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IoT-Based Generator Room Monitoring System at Diskominfo West Java

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ABSTRACTS

Dinas Komunikasi dan Informatika (Diskominfo) has an important role in maintaining the continuity of information technology services by ensuring system availability in accordance with the availability principle of the ISO 27001 standard. To support this ISO 27001 principle, routine generator warm-up activities are conducted every Saturday to ensure that the generator functions properly as a backup power source in the event of a disruption to the main power supply. Therefore, monitoring the environmental conditions of the generator room is necessary when the generator operates during the warm-up process as well as when it is in use. This research aims to design and implement a web-based generator room monitoring system capable of displaying environmental conditions in real-time. The developed system utilizes DHT22, KY-037, and BH1750 sensors to monitor parameters such as temperature, humidity, light intensity, and noise levels. In addition, the system is equipped with an actuator in the form of a relay connected to an exhaust fan in the generator room, which automatically turns on when the temperature exceeds the predetermined threshold. Data obtained from the sensors are transmitted using the MQTT protocol and displayed on the InTegrated SOlution (ITSO) website of Diskominfo as a monitoring platform. The testing results indicate that the system is able to respond effectively to environmental changes, particularly in the noise parameter when the generator is active. Usability testing using the System Usability Scale (SUS) method produced an average score of 94, which falls into the excellent category, indicating that the system is easy to use and highly accepted by users..

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1. INTRODUCTION

The development of the Internet of Things (IoT) has become a key driver of digital transformation across various sectors. IoT not only connects devices but also enables the automatic collection, processing, and utilization of data to improve operational efficiency and support real-time decision-making. The integration of sensors, actuators, and communication networks allows devices to exchange information with one another [1], thereby enhancing operational efficiency [2]. An IoT system consists of several core components, including sensors, actuators, communication protocols, and cloud computing [3]. Furthermore, the implementation of IoT in predictive monitoring improves accuracy while minimizing errors associated with manual supervision [4].

In government institutions, a generator set (genset), which serves as a backup power source during electrical outages [5], plays a crucial role in ensuring service continuity. The West Java Communication and Information Office (Dinas Komunikasi dan Informatika Jawa Barat) utilizes a generator set as a backup electrical power supply to support the availability principle, one of the fundamental principles of information security management, thereby ensuring that information systems remain operational during power disruptions. However, the current monitoring process is still performed manually, creating the potential for data inconsistencies and a lack of transparency. In addition, operating the generator set before it reaches its optimal operating temperature may accelerate component deterioration [6].

Based on these conditions, an IoT-based generator room monitoring system was developed to perform real-time monitoring of temperature, light intensity, and noise levels using the DHT22, BH1750, and KY-037 sensors. Previous research focused on developing an Arduino Uno-based automatic exhaust fan prototype [7]. In contrast, this study not only implements an automatic control mechanism but also integrates multi-parameter monitoring, a web-based dashboard, and MQTT communication. The system is further equipped with automatic temperature control using a relay-based cooling fan. Monitoring data are displayed on an internal web dashboard, enabling all relevant stakeholders to access real-time information.

2. MATERIALS AND METHODS

This study proposes an IoT-based monitoring system that operates through an integrated workflow consisting of sensor data acquisition, data transmission via MQTT protocol, processing by a web-based system, and real-time visualization

2.1 System Design

The following figure illustrates the architecture of the IoT-based generator room monitoring system, which consists of sensors, actuators, a microcontroller, and a web-based monitoring platform.

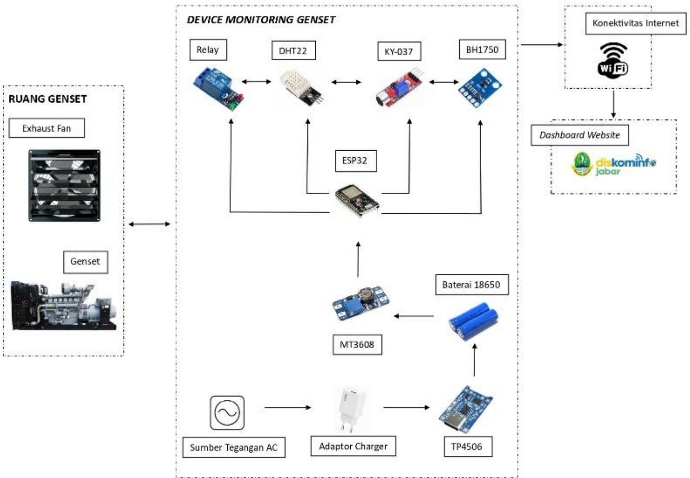

Figure 1. IoT-Based Generator Room Monitoring System Design

Figure 1 illustrates the design of the Internet of Things (IoT)-based generator room monitoring system, which was developed to monitor environmental conditions inside the generator room and automatically control specific devices in real time. The generator room consists of two main components: the generator set (genset) and an exhaust fan. The exhaust fan is used to maintain proper air circulation inside the room, thereby ensuring a stable temperature.

