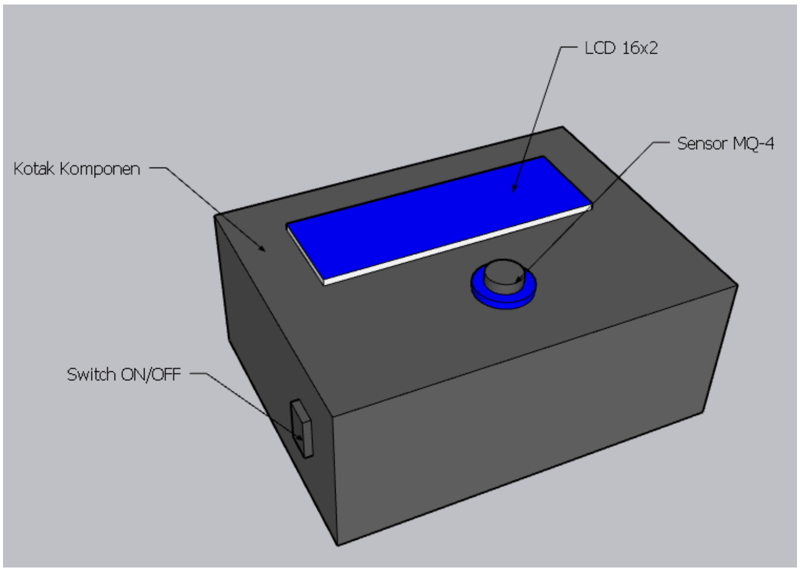

Figure 3 Tool Framework Design

In Figure 3 is the design of the tool frame. At this stage, the design of the tool frame has the aim that the components used can be installed correctly so that they can work as desired.

Design and Construction of an IoT-Based Methane CH4 Level Monitoring System

In designing an IoT-based CH4 (Methane) level monitoring system, an Arduino application is used to enter the module program, as well as determining the tools and materials to be used.

Electrical Hardware Design for CH4 (Methane) Monitoring System

In the electrical hardware design of the IoT-based CH4 (Methane) level monitoring system, several components are used, including the following: NodeMCU ESP32, MQ-4 Sensor, Buzzer, LCD, and several other electrical components.

CH4 (Methane) Monitoring System Software Design Based on IoT

The steps in creating software are as follows:

1. NodeMCU ESP32 programming to display sensor data changes from the MQ-4 Sensor (Methane Gas)
2. NodeMCU ESP32 programming to activate the Buzzer as an action if CH4 (Methane) gas is overloaded, and the LCD as a gas level indicator.
3. Creating an interface program for an android application on a smartphone. Using the Thinger Io application.

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Hardware Testing Stage of IoT-Based CH4 (Methane) Level Monitoring System

This hardware testing is carried out to determine whether the components can work as desired:

1. Testing the NodeMCU ESP32 with the MQ-4 sensor to determine the sensitivity of the sensor's detection of Methane gas.
2. PNodeMCU ESP32 testing with buzzer as a marker if methane gas is detected as overloading
3. Testing NodeMCU ESP32 with LCD to determine the level of CH4 (Methane) gas.

IoT-Based CH4 (Methane) Level Monitoring System Software Testing

This software testing is carried out to find out the final results that have been created, whether they can work as expected:

1. Testing the application interface on Android to monitor sensor value data via smartphone.
2. Testing to turn on Buzzer, LCD manually via ESP32.

Block Diagram

This IoT-based methane (CH4) gas level monitoring system is designed to display changes in data from the CH4 (Methane) gas sensor at PT. Bukit Asam which will be displayed via smartphone. In this monitoring system, there is an MQ-4 sensor input connected to ESP32 to process input data using ArDuino IDE software for coding. Then the output is obtained in the form of data readings from the gas sensor on the smartphone and LCD Display. If the CH4 (Methane) gas level is detected > 60%, the system will automatically activate the Buzzer. Can be seen in Figure 3

