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# Implementation of integrated temperature, humidity, and dust monitoring system on building electrical panel

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**ABSTRACT**

This research aims to develop and implement an electrical power monitoring system at the Sub Sub Distribution Panel (SSDP) in the Building. The system is designed to monitor power usage in real-time, provide accurate information on energy consumption, and detect potential energy waste. The methodology used includes hardware and software design. The hardware consists of current and voltage sensors connected to a microcontroller. The data collected by the sensors is then transmitted via Wi-Fi network to the server for analysis. The software uses an Internet of Things (IoT) platform that displays the data in the form of graphs and tables. The implementation shows that the system is capable of monitoring power usage with a high degree of accuracy. The sensors used, namely PM2100 for voltage, SHT20 for temperature and humidity, and GP2Y101AU0F for dust concentration, proved effective in generating accurate real-time data. Based on the test results, the voltage measurement error with the PM2100 was only 0.035%, while the current measurement resulted in an error of 0.48%. The SHT20 sensor recorded an error of 2.4% for temperature and 1.0% for humidity. Dust measurements with the GP2Y101AU0F sensor had a very small error of 0.02%. These results indicate that the tested device has a sufficient level of precision for electrical power and environmental monitoring applications.



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## 1. INTRODUCTION

The use of electrical energy has become one of the main factors driving the development of modernity in various sectors of human life [1]. Since the discovery of electricity by Thomas Edison and Nikola Tesla in the 19th century, it has changed the way we work, communicate and go about our daily activities. From lighting to operating machinery and information technology, electricity plays an important role in fulfilling the needs of modern society [2]. Despite its convenience and efficiency, the use of electricity also poses challenges related to limited natural resources and environmental impacts, prompting efforts to shift to renewable energy and improve energy efficiency for the sustainability of the planet [3]. Along with the development of technology and the rapid progress in South Sumatra, the demand for electrical energy has increased. However, the demand fluctuates annually, creating challenges in meeting the demand without harming electricity providers such as PLN. One solution to overcome this is through careful planning, by estimating the electricity load in order to provide important information for PLN [4]. There are several methods that can be used to predict electricity load [5].

In the process of electricity distribution through SSDP (Sub Sub Distribution Panel), an integrated approach is required to improve efficiency and reliability. SSDP is a critical element in the distribution of electricity from generators to end consumers [6]. The importance of maintaining SSDP stability and reliability is further reinforced by the need for intelligent load management, real-time monitoring, and automation devices that can detect and resolve disturbances quickly. Emerging digital technologies and the use of geographic information systems (GIS) also support the improvement of SSDP management [7]. In addition, the application of smart grid technology with smart sensors, automatic control, and data analysis can help optimize energy flows, reduce power losses, and respond quickly to load fluctuations and power grid disturbances [8]. In this context, creating an efficient, controllable, and adaptive SSDP is a strategic step to ensure optimal distribution of electrical energy.

To overcome the above challenges, a panel monitoring system using PM2100 sensors is needed to measure the current, voltage, and power generated by the panel. The SHT20 temperature sensor is used to detect the temperature and humidity of the panel [9]. If the panel temperature exceeds 33°C, the fan will turn on automatically, and the humidity standard is set at 65% [10]. In addition, the GP2Y101AU0F dust sensor is used to detect the level of dust accumulation on the panel. If the dust thickness is significant, this sensor will trigger an alarm as a warning, so that the user immediately cleans the electrical panel, so that the cleanliness and performance of the system is maintained. This monitoring process uses ESP32 for data communication, which is then processed using the Arduino IDE programming system and connected to the Android application.

## 2. METHOD

This research focuses on system design with full details of the hardware and software structure. The stage begins with the preparation of a system block diagram to provide an overview of the interactions between components in the system. Next, a flowchart is created that explains the system workflow in detail. Reference in the discussion is marked by literature number which is referenced in square brackets.