The generator monitoring device incorporates several sensors and actuators. The DHT22 is a digital sensor used to measure the room's temperature and humidity [8]. In addition, a 5 V single-channel SPDT relay module is employed as an automatic switch to control electrical devices [9], such as the exhaust fan. The system also utilizes the BH1750 sensor, a digital light sensor that communicates through the I²C bus interface [10]. The BH1750 is used to detect the lighting conditions inside the generator room, while the KY-037 sensor measures the noise level generated by the generator in decibels (dB) [11]. The sensitivity of the KY-037 sensor can be adjusted using a potentiometer, allowing the sensor's response to be calibrated according to variations in ambient sound intensity [12].

All sensor data are processed by the ESP32 microcontroller, which is equipped with built-in Wi-Fi and Bluetooth capabilities for wireless communication [13]. The ESP32 functions as the central controller of the system by processing the collected data and transmitting them via the Internet.

The transmitted data are displayed on the InTegrated Solution (ITSO) web dashboard, a web-based information service managed by the West Java Communication and Information Office (Dinas Komunikasi dan Informatika Jawa Barat). Through this dashboard, authorized users can monitor the generator room conditions in real time. Furthermore, the system is connected to the Internet through the local Wi-Fi network of the Communication and Information Office.

Regarding the power supply, the system uses 18650 lithium-ion batteries connected in a series configuration. The use of 18650 batteries offers the advantage of being safe and reliable for electronic systems [14]. The batteries are connected to an MT3608 step-up converter module, which increases the battery output voltage from 3.7 V to the 5 V required by the system [15]. In addition, a TP4056 charging module is employed to recharge the 18650 batteries. The primary power source is derived from an AC supply, which is converted through a charger adapter before being stored in the batteries. Overall, the proposed system supports automatic, efficient, and real-time monitoring of the generator room environment.

2.2 System Architecture

The design of the generator room monitoring system is illustrated in Figure 2, which presents the system architecture diagram consisting of four main components: input, process, output, and actuator. These components are integrated to support data acquisition, data processing, and automatic system control.

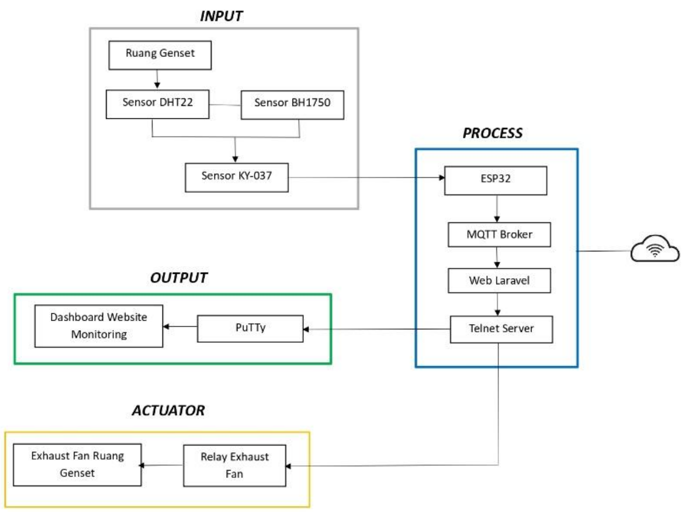

Figure 2. System Architecture Diagram

Figure 2 illustrates the system architecture, which is divided into four stages: input, process, output, and actuator. During the input stage, the system integrates several sensors, including the DHT22 sensor for measuring temperature and humidity, the BH1750 sensor for measuring light intensity, and the KY-037 sensor for measuring noise levels inside the generator room.

During the process stage, sensor data are processed by the ESP32 microcontroller and transmitted using the Message Queuing Telemetry Transport (MQTT) protocol, a lightweight communication protocol widely implemented in IoT-based monitoring systems [16]. The MQTT broker and monitoring dashboard are deployed within the organization's internal network, allowing access only to users connected to the local network. This network restriction reduces the risk of unauthorized access and enhances the security of system data communication. The MQTT protocol publishes data to the broker through the topics genset/telemetry, genset/status, and genset/control/exhaust. A Laravel-based web application acts as an MQTT subscriber by receiving data from the broker, storing and processing the data, and displaying them on the monitoring dashboard in real time.

In addition, the system supports local monitoring through the Telnet protocol, a client–server communication protocol that enables remote system access and control over a Local Area Network (LAN) [17]. The local monitoring process is performed using the Arduino IDE, an open-source electronic prototyping platform used for designing and developing interactive embedded systems [18].

During the output stage, monitoring data can be accessed through PuTTY, a terminal emulator application that supports SSH, Telnet, and Rlogin network protocols [19]. PuTTY is used within the local network, while the ITSO Diskominfo website provides real-time visualization of the generator room conditions, including the operational status of the generator, lighting system, and exhaust fan. When the measured temperature exceeds the predefined threshold, the relay automatically activates the exhaust fan to prevent overheating.

