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# Internet of Things-based fire alarm monitoring system for industrial electrical panels

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## ABSTRACT

Industrial electrical panels play a crucial role in electrical systems, particularly in power distribution and electric machine control panels that operate continuously during production processes. However, they also pose a potential fire hazard due to factors such as human error or equipment malfunction, including high temperatures, gas leaks, or undetectable installation errors. This study aims to design a fire alarm monitoring system based on the Internet of Things using an ESP32 microcontroller integrated with a DHT22 temperature and humidity sensor, an MQ-2 gas sensor, and a flame sensor. The research adopts an experimental method. A three-phase distribution panel is used in this study. Based on the test results, sensor data can be displayed in real time through an LCD and the Blynk application, and automatically logged to Google Sheets. The results demonstrate that the system is capable of detecting hazardous conditions and providing early warning alerts via an alarm.

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## 1. INTRODUCTION

In industrial environments, electrical systems are essential components that support various operations, ranging from production processes to power distribution [1]. Electrical panels are a critical part of these distribution and control systems in industrial settings [2]. They function to regulate, distribute, and protect the flow of electricity to various industrial equipment. Most industrial electrical panels are equipped with protective systems to guard against disturbances such as overloads and short circuits [3]. However, despite these safety features, electrical panels still pose risks of damage and safety hazards, including fire. Fires often result from factors that are difficult to detect, with one of the primary causes being excessive temperature increases (overheating) [4], gas or smoke leaks in the panel environment, and installation errors such as loose connections [5]. Manual monitoring of panel conditions using infrared thermometers is considered inefficient and prone to delayed detection [6]. This highlights the need for an automatic monitoring system capable of operating in real time and providing early warnings of potential fire hazards.

Previous studies have addressed similar topics. Relif Marbun developed a fire detection system for electrical panels based on IoT and a mobile application [7]. However, the system experienced a delay of approximately 3.2 seconds in transmitting and receiving data via the Firebase database. Another study by Basino, titled Design and Development of a Fire Detector for Electrical Panels Based on Atmega 328 Microcontroller on Fishing Vessels [8], resulted in a device that lacked support for remote and real-time monitoring and warning capabilities. Fisabili conducted a study titled Development of a Fire Extinguishing System for Outdoor Panel Boxes Using Arduino Uno Based on GSM SIM800L [9]. The system was capable of sending remote warnings via SMS, but it lacked a remote monitoring feature. Therefore, this research aims to develop a system that provides early warnings and supports both remote and real-time monitoring.

This study develops an IoT-based fire alarm monitoring system for industrial electrical panels by integrating a DHT22 temperature sensor, an MQ-2 gas sensor, and a flame sensor to enable early detection of potential fire hazards. The sensor data are displayed via an LCD and the Blynk application, and are automatically logged to Google Sheets. The implementation of this system is expected to enhance workplace safety, particularly in power distribution areas that are vulnerable to fire risks. This research provides a tangible contribution by offering a smart technology-based solution to support industrial safety

## 2. METHOD

Explaining This research was conducted using an experimental method. Through this approach, temperature test data were collected and compared with actual temperatures. Additionally, voltage measurements of components were taken and compared with the values specified in their respective datasheets to assess their condition and suitability. The study utilized a three-phase electrical distribution panel. The research instruments included a multimeter, an infrared thermometer, and a stopwatch. The research process involved designing the circuit within the panel, developing a system flowchart, and conducting performance testing

Figure 1. Distribution panel circuit

Figure 1 illustrates a simple three-phase electrical distribution panel equipped with several primary protection components in the form of Miniature Circuit Breakers (MCB). This panel functions to distribute and safeguard the electrical current across multiple load lines. Four MCB are positioned at the top, serving to distribute electricity to various loads. One MCB located at the bottom acts as the main input source prior to distribution. This MCB is rated with a higher current capacity and serves as protection against overload conditions.

