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Blynk-Based Air Handling Unit (AHU) Air Filter Monitoring System Prototype at Juwata Tarakan Airport Terminal

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Abstract

The Juwata Tarakan Airport Terminal faces challenges in managing indoor air quality due to the suboptimal monitoring system of the Air Handling Unit (AHU) filter, which plays an important role in maintaining passenger comfort and health. Filter cleaning or replacement is currently done manually and reactively after a decline in air quality. This study aims to design an IoT-based air filter monitoring system for the AHU using the Blynk application. The system utilizes the Sharp GP2Y1010AU0F dust sensor and the ESP32 microcontroller, along with an LM2596 voltage regulator module to adjust the power supply. Test results show that the system can detect dust concentration in real-time and send notifications via the app and email when the threshold is reached. This system enables more efficient and predictive filter maintenance. Thus, this monitoring system can support improved energy efficiency and environmental comfort at airport terminals.

Keywords: Air Handling Unit, monitoring, Blynk, ESP32, air filter, IoT, Blynk, Sharp GP2Y1010AU0F sensor.

INTRODUCTION

Airports are strategic areas in the air transportation system that function as hubs for passenger and cargo movement, and are equipped with various supporting facilities to ensure the safety, security, and comfort of service users (Kementerian Perhubungan RI, 2015). One important aspect in supporting passenger comfort is the air quality inside the terminal, which is greatly influenced by air conditioning systems such as Air Handling Units (AHUs). Air handling systems/Air Handling Units (AHUs) condition the environment by regulating temperature, relative humidity, airflow direction, air quality, particle control, and the removal of contaminants present in the air. An AHU is referred to as a system because it consists of several machines/devices with different functions (Sholihah, 2022). Currently, the maintenance process for the AHU filter at Juwata Tarakan Airport terminal is still carried out manually and reactively, i.e., only after a decline in system performance or air quality issues have occurred.

Filters are part of the Air Handling Unit (AHU) that function to control and regulate the amount of particles and microorganisms (foreign particles) that contaminate the air entering the production room. AHU filters are components used to filter out dirt and dust particles in the air so that they do not enter the room (Fatra et al, 2023). Air filters in AHUs play an important role in maintaining air quality, but they are prone to dust and dirt buildup, which can reduce system efficiency and increase energy consumption. This approach is inefficient and risks causing operational disruptions. Therefore, a monitoring system is needed that can monitor filter conditions in real time so that maintenance can be carried out predictively and efficiently.

This study aims to design and implement an Internet of Things (IoT)-based Air Handling Unit (AHU) air filter monitoring system. The IoT concept is utilized to expand internet connectivity functions sustainably through the integration of the Sharp GP2Y1010AU0F dust sensor with the ESP32 microcontroller connected to the Blynk application as a digital dashboard to facilitate project interface creation (Gunawan, Akbar, & Ilham, 2020). The ESP32 acts as a control center that manages and collects data from sensors (Afifuddin, 2020). The Sharp GP2Y1010AU0F dust sensor, which is infrared-based, is capable of detecting fine particles such as dust and cigarette smoke (Brajamusti & Nurjanah, 2023). This system enables remote monitoring of dust concentration levels in the AHU filter and sends automatic notifications via the app and email when the filter requires cleaning or replacement. With the implementation of this system, it is hoped that maintenance will become more efficient, the lifespan of the AHU can be extended, and air quality at the airport terminal remains maintained. This research is titled

"Prototype System for Monitoring Air Handling Unit (AHU) Air Filters Based on Blynk at Juwata Tarakan Airport Terminal."

METHOD

1. Data Collection Method

The data collection method outlines the procedures used to obtain information during the research process. In this study on monitoring the air filter of an Air Handling Unit (AHU), data were gathered using two primary techniques: observation and documentation. Observation is a data collection technique involving direct monitoring of participants and the context related to the research phenomenon (Jailani, 2023). In this case, observations were conducted directly on the AHU system installed at Juwata Tarakan Airport Terminal, focusing on its operational process, the condition of the air filter, and recording any issues encountered. Documentation involved collecting relevant records and supporting data related to the research, making it a crucial component in supporting qualitative data collection.