The monitoring website was developed using Visual Studio Code and is connected to the ITSO Diskominfo server. The system is also equipped with a generator warm-up history logging feature, allowing monitoring records to be exported in both PDF and Microsoft Excel formats..

2.3 Hardware Design

The following figures illustrate the pin interconnection scheme used in the hardware design of the ESP32-based generator room monitoring system.

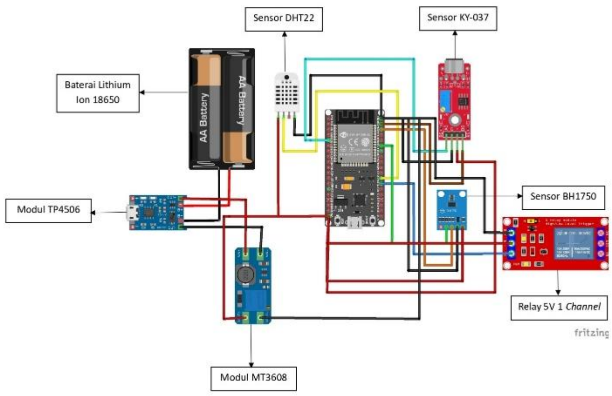

Figure 3. Pin Interconnection Diagram

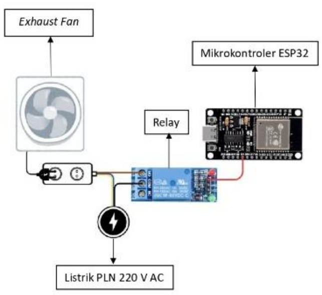

Figure 4. Actuator Circuit

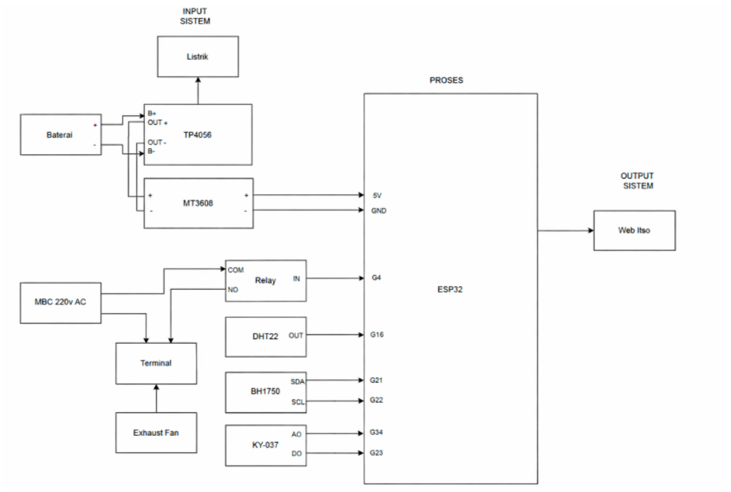

Figure 5. Wiring Diagram of the Generator Room Monitoring System

Figures 3 and 4 present the pin interconnection scheme for the hardware design of the ESP32-based generator room monitoring system. The circuit consists of a DHT22 sensor for temperature and humidity measurement, a KY-037 sound sensor for noise detection, and a BH1750 sensor for measuring light intensity. The power supply is provided by a 18650 lithium-ion battery connected to a TP4056 charging module and an MT3608 step-up converter for voltage regulation. In addition, a 5 V relay module is employed as the system actuator. All components are interfaced with the ESP32 through its input and output pins.

Figure 5 illustrates the wiring configuration of the exhaust fan control system using the ESP32 and a relay module. The relay functions as an electrical switch that connects or disconnects the 220 V AC power supply to the exhaust fan. Based on sensor readings or predefined control logic, the ESP32 activates or deactivates the relay, allowing the exhaust fan to automatically turn on or off according to the environmental conditions inside the generator room.

2.4 Software Design

The software design focuses on the system workflow and sensor data processing, including data acquisition, transmission, and visualization on the generator room monitoring website, as illustrated in Figure 6.