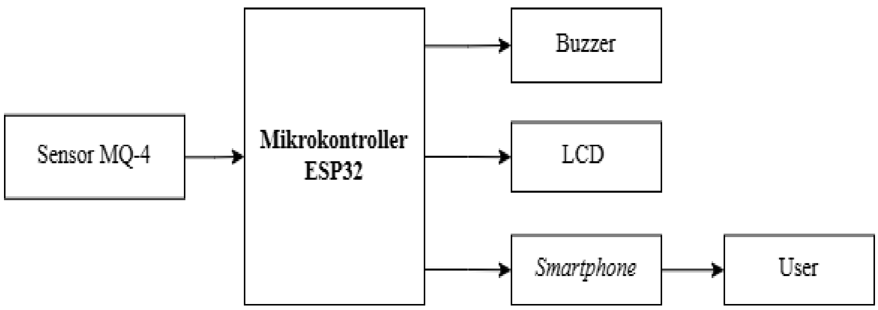

Figure 4 Block Diagram of Tool Working System

Flow chart

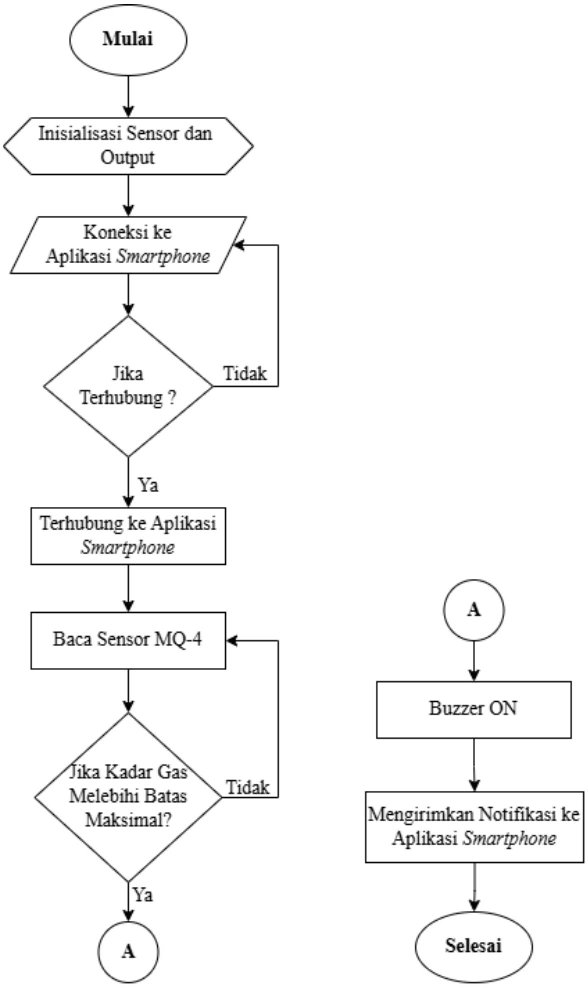

Figure 5 *Flowchart of IoT-Based Methane Gas Monitoring Device*

At this stage, the flowchart is made by designing a simple algorithm in the form of a flow diagram to facilitate the manufacture of the tool. In order for the manufacture of the tool to be carried out smoothly, the algorithm on the tool is first described with a flow diagram as in Figure 5.

Software Design

Software design includes everything related to the design and manufacture of physical tools and applications in the form of software. The following software is related to the designed tool.

ESP32 IDE Programming

To run an Arduino board requires software to write programs that can give commands to the Arduino board. The programming language for programming the Atmega 2560 microcontroller IC is C. To create programs and upload programs to the microcontroller requires software, namely the Arduino IDE (Integrated Development Environment).