### 2.1 Block Diagram of the System

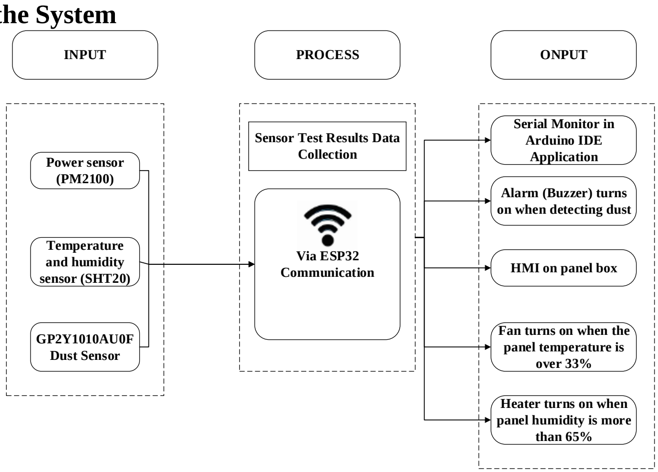


Figure 1. Block Diagram of the System

Figure 1 shows a block diagram of a system that utilizes various components to collect data (input) and produce a response or action (output). The system utilizes three sensors: a PM2100 power sensor to measure current, voltage, and power, a SHT20 temperature and humidity sensor to measure temperature and humidity conditions around the appliance, and a GP2Y101AU0F dust sensor to detect dust on the electrical panel. After the data is collected, the system can take action based on the information through several outputs, namely an Android application for remote monitoring, an alarm to provide a warning if a problem occurs, an HMI to display information directly to the user, and a fan to cool the electrical panel when the temperature exceeds 33°C. Data processing from the sensors is done using the ESP32 program, which allows the system to learn data patterns and make decisions based on these patterns. The processed data is then sent through the ESP32 communication module, allowing the electrical panel to be monitored and managed in real-time. Furthermore, the data is also sent to the database which will be displayed on the android application.

**2.2 Flowchart of the System Workflow**

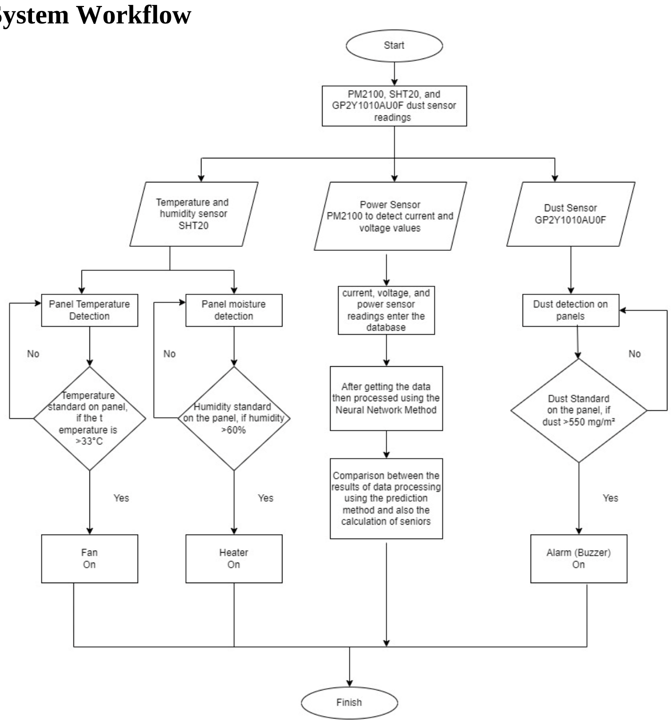


Figure 2. Flowchart of the System Workflow

Figure 2 illustrates the steps in the system monitoring process on the power panel. When the power panel is turned on and the monitoring system in the Arduino IDE application connected to the ESP32 is active, the monitoring process begins. The serial monitor will keep an eye on three main aspects: electrical power, temperature, and dust on the electrical panel. The first step in the process is to monitor the panel power using the PM2100 sensor [11]. This sensor measures the power, current, and voltage values generated by the electrical panel. The information is displayed to provide an overview of the power conditions used by the panel. Next, the system detects the temperature on the panel using the SHT20 sensor [12]. If the temperature exceeds 33°C, the fan connected to the panel will automatically turn on to cool the panel until the temperature drops below 33°C, thus preventing overheating that can damage panel components [13]. The final step involves monitoring the dust on the electrical panel using a GP2Y101AU0F sensor [14]. If dust is detected, an alarm sounds through a buzzer as a warning that there is dust on the electrical panel [15]. This warning signals the user or technician to immediately check and deal with the problem. Taken together, these measures create a series of preventive and responsive actions. From power monitoring to temperature handling and dust detection, the system is designed to maintain the safety and optimal performance of electrical panels by providing alerts and automatic actions according to the detected conditions.