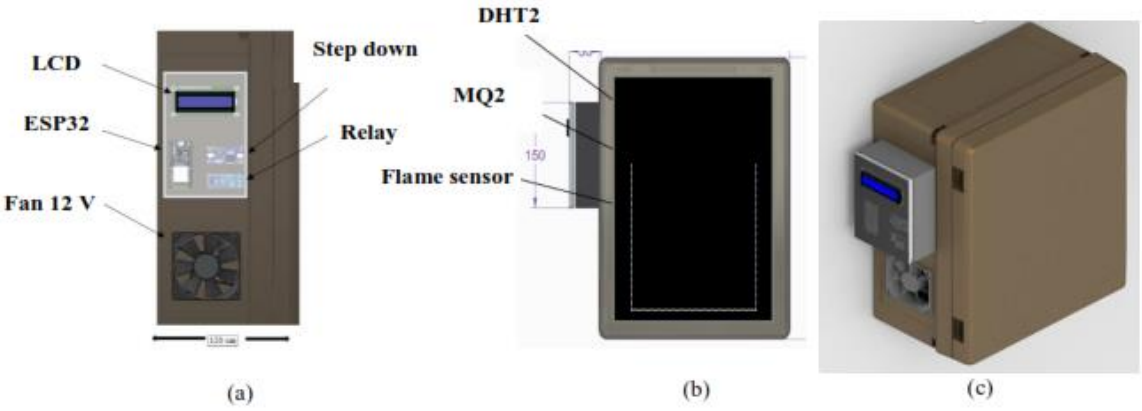

Figure 2. Side view (a) Front view (b) overall design (c)

Hardware design is the process of planning, designing, and developing the physical structure of a system, which includes architectural design, component selection, and technical specification of the devices to be built [10]. Figure 2 presents the hardware design of the proposed system.

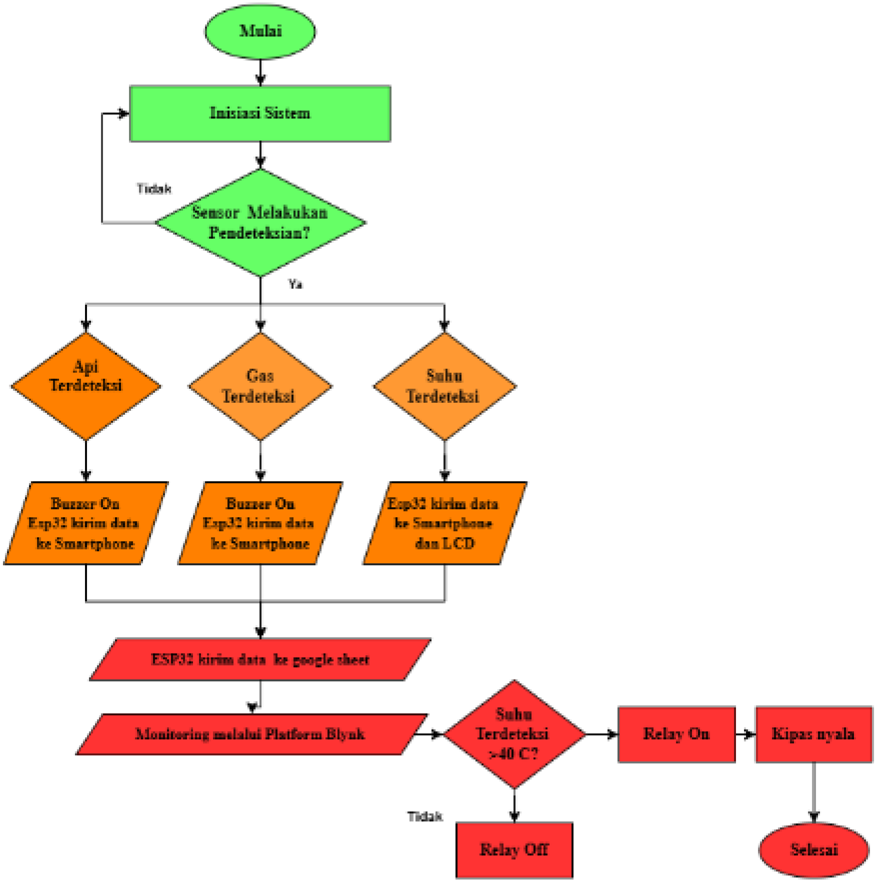

Figure 3. Flowchart

A flowchart is a diagram that illustrates the sequence of processes or steps within a program, including the relationships between processes and the statements involved [11]. It consists of various symbols connected by lines, each symbol representing a specific function or operation. Flowcharts are also used to depict the conceptual structure of complex software systems and serve as design documents used by system analysts to communicate, negotiate, and visualize the complexity of a process. Figure 3 presents the system flowchart