Here are the steps to run the Arduino IDE software:

1. First download the Arduino IDE installer on the official Arduino website at www.arduino.cc/en/Main/Software. After downloading, install the Arduino IDE installer on your PC and then run it. The results of the Arduino IDE installer can be seen in Figure 4 below:

Figure 6 Arduino IDE initial view

2. After the software is run, the main page will appear on the Arduino IDE which is used to write the program to be run. The main page display can be seen in Figure 7, as follows:

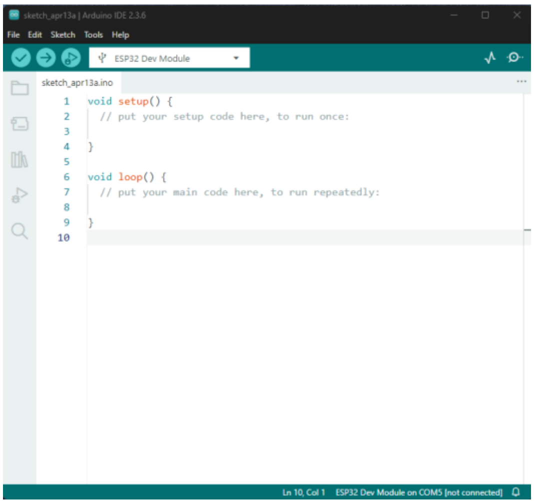

Figure 7 Arduino IDE main window display

3. Change the Arduino board to the ESP32 Dev Module board on the Tools toolbar menu – Board – ESP32 – ESP32 Dev Module, and adjust the serial port on the Port toolbar menu – select the port with the settings on the PC. In making this program, the author used the COM 4 serial port. The board and port settings can be seen in Figure 8 and Figure 9 below:

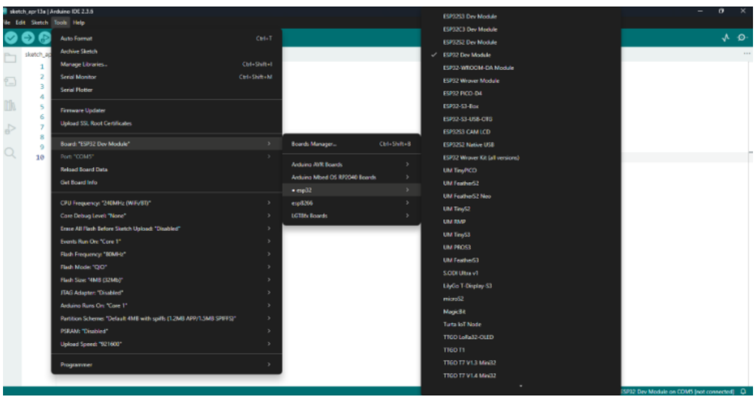

Figure 8 Arduino IDE main window display

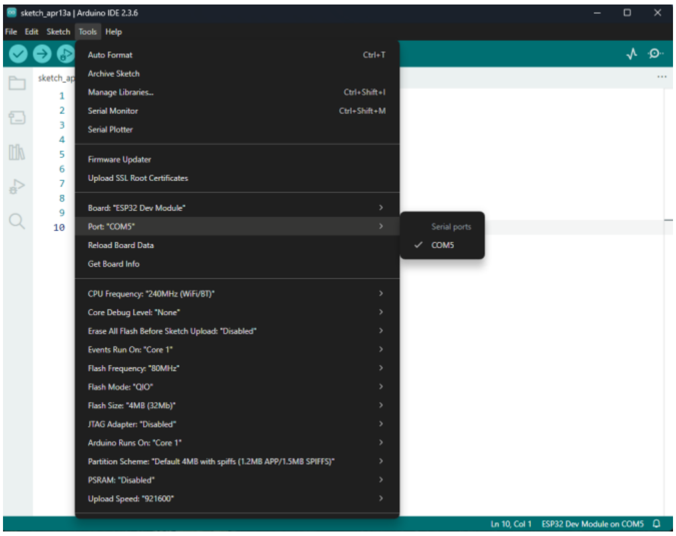

Figure 9 Arduino IDE serial port settings

4. Create a program using C programming language according to the flowchart that has been designed. The purpose of creating a program on Arduino is to convert the analog signal that has been received by the MQ-4 Sensor into a command to display data on the LCD and the Blynk application.
5. Upload the program that has been created to the Arduino board using a USB Serial cable.