**2.3 Internet of Ting**

The Internet of Things (IoT) is a concept that connects various physical devices to the internet, allowing them to communicate with each other and exchange data automatically without human intervention [16]. IoT utilizes sensors, software, and other technologies to collect, send, and receive data from the surrounding environment, which is then analyzed to generate useful information. This technology is applied in various fields, such as smart homes, transportation, industry, and healthcare, with the aim of improving efficiency, convenience, and real-time data-based decision-making [17]. IoT also enables remote management and automation of various systems, changing the way we interact with technology on a daily basis.

**2.4 Electrical Power**

Electrical power is a measure of the electrical energy used or generated by a device in a given unit of time, usually expressed in watts (W). Electrical power is the product of voltage (volts) and electric current (amperes) flowing through a circuit [18]. In the context of use, electrical power shows how fast electrical

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energy is consumed by electronic devices or machines to carry out their functions. The greater the electrical power required by a device, the greater its electrical energy consumption [19]. An understanding of electrical power is important to optimize the efficiency of energy use, as well as to ensure that electrical loads are safe and in accordance with the capacity of existing electrical installations.

### 2.5 Sub Sub Distribution Panel

A Sub Distribution Panel (SSDP) is an important component in an electrical distribution system that acts as an additional distribution point from the main distribution panel to various parts within a building or facility [20]. SSDP receives electricity from the main distribution panel and distributes it to smaller distribution panels or directly to equipment and systems that require power. The main function of an SSDP is to manage and distribute electrical power in a more structured and segmented manner, thus allowing for more efficient load regulation and improved electrical system security [21]. SSDPs are also often equipped with protections such as circuit breakers to prevent damage from overloads or electrical faults, as well as facilitate maintenance and repair of electrical systems in a more organized manner.

### 2.6 Arduino IDE

The Arduino IDE (Integrated Development Environment) is software used to write, edit, and upload program code to the Arduino development board [22]. This IDE provides a simple user interface with a code editor, compiler, and upload tool for programming Arduino microcontrollers. With features such as board type and serial port selection, and libraries that make it easy to use various sensors and modules, the Arduino IDE allows developers to design and test electronic projects efficiently [23]. In addition, the IDE supports various programming languages, especially C and C++, and provides a variety of code samples and documentation that help users in the development and debugging process. The Arduino IDE is very popular among hobbyists and professionals due to its ease of use and extensive community support.

### 2.7 Android Studio

Android Studio is an official integrated development environment (IDE) designed specifically for Android application development. Developed by Google, Android Studio provides various tools and features to simplify the development process, such as an advanced code editor, Android emulator for application testing, and tools for user interface design [24]. This IDE supports Java, Kotlin, and C++ programming languages, and provides various templates, libraries, and SDKs that assist developers in creating responsive and performant applications. Android Studio is also integrated with a version control system and build tools that enable more efficient project management [25]. With an intuitive interface and comprehensive features, Android Studio makes it easy for developers to build, test, and launch Android apps on a variety of devices.

### 2.8 Hardware Design

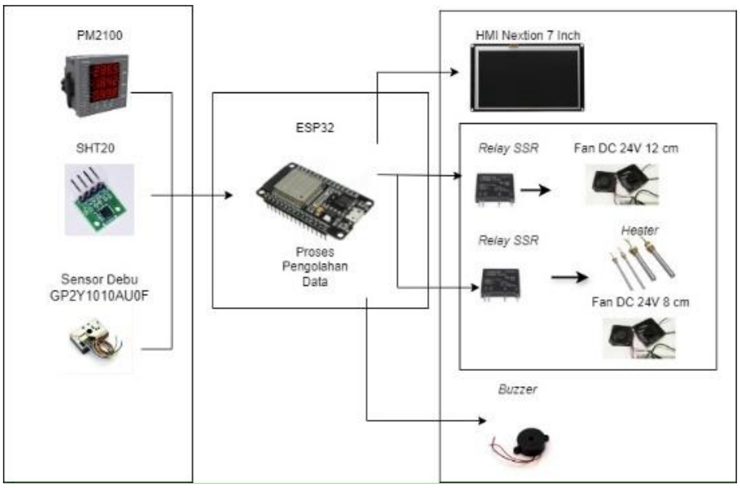



Figure 3. Hardware Design

Figure 3. describes the workflow of the hardware design system for electrical panels equipped with specialized sensors to monitor conditions and security. First, PM2100 sensors are installed to monitor the current, voltage, and power coming out of the panel. The SHT20 temperature and humidity sensor is used to monitor the temperature and humidity around the panel; if the temperature exceeds 33°C or the humidity exceeds 65%, the system will automatically activate the fan and heater to cool the panel and prevent