In the scientific method, the research subject refers to the entity or system being observed and serves as the primary source of data collection [12]. The testing was conducted on an unloaded electrical distribution panel in the Energy Conversion Laboratory, Department of Electrical Engineering, Padang state University. The panel box was made of mild steel, with dimensions of 400 × 300 × 180 mm and a plate thickness of 2 mm, as shown in Figure 4. The testing was carried out over the course of one day, during which the monitoring results were observed and recorded.

Figure 4 . Distribusition panel

The research object denotes the specific aspect or variable being examined within the research subject [13]. In this study, the object comprises the sensor readings specifically temperature, smoke, and flame detection data acquired from the electrical panel. This data is subsequently analyzed to evaluate the reliability of the monitoring system in detecting potential fire hazards. The data collection methodology involved strategically installing sensors on critical sections of the three-phase electrical distribution panel. The DHT22 sensor was positioned near cable connections and MCBs to identify abnormal temperature rises, while the MQ- 2 sensor was located inside or near the panel's upper section to capture accumulating combustible gases or smoke. The flame sensor was oriented towards areas susceptible to sparking. All sensors were interfaced with an ESP32 microcontroller, which periodically acquires sensor readings and transmits them via Wi-Fi to both the Blynk IoT platform and Google Sheets for data logging. Data collection occurred automatically and continuously, utilizing a programmed sampling interval of one hour through the microcontroller's timer function, with supplementary real-time transmission triggered by abnormal conditions. Data is concurrently relayed to the IoT platform Blynk Cloud for remote dashboard monitoring and automatically archived in Google Sheets upon alarm activation.

## 3. RESULTS AND DISCUSSION

The subsequent phase involved sensor validation. The DHT22 sensor was empirically tested through comparative measurements against an infrared thermometer. The experimental results are presented in Table 1 below..

Table 1. Testing result of DHT22

| **Testing** | **Sensor DHT22 Reading (°C)** | **Thermometer IR Reading (°C)** | **Error %** |
|---|---|---|---|
| 1 | 31,0 | 31,1 | 0,003% |
| 2 | 30,7 | 30,8 | 0,003% |
| 3 | 33,8 | 33,8 | 0% |
| 4 | 33,9 | 33,8 | 0,002% |
| 5 | 34,0 | 34,0 | 0% |
| Average | 32,68 | 32,7 | 0,0016% |

The experimental data for the aforementioned parameters indicate minor errors in the DHT22 sensor readings. The observed error range spanned from 0% (minimum) to 0.003% (maximum), with a mean aggregate error of 0.0016%. While the manufacturer's datasheet specifies a sensor accuracy of ±0.5°C, the maximum deviation recorded in the test results in table 1 was 0.1°C. These findings demonstrate that the DHT22 sensor functions reliably within this experimental framework and is suitable for deployment.