RESULTS AND DISCUSSION

System Implementation

The Design and Construction of an Internet of Things (IoT) Based Monitoring Tool for Methane Gas Monitoring in Coal Mines Using the MQ-4 Sensor is realized based on several theories and references studied by the author so as to obtain a system that is quite efficient and easy to use. To find out whether the system can work according to the objectives and problems of designing this tool, testing and analysis of the design system are needed.

Measurement and Testing

MQ-4 Sensor Measurement

Before being used on direct objects in coal mines, the gas sensor circuit is first tested to determine whether the sensor can detect gas well in this test, the results are shown in Table 4.1 by displaying the ADC value first, then converted into parts per million (ppm) with an equation formula that has been adjusted to the datasheet of the MQ-4 sensor. The results of the MQ4 measurements are displayed on the ubidots website page.

Table 1 Experiment results of voltage conversion values to PPM

Voltage)	Gas Volume (PPM)
3.3	1000
2.34	726
1.44	450
1.32	400
1.27	380
0.5	200
0.4	180

0.3	170
0.25	160
0.23	150
0.21	140
0.2	130
0.19	115
0.18	105
0.17	95
0.16	80
0.15	70
0.14	60
0.13	50
0.12	30
0.11	20
0.1	10
< 0.1	0

Table 1 shows the results of the experiment converting the sensor voltage into methane gas concentration values in PPM units. From the data, it can be seen that when the voltage decreases from 3.3 volts to less than 0.1 volts, the methane gas concentration value also decreases drastically from 1000 PPM to 0 PPM. This decrease indicates that the MQ4 gas sensor works based on changes in internal resistance influenced by the presence of methane gas around it—the lower the gas levels detected, the lower the output voltage of the sensor. In the voltage range between 0.18 volts to 0.17 volts, the PPM value was observed to be stable in the range of 90–95 PPM, which can be considered a relatively safe or normal environmental condition. This indicates that the sensor has reached a point of stability in reading gas levels under conditions with little or no additional gas exposure.

MQ-4 Sensor Testing

Before being used in the coal mining area, the MQ-4 gas sensor was tested first to ensure its ability to detect methane gas. The test is shown in Figure 4.1, which displays the results of the sensor readings in the form of voltage values converted into PPM units using a formula based on the datasheet. The results of this test are also visualized in real-time via the Ubidots platform.

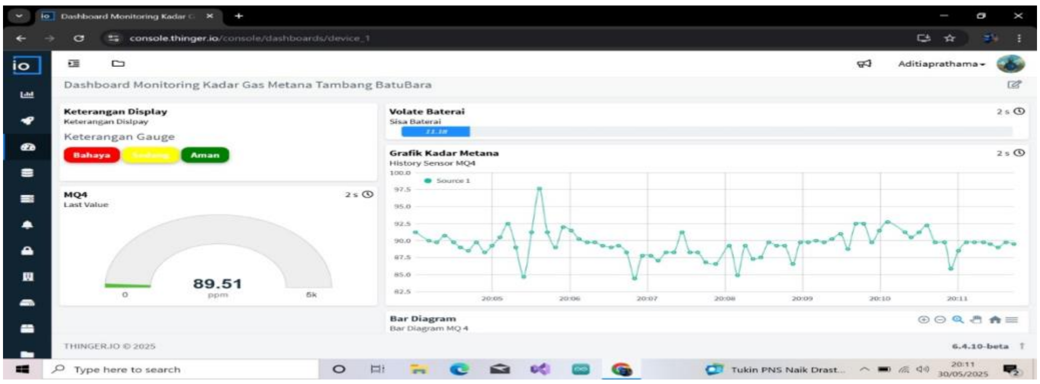

Figure 10 MQ-4 sensor test result graph

Figure 10 shows a dashboard view of methane gas levels monitoring.*real-time monitoring system built using the Thinger.io platform and MQ4 sensors. The dashboard contains several visual elements, including a gauge meter to show current gas levels, a historical graph of gas levels, and a bar chart. The latest gas concentration value displayed is 89.51 PPM, which is in accordance with normal conditions as listed in Table 4.1. In addition, the dashboard also includes color indicators—red (danger), yellow (moderate), and green (safe)—to facilitate quick interpretation of risk levels. Although the dashboard appears to be on the Thinger.io platform, the monitoring system is actually built using Ubidots, an open-source IoT platform. The use of Ubidots provides advantages in terms of* *flexibility, ease of sensor integration, and cost efficiency. With this system, monitoring of methane gas levels in coal mining areas can be carried out more responsively, accurately, and economically.*