2. Data Processing

Data processing refers to the procedure of preparing research variables so they are ready for analysis (Jailani & Saksitha, 2024). It describes how data are handled using a specific approach, either qualitatively or quantitatively. In this study, the data obtained from testing were processed quantitatively to determine the accuracy level of the sensor in monitoring the AHU filter.

3. Data Analysis

Data analysis includes an explanation of the tools and techniques used for organizing and interpreting the collected information. According to (Sugiyono, 2019), data analysis is the process of systematically searching and organizing information obtained from observations, field notes, and documentation by categorizing data, breaking it into units, synthesizing, arranging into patterns, selecting essential elements, and drawing conclusions to make the findings more understandable. The stages of data analysis consist of: Data Reduction, Data Display, and Conclusion Drawing/Verification.

RESULTS AND DISCUSSION

1. Research Results

The conducted research successfully achieved its primary objective, namely the design and implementation of a dust monitoring system for the Air Handling Unit (AHU) filter, integrated with a microcontroller and a dust sensor, and operated via the Blynk application. The final product is a real-time monitoring system capable of detecting dust concentration levels within the AHU filter and transmitting the data directly to the Blynk application, thereby enabling remote monitoring through mobile devices. This system was specifically designed to address delays in filter maintenance, which can negatively impact indoor air quality and the operational efficiency of the AHU. The dust sensor is strategically positioned between the pre-filter and final filter within the AHU system to ensure optimal air quality monitoring. This location was selected as it represents a critical point where changes in dust particle density can be clearly detected after the initial filtration process by the pre-filter. By placing the sensor in this area, the system can provide real-time data on the effectiveness of both the pre-filter and final filter in capturing dust particles, as well as detect any increase in dust load that may indicate the need for filter cleaning or replacement.

Figure 1. Prototype Air Handling Unit (AHU)

Physically, the results of this research are in the form of a monitoring prototype unit consisting of a Sharp GP2Y1010AU0F sensor, an ESP32 microcontroller, and other supporting circuits assembled on a PCB. The dust sensor is installed in such a way that it can continuously read air particles passing through the Air Handling Unit (AHU) filter. This module is also equipped with WiFi connectivity, enabling data transmission to the Blynk platform for automatic monitoring and historical data logging.

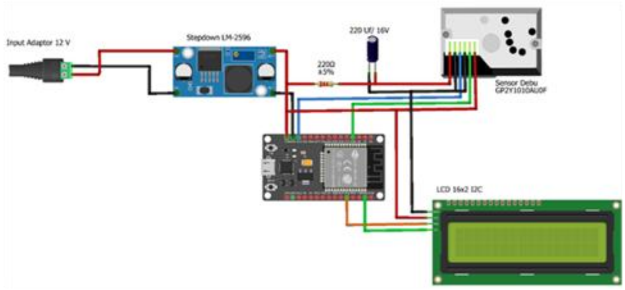

Figure 2. Wiring system monitoring air filter AHU

The core innovation of this research lies in the successful design and integration of an IoT-based control and monitoring system powered by the ESP32 microcontroller. As outlined in the system block diagram, the ESP32 functions as the central processing unit, receiving data from the dust sensor and transmitting it to the Blynk application via an internet connection. The application visualizes this information in the form of graphs and numerical dust concentration values on the filter, and it can automatically send notifications when dust levels exceed the predefined threshold. This capability facilitates timely maintenance decisions for the filter.

The highlight of the study is the demonstration that the Blynk-based monitoring system can improve maintenance efficiency and extend the service life of Air Handling Unit (AHU) filters by delivering accurate and timely information to technicians. With a one-time installation and the ability for remote monitoring, the system significantly reduces manual inspection costs and minimizes potential damage caused by delayed filter replacement. These results confirm that integrating IoT technology into AHU monitoring systems offers an effective and efficient solution to support the operation of modern buildings.

a. Pengujuan Data Uji Coba

1) NodeMCU ESP32 Testing

The purpose of testing the NodeMCU ESP32 was to verify its capability to transmit data using the Arduino IDE software and the Blynk application. The test results indicated that the NodeMCU ESP32 successfully transmitted data via a Wi-Fi connection. The data acquired by the NodeMCU ESP32 could be accessed through the Blynk application.