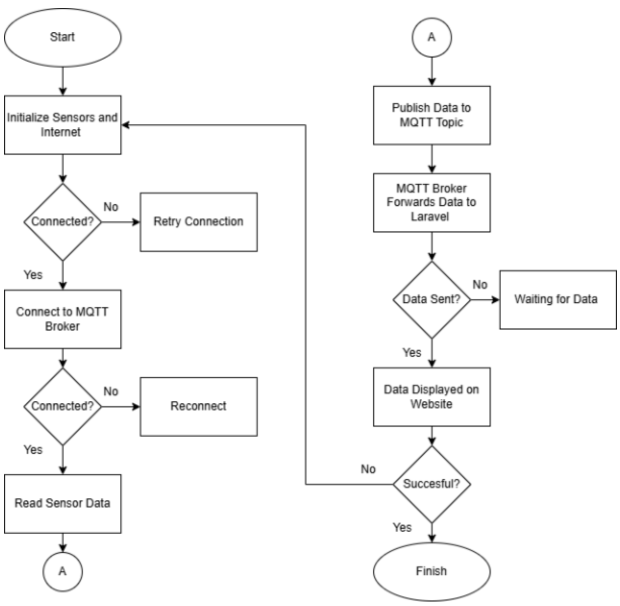

Figure 6. Software Design Flowchart

Figure 6 presents the software design flowchart of the proposed monitoring system. Overall, the monitoring system operates through an integrated sequence of processes, beginning with sensor data acquisition and ending with real-time data visualization on the monitoring website. The process starts with the initialization of the sensors and network connection, followed by verification of Internet connectivity and connection to the MQTT broker. The system is designed to automatically retry the connection whenever a failure occurs, ensuring reliable and continuous data communication.

Once the connection has been successfully established, the ESP32 microcontroller reads data from the sensors and publishes them to predefined MQTT topics using the MQTT protocol. The MQTT broker acts as an intermediary that distributes the published data to the Laravel-based web application. The received data are then processed and displayed on the monitoring dashboard in real time.

2.5 Website Design

The user interface design stage was carried out to visualize the layout of the generator room monitoring website. The design includes the page structure, menu layout, and presentation of monitoring data. The web-based monitoring system interface design is illustrated in Figure 7.

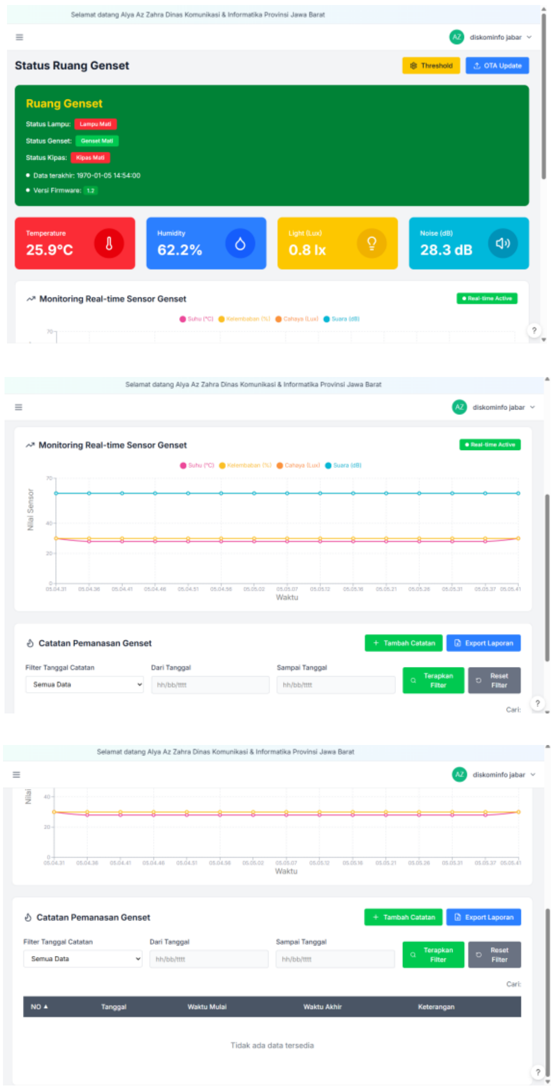

Figure 7. User Interface Design of the Generator Room Monitoring Website

Figure 7 presents the user interface design of the generator room monitoring website. The dashboard displays the operational status of the generator room through status indicators for the lighting system, generator set (genset), and cooling fan (exhaust fan). In addition, the generator room status section includes the date and time corresponding to each transmitted dataset.

The dashboard also provides monitoring indicators for temperature, humidity, light intensity, and noise level. The values displayed by these indicators represent real-time data transmitted from the corresponding sensors. Furthermore, the interface includes real-time monitoring charts that visualize changes in sensor measurements over time.

At the bottom of the webpage, a generator warm-up log section allows authorized personnel to record maintenance notes related to generator warm-up activities. This section also provides an export feature that enables the recorded data to be downloaded in both PDF and Microsoft Excel formats.

2.6 Sensor Testing

Sensor testing was conducted to evaluate the characteristics of the output data generated by the developed generator room monitoring system under actual operating conditions. The evaluated parameters included air temperature (°C), relative humidity (%), sound intensity (dB), and light intensity (lux), as measured by the sensors integrated into the monitoring system.Sensor data were collected using the PuTTY terminal emulator, which was employed to display sensor readings in real time. The collected data were subsequently exported to CSV format using Microsoft Excel for further analysis. Data acquisition was performed using a periodic sampling method, in which sensor readings were recorded every 6 seconds throughout the predetermined testing period. This sampling approach was adopted to obtain representative data for evaluating the performance of the proposed monitoring system.