overheating. In addition, the GP2Y101AU0F dust sensor detects the presence of dust on the panel and activates a buzzer alarm as a warning to clean the dust if detected. All data from these sensors is processed using an ESP32 communication module, which then sends the information to two locations: HMI screen for direct monitoring by the user and Android app for remote monitoring. The system is designed to ensure efficient and responsive monitoring of electrical panel conditions.

### 2.9 Electrical Panel Design


Figure 4. Electrical Panel Design Exterior

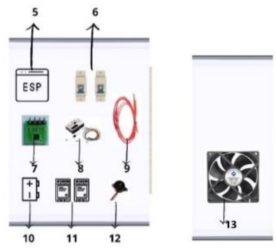



Figure 5. Electrical Panel Design Interior

In Figure 4 and Figure 5 are pictures of the panel design that will be made for monitoring electrical panels in lecture buildings. The following is a description of the picture above:

1. Pilot Lamp
2. HMI (Human Machine Interface)
3. PM2100
4. Emergency Button
5. ESP32
6. MCB
7. SHT20
8. Dust Sensor GP2Y1010AU0F
9. Heater Cartridge
10. Power Supply
11. Relay
12. Buzzer
13. Fan 24VDC

## 3. RESULTS AND DISCUSSIONS

### 3.1 Hardware Design Results

The following are the results of hardware design. The hardware design in this study includes the realization of a panel box that has been hollowed out on the cover to install the necessary components on the front of the panel box, such as a pilot lamp, a 7-inch Nextion HMI, PM2100, and an emergency button. In addition, on the right side of the panel there is a DC 24V fan. The physical form of the mechanical design can be seen in Figure 6 and Figure 7.

Figure 6. Front of Box Panel

Figure 7. Side of the Box Panel

Figure 6. the Front Panel Box shows several components mounted on the front of the panel box. Three pilot lamps function as three-phase indicators, 7-inch Nextion HMI is used as a display of the monitoring system on the panel, and PM2100 functions to measure current, voltage, and power on the electrical panel. The panel used in this research measures 50x40x25 cm and is designed to be used indoors. Figure 7. the Side Panel Box shows the installation location of a 12-inch DC 24V fan, which functions to remove heat from inside the

panel if the panel temperature exceeds 33°C. With the 12-inch DC 24V fan, it is expected that the panel box can work optimally at a predetermined temperature.

### 3.2 Sensor and Actuator Testing Results

In the sensor and actuator testing stage, all components that have been assembled on the electrical panel are tested. This test ensures that the sensor detects the parameters correctly and the actuator responds to commands properly. The result is expected that the entire system on the electrical panel functions optimally and is well integrated.

#### 3.2.1 PM2100 Sensor Testing

Voltage testing is done using PM2100 by entering the PM2100 read value into the ESP32 program using the Arduino IDE application. In this test comparing the PM2100 measurement read value with the read value on the serial monitor on the Arduino IDE.

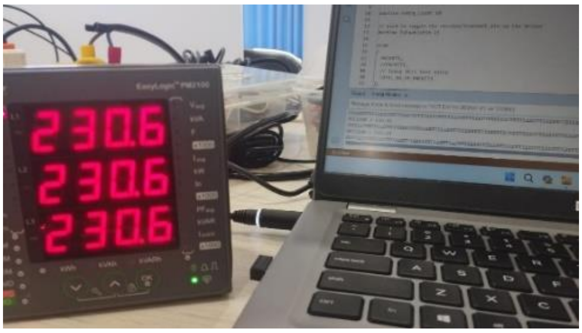



Figure 8. PM2100 Sensor Testing

Figure 8 shows the results of PM2100 voltage testing using RS485 connection between ESP32 and PM2100. Next, the PM2100 is applied AC voltage to detect the value of the voltage under test. This process compares the value displayed on the PM2100 screen with the value read on the serial monitor of the Arduino IDE application.