Table 1. NodeMCU ESP32 Testing Results

Wi-Fi Network Availability	Data Transmission	Connection to Blynk	LED Indicator	Description
Available	Sent	Connected	On	NodeMCU connected to Wi-Fi
Not Available	Not Sent	Not Connected	On	NodeMCU not connected to Wi-Fi

Based on the trial results, the NodeMCU ESP32 can successfully transmit data and connect to the Blynk application when a Wi-Fi network is available. This is evidenced by the LED indicator lighting up and blinking, along with the successful delivery of data to the Blynk application.

2) Sharp GP2Y1010AU0F Dust Sensor Testing

The objective of this test was to evaluate the performance of the Sharp GP2Y1010AU0F dust sensor in detecting dust levels on the filter, thereby determining the dust concentration within the Air Handling Unit (AHU) filter. Additionally, the test aimed to ensure that the sensor could deliver accurate and stable readings, enabling precise scheduling of AHU maintenance. The testing procedure involved placing the Sharp GP2Y1010AU0F sensor inside the filter. The sensor successfully measured dust concentration values, producing consistent readings with minimal error. This demonstrated its effectiveness for monitoring dust accumulation on the filter.

Table 2. Sharp GP2Y1010AU0F Dust Sensor Testing Results

Filter Condition	Dust Concentration on Serial Monitor (mg/m³)
Clean Filter	0.00
Light Dust	0.40
Moderate Dust	0.80
Heavy Dust	1.30

The results indicate that the sensor responds proportionally to the increase in dust levels. Dust concentration readings rose in correlation with the number of airborne particles, consistent with the sensor's specifications.

3) 16x2 I2C LCD Testing
This test was conducted to verify that data from the Sharp GP2Y1010AU0F sensor could be displayed accurately and in real time on the screen. The LCD served to present the dust concentration level in mg/m^3. The test involved introducing various dust levels and observing whether the LCD values changed in accordance with the sensor readings.

Table 3. 16x2 I2C LCD Testing Results

Air Condition	LCD Display	Result
Clean	0.00 mg/m^3	Success
Moderate	0.80 mg/m^3	Success
Dirty	1.73 mg/m^3	Success
No Data / Sensor Off	No Display	Success

4) LM2596 Voltage Regulator Module Testing
The 5 VDC power test aimed to determine the output capability of the power supply in delivering sufficient voltage to the NodeMCU ESP32, dust sensor, and LCD. The results confirmed that the 5 VDC supply was able to power all components effectively.

Table 4. LM2596 Voltage Regulator Module Testing Results

Component	Input Voltage	Output Status	Description
NodeMCU ESP32	12V	Stable	Connected – NodeMCU ESP32 functional
Dust Sensor	12V	Stable	Output voltage readable
16x2 I2C LCD	12V	Stable	Normal display
All Components On	12V	Stable	All active without power issues

Based on the test results, the LM2596 voltage regulator module operated effectively in supplying power to the NodeMCU ESP32, dust sensor, and 16x2 I2C LCD. The module successfully reduced the 12V input to a stable 5V output, meeting the voltage requirements of each component. No signs of voltage drop, functional disruption, or instability were observed when powering all components simultaneously.

5) Blynk Application Testing
A series of evaluations was conducted to verify that all features and functionalities of the Blynk application operated as intended. The testing process included assessing connectivity between the Internet of Things (IoT) device and the Blynk server, as well as evaluating the user interface to ensure responsive real-time interaction. The primary objective was to determine the effectiveness of Blynk as an interface for monitoring real-time dust concentration data from the Sharp GP2Y1010AU0F sensor via an internet connection.

Figure 3. Blynk Application Testing

The results showed that the Blynk application successfully displayed dust concentration data in real time, enabling users to remotely monitor air quality. Furthermore, it provided notifications via the Blynk application and email when the dust concentration on the filter exceeded the specified threshold of 1 mg. These findings indicate that the integration between the hardware (dust sensor) and the Blynk application functioned effectively, delivering accurate real-time information and allowing users to take timely actions to maintain filter cleanliness.

b. Data Analysis Results

Based on the test results of the Blynk-based dust monitoring system for the Air Handling Unit (AHU) filter, it was found that all system components functioned properly according to their respective roles. The dust sensor demonstrated stable accuracy in detecting particle concentrations, and the data transmitted to the Blynk platform were displayed in real time via a smartphone. In-depth evaluation confirmed that all components operated optimally in line with the initial design and objectives. The system's performance met the expected outcomes, with each part well-integrated and capable of delivering accurate responses to detected dust concentrations. These findings validate that the system's design and implementation were effective and reliable.

c. Product Revision

As part of the enhancement of the AHU air filter monitoring device, an LM2596 voltage regulator module was added to step down the voltage from a 12V adapter to the 5V required by components such as the microcontroller and sensor. Without this module, the risk of over-voltage could potentially damage the system. The inclusion of the LM2596 ensures stable voltage delivery, thereby improving reliability and extending the device's lifespan.