2.7 System Usability Scale Testing

To evaluate the usability of the proposed IoT-based generator room monitoring system, a usability assessment was conducted using the System Usability Scale (SUS). This method was selected because it is practical, efficient, and widely used for measuring system usability based on users' perceptions [20]. The evaluation results were used to assess the system's ease of use, user satisfaction, and overall effectiveness in supporting generator room monitoring activities.

The SUS instrument consists of 10 questionnaire items rated on a five-point Likert scale, where 1 represents Strongly Disagree and 5 represents Strongly Agree. The questionnaire was distributed through Google Forms to IT staff and security personnel (Kamdal) of the West Java Communication and Information Office (Dinas Komunikasi dan Informatika Jawa Barat). The SUS questionnaire items used in this study are presented in Table I.

TABLE 1. System Usability Scale (SUS) Questions

	Question
Q1	I think that I would use this generator room monitoring system frequently.
Q2	I found this system unnecessarily complex.
Q3	I thought this system was easy to use.
Q4	I think that I would need the support of another person to be able to use this system.
Q5	I found that the features of this system functioned well and met the requirements for monitoring the generator room.
Q6	I found there was too much inconsistency in this system.
Q7	I think that most people would learn to use this system very quickly.

Q8	I found this system confusing to use.
Q9	I felt confident and comfortable using this system independently.
Q10	I think that I would need to learn a lot of things before I could use this system.

To process the usability evaluation results, the System Usability Scale (SUS) scoring formula was used to calculate the SUS score [21]. The SUS score employed in this study is calculated as follows:

$$Skor\ SUS == \big((\mathrm{P1}-1)+(5-\mathrm{P2})+(\mathrm{P3}-1)+(5-\mathrm{P4})+(\mathrm{P5}-1)+(5-\mathrm{P6})+(\mathrm{P7}-1)+(5-\mathrm{P8})+(\mathrm{P9}-1)+(5-\mathrm{P10})\big)\ \mathrm{X}\ 2{,}5 \quad (1)$$

The SUS score was calculated individually for each respondent. Subsequently, the overall usability score was obtained by calculating the average of all individual SUS scores using the following equation:

$$\mathrm{Rata-Rata} = \frac{Total\ Skor\ Individu}{Jumlah\ Responden} \quad (2)$$

After the SUS scores had been calculated, the resulting values were classified into usability categories to facilitate the interpretation of the system's usability level. The SUS score classification adopted in this study is presented in Figure 8.

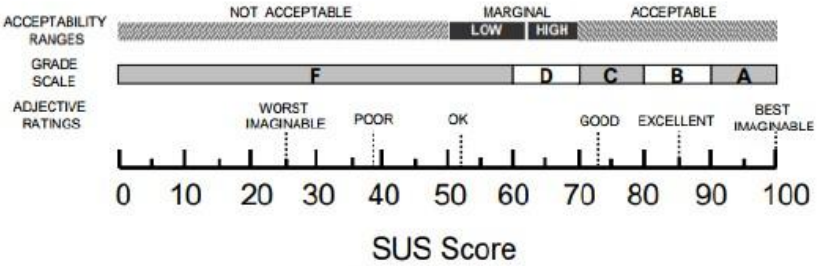

Figure 8. SUS Score Classification

3. RESULTS AND DISCUSSION

3.1 Hardware Design Results

The hardware implementation of the generator room monitoring system is presented in Figure 9.

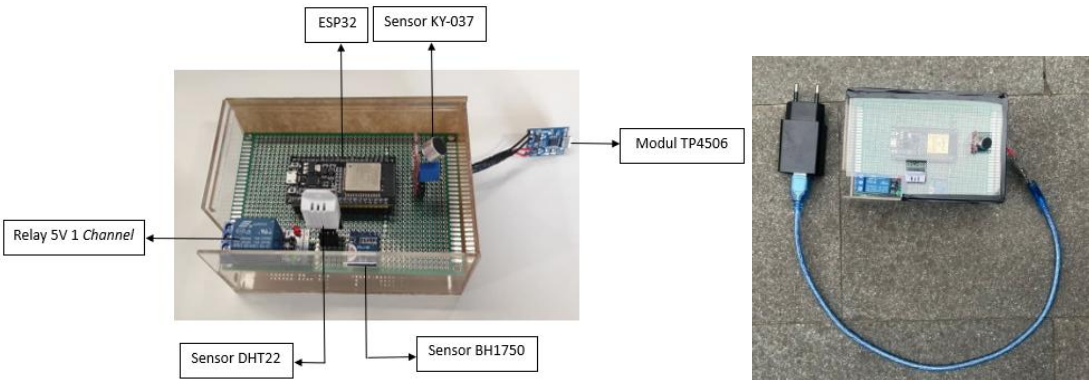

Figure 9. Hardware Implementation of the Generator Room Monitoring System

The hardware of the proposed generator room monitoring system consists of a DHT22 sensor, which is used to continuously monitor the temperature and humidity inside the generator room. The temperature data acquired from the DHT22 serve as the primary parameter for controlling the relay connected to the exhaust fan. When the measured temperature exceeds the predefined threshold, the relay is activated to automatically operate the exhaust fan.