Table 1. The Results of PM2100 Voltage

| No. | Rated Voltage on PM2100 | Value Serial monitor voltage | Persentase Error (%) |
|---|---|---|---|
| 1. | 230.5 | 230.60 | 0.04 |
| 2. | 230.6 | 230.60 | 0 |
| 3. | 230.7 | 230.63 | 0.02 |
| 4. | 230.8 | 230.84 | 0.02 |
| 5. | 230.8 | 230.91 | 0.04 |
| 6. | 230.7 | 230.77 | 0.02 |
| 7. | 230.7 | 230.76 | 0.02 |
| 8. | 231.0 | 231.05 | 0.017 |
| 9. | 230.7 | 230.68 | 0.01 |
| 10. | 230.8 | 230.83 | 0.01 |
| Average Error | | | 0.035 |

Table 1. PM2100 Testing Results displays the results of voltage readings by the PM2100 monitored through the serial monitor in the Arduino IDE application. During the test, there is a percentage error calculated by comparing the monitoring results from the PM2100 with the data received through the ESP32 serial monitor in the Arduino IDE application.


Figure 9. PM2100 Current Testing

Figure 9 shows the results of testing the current value of the PM2100 using an RS485 connection between the ESP32 and PM2100. Furthermore, the PM2100 is given a load in the form of an incandescent lamp to detect the current value to be tested. This process compares the value displayed on the PM2100 screen with the value read through the serial monitor in the Arduino IDE application.

Table 2. PM2100 Current Testing Results

| No. | Load used | Rated Current on PM2100 | Current value on serial monitor | Persentase Error (%) |
|---|---|---|---|---|
| 1. | Lampu pijar 25 watt | 0.052 | 0.05 | 0.38 |
| 2. | Lampu pijar 25 watt | 0.052 | 0.05 | 0.38 |
| 3. | Lampu pijar 25 watt | 0.052 | 0.05 | 0.38 |
| 4. | Lampu pijar 25 watt | 0.052 | 0.05 | 0.38 |
| 5. | Lampu pijar 25 watt | 0.052 | 0.05 | 0.38 |
| 6. | Lampu pijar 40 watt | 0.106 | 0.10 | 0.57 |
| 7. | Lampu pijar 40 watt | 0.106 | 0.10 | 0.57 |
| 8. | Lampu pijar 40 watt | 0.106 | 0.10 | 0.57 |
| 9. | Lampu pijar 40 watt | 0.106 | 0.10 | 0.57 |
| 10. | Lampu pijar 40 watt | 0.106 | 0.10 | 0.57 |
| Average Error | | | | 0.48 |

Table 2. PM2100 Test Results displays the results of the current readings by the PM2100 monitored through the serial monitor in the Arduino IDE application. During the test, the percentage error is calculated by comparing the monitoring results from the PM2100 with the data received through the ESP32 serial monitor in the Arduino IDE application.

### 3.2.2 SHT20 Sensor Testing

SHT20 sensor testing using ESP32 is done by comparing its readings with HTC-2 measuring instrument. The purpose of this test is to evaluate the accuracy and consistency of the SHT20 sensor in measuring environmental parameters such as temperature and humidity, using ESP32 as a microcontroller. The reading results from the SHT20 sensor are then compared with the results obtained from the HTC-2 to ensure the accuracy and reliability of the data generated by the SHT20 sensor.

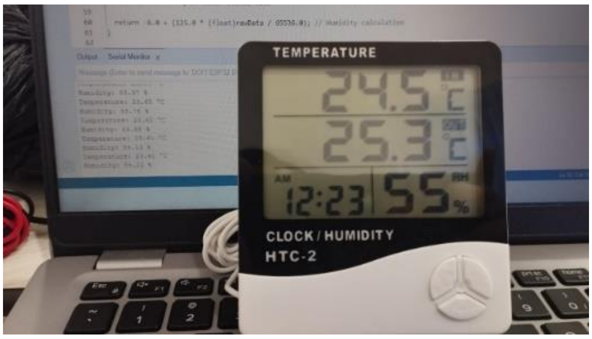



Figure 10. SHT20 Sensor Testing

The SHT20 sensor test results are a comparison of the values obtained from the SHT20 sensor with the HTC 2 device, which is used as a reference for measuring temperature and humidity in the room. In this test, the temperature and humidity data generated by the SHT20 sensor is analysed and compared with the data obtained from HTC-2.