2. Discussion of Research Findings

The Blynk application has proven to be an effective solution for monitoring dust sensors on Air Handling Unit (AHU) air filters due to its ability to present real-time data remotely through an intuitive smartphone interface. This capability not only saves time and effort but also enables faster preventive actions when the filter begins to clog. Visual alerts via notifications and email provide clear information about the filter's condition, thereby facilitating timely decisions regarding maintenance or replacement. Consequently, the use of the Blynk application enhances operational efficiency and improves the overall reliability of air filter maintenance systems.

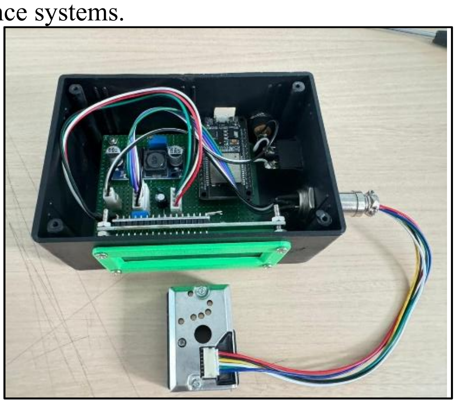

Figure 4. Air Filter Monitoring Display

The operating principle of the proposed design is notably efficient. The air filter monitoring system utilizes a Sharp GP2Y1010AU0F dust sensor installed inside the filter to detect dust concentration levels. Data from the sensor are transmitted in real time to the ESP32 microcontroller, which functions as the central control unit. The ESP32 processes the data to determine whether the dust density has exceeded the predefined threshold of 1 mg. If the threshold is surpassed, the system displays a warning on the 16x2 I2C LCD screen indicating that the filter is saturated with dust. Additionally, the ESP32 sends notifications via the Blynk application and email to the user or maintenance personnel, enabling immediate cleaning or replacement actions. Based on the test results, the system successfully transmitted real-time data, displayed filter status, and delivered notifications promptly when the dust threshold was exceeded. These outcomes demonstrate that the system operates in accordance with its design objectives.

3. Research Implications

The findings of this study provide a significant contribution to improving the efficiency and effectiveness of the air handling system at Juwata Tarakan Airport Terminal. In the modern era, where energy efficiency and data-driven maintenance are increasingly essential, the implementation of an Internet of Things (IoT)-based monitoring system represents a highly relevant innovation. This technology enables real-time monitoring of air filter conditions without the need for time-consuming and costly manual inspections.

A key advantage of this system lies in its ability to deliver accurate and up-to-date data via the Blynk application, allowing technicians to make prompt and informed decisions regarding filter maintenance and replacement. By utilizing the cost-effective yet reliable Sharp GP2Y1010AU0F dust sensor, the system demonstrates that air quality monitoring within an Air Handling Unit (AHU) can be implemented at a relatively low cost without compromising functionality.

CONCLUSION

This study successfully designed and developed a prototype of a Blynk-based air filter monitoring system for the Air Handling Unit (AHU), integrated with a microcontroller and a dust sensor. The system is capable of detecting the dust concentration level in real time and transmitting the data directly to the Blynk application, enabling remote monitoring via mobile devices. It can also send automatic notifications when the dust level exceeds the predefined threshold (1 mg), facilitating timely and informed maintenance decisions for the filter.

With this system, the maintenance of AHU air filters at Juwata Tarakan Airport becomes more efficient, faster, and technologically driven. Filter monitoring is optimized, as cleaning or replacement can be carried out precisely when needed, ensuring the air quality within the airport terminal is consistently well-maintained. The implementation of this Blynk-based monitoring system has proven effective in enhancing operational efficiency and maintaining passenger comfort within the terminal.

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