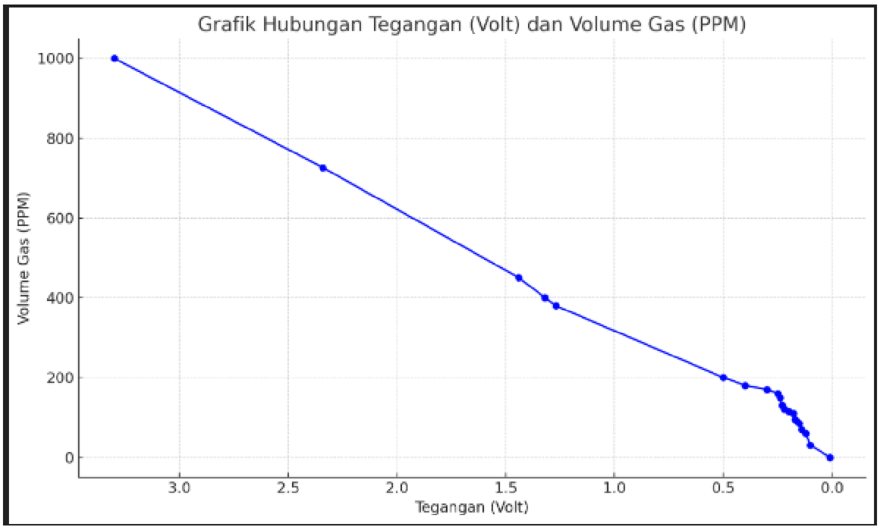

Figure 11 Graph of the relationship between voltage (Volts) and gas volume (PPM)

Figure 11 is a graph of the relationship between voltage (Volt) and gas volume (PPM). The graph shows that the smaller the voltage value, the lower the gas volume (in PPM units). This indicates that the MQ4 gas sensor used has a characteristic that decreases non-linearly with methane gas concentration—high voltage indicates high gas concentration, and vice versa. This graph reinforces the results of Table 4.1, where at voltages below 0.18 volts, the PPM value begins to stabilize and approaches zero, indicating that the environment is in a safe condition or has minimal methane gas.

Network Testing

This network test aims to measure the speed of data transmission from the mq-4 sensor which is read by the esp32 which is then sent to the ubidots website online.

Table 1 *ESP32 Data Transfer Speed Measurement*

Testing Data Sending Speed to Ubidots Website			
No	**Size Data Sent**	**Time (s)**	**Status**
1	64 bytes	0.242	okay
2	64 bytes	0.31	okay
3	64 bytes	0.293	okay
4	64 bytes	0.353	okay
5	64 bytes	0.17	okay
Average		**0.2736**	

Table 2 shows the data sending speed measurement from ESP32 to Ubidots website. The data sent is 64 bytes in size with the sending time varying in each test, starting from 0.17 seconds to 0.353 seconds. The test was carried out 5 times and the entire sending process showed the status "ok", which indicates that the data was successfully sent without error. From the test results, the average sending time was 0.2736 seconds, which shows that the ESP32 connection to the Ubidots platform is running well and stable.