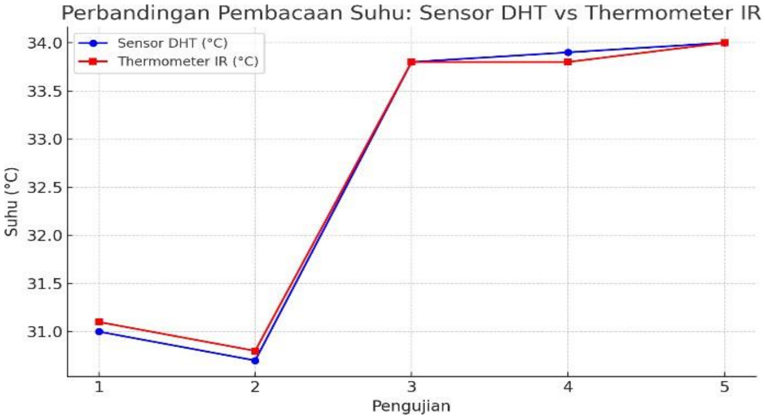

Figure 5. Quality Graph DHT22

The column chart above presents a comparative analysis of temperature readings between the DHT22 sensor and an infrared (IR) thermometer across five experimental trials. Each paired column set (blue/red) represents temperatures detected simultaneously by both instruments. Visually, the measured values exhibit negligible divergence, with most trials showing either identical results or marginal deviations of 0.1°C. This demonstrates the DHT22 sensor's high measurement accuracy and consistent performance, validating its suitability for temperature monitoring in electrical distribution panels

Table 2. Test result of MQ2 sensor

| No. | Test Source | Gas Concentration (Ppm) | Blynk Display | Lcd Display |
|---|---|---|---|---|
| 1 | Lighter gas | 715 | Danger | Danger |
| 2 | LPG | 250 | Danger | Danger |
| 3 | urning paper | 597 | Danger | Danger |
| 4 | Cigarette smoke | 800 | Danger | Danger |

Based on the results of tests conducted using the MQ2 sensor on various sources of gas and smoke— such as lighter gas, LPG, burning paper, and cigarette smoke—the detected gas concentrations ranged from 250 to 800 ppm. When compared to the MQ2 sensor datasheet, these values fall within the sensor's sensitivity range, which begins at 200 ppm for gases such as LPG, butane, propane, smoke, and hydrogen. These findings indicate that the MQ2 sensor operates in accordance with its specified performance parameters.

Table 3. Test Results of the Flame Sensor

| No. | Test Distance (cm) | Output sensor | Buzzer | LCD status | Blynk status |
|---|---|---|---|---|---|
| 1 | 5 | HIGH | On | Danger | Danger |
| 2 | 10 | HIGH | On | Danger | Danger |
| 3 | 20 | HIGH | On | Danger | Danger |
| 4 | 30 | HIGH | On | Danger | Danger |
| 5 | 40 | HIGH | On | Danger | Danger |
| 6 | 50 | HIGH | On | Danger | Danger |
| 7 | 60 | HIGH | On | Danger | Danger |
| 8 | 70 | HIGH | On | Danger | Danger |
| 9 | 80 | HIGH | On | Danger | Danger |
| 10 | 90 | LOW | Off | Normal | Normal |

Based on Table 3, the flame sensor is capable of detecting fire at a maximum distance of 80 cm under normal flame conditions. However, if the flame is larger, the sensor can still detect it at a distance of up to 90 cm. The test results indicate that the sensor is in good condition and suitable for use.

Table 4. Overall Test Results on the Panel

| No | Time | Temperature (°C) | Gas Concentration (Ppm) | Flame | Status | | Delay |
|---|---|---|---|---|---|---|---|
| | | | | | LCD | BLYNK | |
| 1 | 10 : 30 | 31,2 | 36 | Low | Danger | Danger | 5 second |
| 2 | 11 : 30 | 31,5 | 35 | Low | Danger | Danger | 5 second |
| 3 | 13 : 30 | 31,9 | 34 | Low | Danger | Danger | 5 second |
| 4 | 14 : 30 | 32 | 35 | Low | Danger | Danger | 4,5 second |
| 5 | 15 : 30 | 32 | 35 | Low | Danger | Danger | 5 second |

The data presented in Table 4 represent the results of fire alarm monitoring conducted on the electrical distribution panel from 10:30 AM to 3:30 PM. It can be concluded that the electrical panel remained in a safe condition throughout the monitoring period. The temperature was relatively stable, ranging from 31.2°C to 32°C, indicating no signs of overheating. Gas levels were low, ranging from 34 to 36 ppm, which falls within the safe category with no indication of leakage or accumulation of hazardous gases. The flame sensor consistently reported a "Low" status, indicating no detection of open flames or dangerous sparks near the panel. However, there was an average delay of 5 seconds in data updates on both the LCD and Blynk interface.