In addition, a KY-037 sound sensor is employed to detect the noise level generated by the generator set. The sensor functions as an indicator of the generator's operating condition, enabling the system to distinguish between active and inactive generator states based on the detected sound intensity.

To monitor the lighting conditions inside the generator room, a BH1750 light sensor is utilized to measure ambient light intensity. The sensor determines whether the room lighting is turned on or off according to the measured illuminance (lux) values.

All sensor data are processed by the ESP32 microcontroller and transmitted to the web-based monitoring system in real time using the Message Queuing Telemetry Transport (MQTT) communication protocol.

3.2 Software Implementation Results

The implementation results of the web-based software are presented in Figure 10.

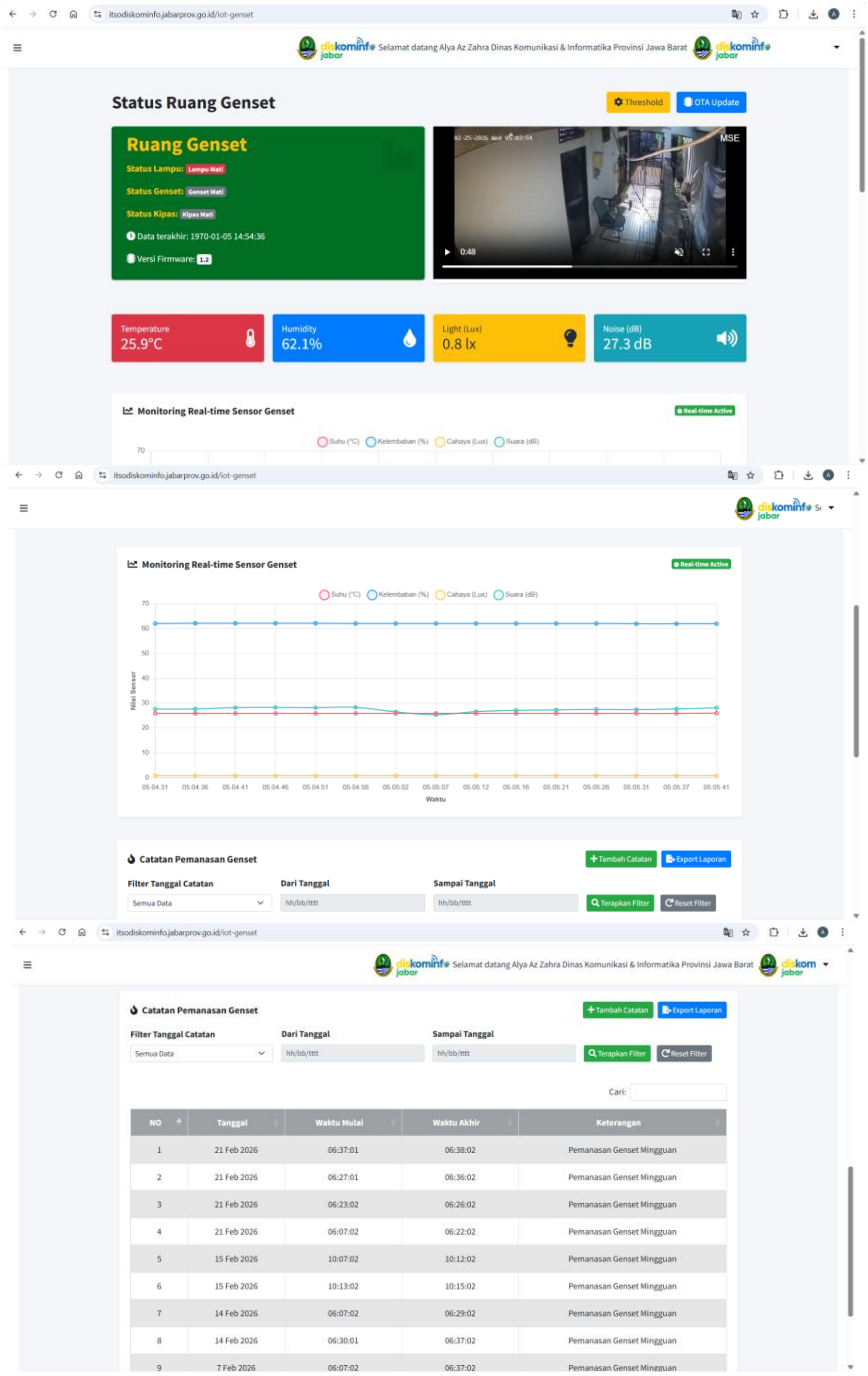

Figure 10. Web-Based Software Implementation

The user interface of the generator room monitoring system was designed as a single integrated web page, enabling users to monitor all generator room conditions in real time. The ITSO Diskominfo website is hosted on a local server and can only be accessed through the organization's internal network to enhance system security and restrict unauthorized access.