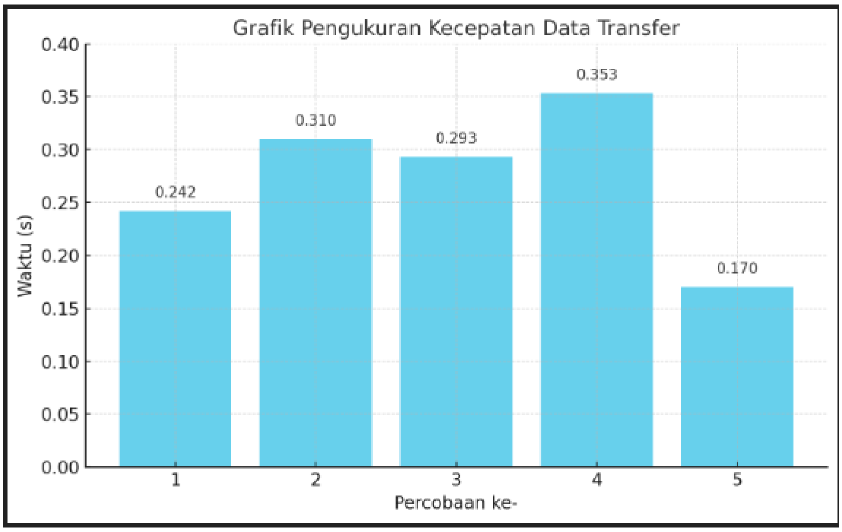

Figure 12 Data Transfer Speed Measurement Graph

Figure 12shows the results of testing the speed of sending data from ESP32 to the Ubidots website. The test was carried out 5 times with a data size of 64 bytes. The results show that the sending time is in the range of 0.170 seconds to 0.353 seconds, with an average sending time of 0.2736 seconds. This speed shows that the data transfer process is fast and stable, because all time values are far below the significant delay threshold. Thus, the system is considered responsive and reliable for use in real-time data monitoring via the internet network.

Discussion

This study explains the design process, testing, and analysis of the results of a methane gas monitoring tool based on the Internet of Things (IoT) using the MQ-4 sensor for monitoring in coal mines. This system is designed based on theory and references to produce an efficient and easy-to-use tool, with testing that ensures the tool works according to the purpose of methane gas monitoring. The MQ-4 sensor test shows the relationship between the output voltage and the methane gas concentration in ppm units, as shown in Table 4.1. The data indicates that when the voltage drops from 3.3 volts to below 0.1 volts, the methane gas concentration drops drastically from 1000 ppm to 0 ppm, indicating that the sensor responds well to gas levels. In the voltage range of around 0.17–0.18 volts, the sensor reading is stable at around 90–95 ppm, indicating that the environmental conditions are relatively safe.

Further testing is visualized through the graphs in Figure 4.1 and the real-time monitoring dashboard in Figure 4.2. The dashboard, built on the Thinger.io platform (with a backend system on Ubidots), displays color indicators and graphs of methane levels, facilitating quick interpretation of risk levels and providing responsive, accurate and cost-effective monitoring. The graph of the relationship between voltage and gas volume (ppm) in Figure 4.3 reinforces the results of previous tests, showing the non-linear characteristics of the MQ-4 sensor, where high voltage indicates high gas concentration and vice versa. The ppm value is stable near zero when the voltage is below 0.18 volts, indicating a safe environment from excess methane gas. Network testing in Table 4.2 and Figure 4.3 shows the speed of data transmission from ESP32 to the Ubidots platform with an average time of 0.2736 seconds for data of 64 bytes. All data was successfully sent without error, proving the network connection is stable and responsive for real-time data monitoring via the internet.

CONCLUSION

1. Based on the results of the design, testing, and analysis of the Internet of Things (IoT)-based methane gas monitoring system using the MQ-4 sensor, it can be concluded that this system was successfully built and can function effectively to detect the presence of methane gas in the coal mining environment. The MQ-4 sensor

is able to measure methane gas concentration accurately by displaying data in ppm units, which are then sent in real-time to the Ubidots monitoring platform via an ESP32 connection.

2. From the test results, the system showed a fast, stable and accurate response, with an average data delivery time of 0.2736 seconds, which makes this system reliable enough to provide early warning of potential gas leaks.
3. The system design has been in accordance with the established limitations, which only focuses on the detection and monitoring of methane gas without a direct mitigation system. The main objective of the research was achieved by compiling an efficient monitoring system, as well as obtaining good MQ-4 sensor performance data for applications in high-risk environments such as coal mines. Overall, this system provides significant benefits, both academically, practically, economically, environmentally, and socially, especially in improving work safety and awareness of the importance of hazardous gas monitoring technology.

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