Table 3. SHT20 Sensor Temperature Testing Results

| ***No.*** | ***SHT20 Rated Temperature (°C)*** | ***Value on HTC-2 (°C)*** | ***Persentase Error (%)*** |
|---|---|---|---|
| 1. | 23.55 | 23.9 | 1.48 |
| 2. | 23.52 | 23.9 | 1.61 |
| 3. | 23.45 | 24.0 | 2.35 |
| 4. | 23.42 | 24.1 | 2.35 |
| 5. | 23.56 | 24.3 | 2.25 |
| 6. | 23.61 | 24.3 | 2.25 |
| 7. | 23.65 | 24.5 | 2.25 |
| 8. | 23.61 | 24.5 | 2.25 |
| 9. | 23.55 | 25.3 | 4.1 |
| 10. | 23.60 | 25.3 | 4.1 |
| Average Error | | | 2.4 |

Table 3 shows the results of testing the temperature value of the SHT20 sensor. This table presents the temperature reading data from the SHT20 sensor tested to evaluate its performance. The data obtained from the SHT20 sensor is compared with the reference value to ensure the accuracy and consistency of the resulting temperature measurement.

Table 4. SHT20 Sensor Humidity Testing Results

| **No.** | **SHT20 Value Humidity (%)** | **Value on HTC-2 (%)** | **Persentase Error (%)** |
|---|---|---|---|
| 1. | 54.39 | 55 | 1.17 |
| 2. | 54.36 | 55 | 1.17 |
| 3. | 54.58 | 55 | 1.16 |
| 4. | 54.62 | 55 | 1.15 |
| 5. | 54.66 | 55 | 1.15 |
| 6. | 54.72 | 55 | 1.11 |
| 7. | 54.71 | 55 | 1.11 |
| 8. | 54.61 | 55 | 1.15 |
| 9. | 54.97 | 55 | 0.04 |
| 10. | 54.95 | 55 | 0.05 |
| Average Error | | | 1.0 |

Table 4. shows the results of testing the humidity value on the SHT20 sensor. This table presents the temperature reading data from the SHT20 sensor tested to evaluate its performance. The data obtained from the SHT20 sensor is compared with the reference value to ensure the accuracy and consistency of the resulting temperature measurement.

### 3.2.3 Dust Sensor Testing

Testing of the GP2Y1010AU0F dust sensor is carried out using an ESP32 to retrieve and record the reading value generated by the sensor. This process aims to evaluate the performance of the GP2Y1010AU0F dust sensor in detecting dust particles in the air. By utilising the ESP32 as a microcontroller platform, the data obtained from the dust sensor will be collected and analysed to ascertain the accuracy and reliability of the readings under various environmental conditions.

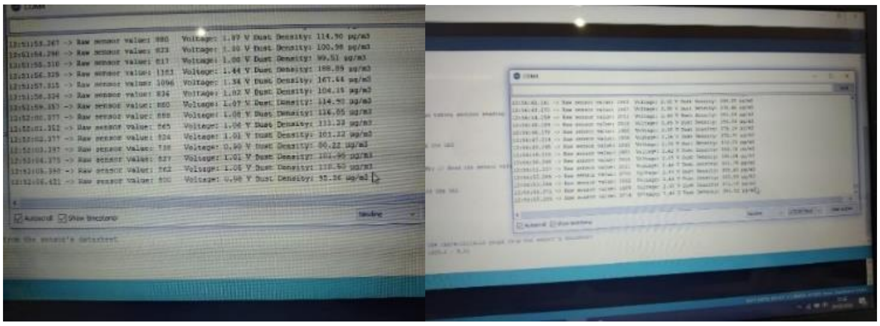


Figure 11. GP2Y1010AU0F Dust Sensor Testing Results

The GP2Y1010AU0F dust sensor test results are obtained from the sensor value readings displayed on the serial monitor in the Arduino IDE application. The GP2Y1010AU0F dust sensor reading value is displayed in units of micrograms per cubic metre (µg/m³). The data displayed on the serial monitor includes the concentration of dust particles detected by the sensor, which can then be analysed to evaluate the sensor's performance in detecting air pollution levels in the tested environment.