Figure 10(a) displays the operational status of the generator room, including the lighting system, generator set (genset), and exhaust fan, together with the timestamp of the latest data update. The dashboard also presents key environmental parameters, including temperature, humidity, light intensity, and noise level, which are transmitted using the Message Queuing Telemetry Transport (MQTT) protocol. In addition, the interface provides threshold configuration and Over-the-Air (OTA) Update features to simplify system configuration and firmware updates.

Figure 10(b) presents real-time monitoring graphs that illustrate changes in environmental parameters over time, enabling users to analyze system trends and responses, such as the automatic activation of the exhaust fan when the measured temperature exceeds the predefined threshold.

Figure 10(c) presents the generator operational history in a tabular format containing the date, time, and activity description. The interface also includes filtering and data export features to facilitate record management and documentation.

3.3 System Testing Results

Sensor testing was conducted during the generator warm-up process on Saturday, February 14, 2026, from 05:55 to 06:37 WIB (Western Indonesian Time) to continuously monitor changes in the environmental parameters. Sensor data were collected using the PuTTY terminal emulator. For each operating condition, 10 samples were recorded as representative sensor readings to analyze parameter variations and evaluate the system's performance. The testing focused on observing sensor outputs under actual operating conditions. However, sensor validation and calibration against standard measurement instruments were not performed in this study.

The generator-off test was conducted to observe the baseline environmental conditions inside the generator room without the influence of generator operation. The purpose of this test was to obtain reference values for temperature, humidity, light intensity, and noise level before the generator was started. A total of 10 data samples were collected to represent the sensor readings during the testing period. The measurement results are presented in Table 2.

Table 2. Measurement Results With The Generator Turned Off

Timestamp	Temperature (°C)	Humidity (%)	Light Intensity (Lux)	Noise Level (dB)	Exhaust Fan	Generator
05:55:00	26.4	68.1	4.2	29.5	Off	Off
05:55:06	26.4	68.0	4.4	28.5	Off	Off
05:55:12	26.4	68.1	4.2	28.8	Off	Off
05:55:18	26.4	68.2	4.2	28.9	Off	Off
05:55:24	26.4	68.0	4.2	28.9	Off	Off
05:55:30	26.4	68.0	4.2	29.0	Off	Off
05:55:36	26.4	68.0	4.2	26.4	Off	Off
05:55:42	26.4	68.0	4.2	25.3	Off	Off
05:55:49	26.4	68.0	4.2	26.3	Off	Off
05:55:55	26.4	68.0	4.2	28.5	Off	Off

Figure 11 presents the generator room status displayed on the main page of the monitoring system, which is accessible through the Diskominfo local network. The dashboard provides the operational status of the lighting system, generator set (genset), and exhaust fan. Before the generator warm-up process, all devices were in the OFF state.

Figure 11. Generator Room Status on the Monitoring Dashboard

The generator-on test was performed to observe changes in the environmental characteristics of the generator room during the warm-up process, when the generator produces heat and noise. The generator warm-up operation is expected to affect the room temperature and noise level; however, during the initial stage of operation, the temperature generally does not exhibit significant changes. A total of 10 samples were collected during this testing period. The measurement results are presented in Table 3.

Table 3. Measurement Results With The Generator Turned On

Timestamp	Temperature (°C)	Humidity (%)	Light Intensity (Lux)	Noise Level (dB)	Exhaust Fan	Generator
06:06:36	26.4	67.3	4.2	190.3	Off	On
06:06:42	26.4	67.5	4.2	148.6	Off	On
06:06:48	26.4	67.3	4.2	273.7	Off	On
06:06:54	26.3	67.2	4.2	329.6	Off	On
06:07:00	26.3	67.2	4.2	403.4	Off	On
06:07:06	26.3	67.2	4.2	347.4	Off	On
06:07:12	26.2	67.2	4.2	263.2	Off	On
06:07:18	26.2	67.4	4.2	199.7	Off	On
06:07:24	26.2	67.5	4.2	235.2	Off	On
06:07:30	26.1	67.7	4.2	268.0	Off	On

The exhaust fan activation test was conducted to evaluate the relay control response to increasing temperature inside the generator room. The exhaust fan was automatically activated when the measured temperature reached the predefined threshold of 27 °C. After the relay was triggered, 10 sensor samples were collected to evaluate the system's response. The measurement results are presented in Table 4.

Table 4. Measurement Results With The Exhaust Fan Activated

Timestamp	Temperature (°C)	Humidity (%)	Light Intensity (Lux)	Noise Level (dB)	Exhaust Fan	Generator
06:24:53	27.9	63.5	4.2	395.0	On	On

06:24:59	28.0	63.5	4.2	296.2	On	On
06:25:05	28.0	63.5	4.2	231.1	On	On
06:25:11	28.0	63.4	4.2	176.5	On	On
06:25:17	28.0	63.3	4.2	215.1	On	On
06:25:23	28.0	63.2	4.2	271.6	On	On
06:25:29	28.1	63.2	4.2	313.3	On	On
06:25:35	28.1	63.1	4.2	243.4	On	On
06:25:41	28.1	62.9	4.2	210.6	On	On
06:25:47	28.1	62.8	4.2	220.0	On	On

Figures 12 and 13 illustrate the generator room status displayed on the monitoring dashboard. Figure 12 shows the system status during the generator warm-up period, where the lighting system was OFF, the generator was ON, and the exhaust fan was automatically activated. In contrast, Figure 13 shows the system status at the end of the warm-up process, where the generator and lighting system had been turned OFF, while the exhaust fan remained ON to stabilize the room temperature.

Figure 12. Generator Room Status During the Generator Warm-Up Process

Figure 13. Generator Room Status After the Generator Warm-Up Process

The usability evaluation of the proposed IoT-based generator room monitoring system was conducted using the System Usability Scale (SUS). The respondents consisted of IT staff from the Secretariat Division and internal security personnel (Kamdal) of the West Java Communication and Information Office (Dinas Komunikasi dan Informatika Jawa Barat). The evaluation results obtained from the respondents are presented in Table 5.

Table 5. Respondent Questionnaire Results

Respondent	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	SUS Score
R1	5	1	5	1	4	2	5	1	5	1	95

R2	5	1	5	1	5	1	5	1	5	1	100
R3	3	1	4	2	5	1	4	1	4	4	77.5
R4	4	1	5	1	5	1	5	1	5	1	97.5
R5	5	1	5	1	5	1	5	1	5	1	100
Average SUS Score											94

4. Discussion

The results obtained from the 10 samples collected between 05:55:00 and 05:55:55 indicate that the room temperature remained stable at 26.4 °C, while the relative humidity ranged from 68.0% to 68.2%, and the light intensity remained constant at 4.2 lux. During this period, all devices, including the generator set (genset), lighting system, and exhaust fan, were in the OFF state, representing the initial environmental conditions before the generator warm-up process.

When the generator was activated between 06:06:36 and 06:07:30, the room temperature remained relatively stable, ranging from 26.1 °C to 26.4 °C, while the relative humidity varied between 67.2% and 67.7%, and the light intensity remained unchanged at 4.2 lux. In contrast, the measured noise level increased substantially, ranging from 148.6 dB to 403.4 dB, indicating that the generator was in operation. During this stage, the exhaust fan remained OFF because the measured temperature had not yet exceeded the predefined threshold of 27 °C.

During the period from 06:24:53 to 06:25:47, when both the generator and the exhaust fan were operating, the room temperature increased to between 27.9 °C and 28.1 °C, causing the exhaust fan to be activated automatically. At the same time, the relative humidity decreased to 62.8%–63.5%, while the light intensity remained constant at 4.2 lux. The measured noise level remained high, ranging from 176.5 dB to 395.0 dB. These results indicate that the automatic control mechanism operated as intended, with the relay successfully activating the exhaust fan once the temperature exceeded the predefined threshold.

The usability evaluation conducted using the System Usability Scale (SUS) involved five respondents and produced an average SUS score of 94, which falls within the Excellent and Highly Acceptable categories. This result indicates that the proposed monitoring system is easy to use and provides an excellent user experience.

Despite these promising results, this study has several limitations. The performance evaluation focused primarily on observing sensor outputs under actual operating conditions, while sensor validation and calibration against standard measurement instruments were not performed. Consequently, the accuracy and reliability of the measured sensor data could not be quantitatively verified. Future studies are therefore recommended to conduct sensor validation and calibration by comparing the measurements obtained from the proposed system with those obtained using standardized reference instruments. Such evaluations would provide a more comprehensive assessment of the accuracy, precision, and reliability of the sensors in monitoring environmental conditions within the generator room.

5. CONCLUSION

Based on the testing results, the proposed web-based monitoring system operated successfully and performed in accordance with the intended system design. The integrated sensors were able to responsively detect changes in environmental conditions, particularly the increase in noise level when the generator was in operation. Furthermore, when the measured temperature reached or exceeded the predefined threshold of 27 °C, the exhaust fan was automatically activated, demonstrating that the control mechanism functioned as designed.

The transmission of sensor data using the Message Queuing Telemetry Transport (MQTT) protocol and its visualization on the monitoring website were performed in real time and remained stable throughout the testing period without significant communication issues. In addition, the usability evaluation using the System Usability Scale (SUS) yielded an average score of 94, which falls within the Excellent category. This result indicates that the proposed system is easy to use and highly acceptable to its intended users..

6. ACKNOWLEDGEMENT

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