Table 5. GP2Y1010AU0F Dust Sensor Testing Results

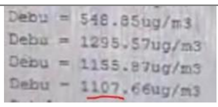
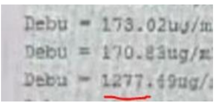
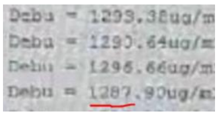
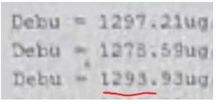
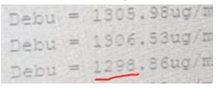
| ***No.*** | ***Serial Monitor*** | ***Haz Dust*** | ***error*** |
|---|---|---|---|
| 1. |  1107.66 ug/$m^3$ |  1.10 mg/$m^3$ | 0.02% |
| 2. |  1277.49 ug/$m^3$ |  1.27 mg/$m^3$ | 0.02% |
| 3. |  1287.90 ug/$m^3$ |  1.28 mg/$m^3$ | 0.02% |
| 4. |  1293.93 ug/$m^3$ |  1.29 mg/$m^3$ | 0.02% |
| 5. |  1298.86 ug/$m^3$ |  1.29 mg/$m^3$ | 0.01% |
| | Rata-Rata Error | | 0.01% |

Table 5 shows the test results of the GP2Y1010AU0F dust sensor, including the percentage error obtained in the measurement. The test results show that this sensor has a very high level of accuracy, with a percentage error of only 0.01%. This data reflects the reliability of the sensor in detecting dust concentration and ensures that the measurement results are very close to the set reference value.

### 3.3 Display on Android Application

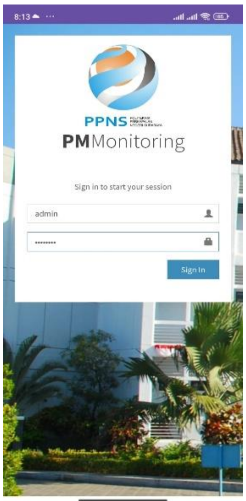



Figure 12. Interface Android Result

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Figure 12 shows the results of the Android Interface which includes the login, registration, and home page views of the Android application. In the home view, this application displays the value readings of each sensor used in the electrical panel in real-time, so that users can monitor the condition and performance of the electrical panel easily and efficiently. The intuitive and user-friendly interface is designed to make it easier for users to access the required information and perform the required actions based on the displayed sensor data.

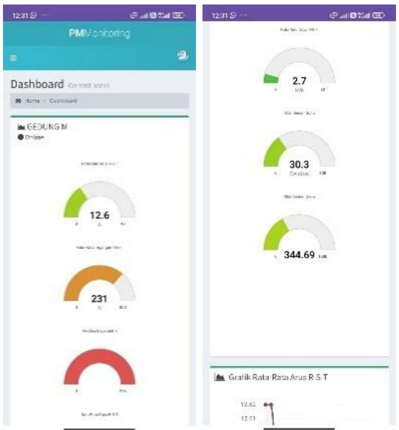


Figure 13. Home View on Android

Figure 13 shows the stored sensor read values. These sensor readings are sent using ESP32 communication, which functions as a real-time data sender to the database. The data sent by the ESP32 includes readings from various sensors installed on the electrical panel. Once the data is stored in the database, the Android app can then access and display the sensor read values. This process allows users to effectively monitor and analyze the condition of the electrical panel through the Android app, thanks to the fast and reliable data transfer from the ESP32.

## 4. CONCLUSION

Based on this research, it can be concluded that the electrical panel monitoring system using PM2100, SHT20, and GP2Y1010AU0F sensors can function effectively. The PM2100 sensor monitors voltage and current with a very low error rate of 0.035% for voltage and 0.48% for current. The SHT20 sensor measured temperature and humidity with good accuracy, 2.4% for temperature and 1.0% for humidity compared to the HTC-2 device. The GP2Y1010AU0F dust sensor detects dust concentration with a percentage error of only 0.02% compared to the Haz Dust device. Data from these three sensors is transmitted and displayed via an ESP32 communication module and Android app, enabling real-time monitoring and management of electrical panel conditions from any location. The system is effective in ensuring the safe and efficient operation of electrical panels, as well as minimizing the risk of disruption or damage. For further research, it can be continued to add to the stability of the internet network by adding an internet speed monitoring system that is used to monitor electrical panels using android applications in real time.


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