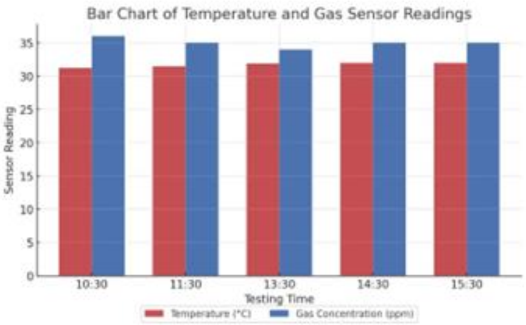

Figure 6. Quality Graph

The fire alarm monitoring data from the panel are stored not only in tabular form but also presented in graphical format to facilitate analysis. In the graph, the red bars represent data obtained from the temperature sensor, while the blue bars represent data from the gas sensor. The testing of the DHT22 sensor within the system demonstrated a very high level of accuracy, with an average error of only 0.0016%. This confirms the sensor's suitability for temperature monitoring in industrial electrical panels. Such precision is crucial, as excessive temperature is an early indicator of fire risk. Similar findings were reported by Zhang, who employed the DHT22 for industrial temperature monitoring and observed a deviation of ±0.3°C [14]. Research by Mukhopadhyay also supports the use of the DHT22 as a digital temperature sensor for microcontroller-based IoT systems, citing its stability across various environmental temperature conditions [15]. These findings indicate that the DHT22 outperforms the DHT11 in terms of accuracy and response time stability.

The MQ2 sensor has proven effective in detecting hazardous gases such as LPG and smoke, with readings ranging from 250 to 800 ppm, which aligns with the sensor's specifications as stated in the datasheet. This effectiveness is further supported by a study conducted by Purwanto, who developed an MQ2-based LPG gas detection system and reported stable sensitivity for concentrations above 200 ppm [16]. Therefore, the MQ2 sensor is highly suitable for enhancing safety systems by mitigating potential fire danger.

The flame sensor in the system demonstrated the ability to detect fire at a distance of up to 80 cm, consistently providing a HIGH signal. Flame detection plays a critical role in early fire prevention and protection. Patel, in his study, demonstrated that flame sensors can be effectively used in medium-range fire detection systems based on Arduino platforms [17]. Additionally, a study published in the International Journal of Engineering Research & Technology (IJERT) confirmed that infrared flame sensors can rapidly detect fire sources in fire-fighting robot systems. Further research by Yadav showed that flame sensors can be effectively utilized in cloud-based monitoring systems for small-scale fire protection[18].

The overall system testing, conducted from 10:30 AM to 3:30 PM (WIB), demonstrated stable performance, with no hazard detections and an average delay of 5 seconds—still within acceptable limits for an IoT-based system. This delay was primarily caused by the data transmission to Google Sheets, which affected the update speed of the LCD and Blynk interfaces. Additionally, a slow internet connection contributed to the system's response time. This is supported by Purwanto, who developed a similar IoT system and reported an average delay of 3–6 seconds, concluding that such values remain safe for industrial applications [19]. Furthermore, Hasan, in his study on factory monitoring systems, reported optimal system performance with delays of up to 7 seconds.

## 4. CONCLUSION

This study successfully developed and tested an Internet of Things (IoT)-based fire alarm monitoring system for industrial electrical distribution panels using DHT22, MQ-2, and flame sensors integrated with an ESP32 microcontroller. The system is capable of real-time early detection of potential fire hazards such as temperature increases, gas/smoke leakage, and the presence of flames. Test results showed that the DHT22 sensor demonstrated high accuracy, with an average error of only 0.0016%. The MQ-2 sensor effectively detected gas concentrations above 250 ppm, in accordance with its sensitivity range, and the flame sensor was capable of detecting fire at distances of up to 80 cm.The system also successfully displayed data in real time via an LCD and the Blynk application, while automatically logging the data to Google Sheets. However, the system exhibited an average delay of approximately 5 seconds in updating data on the LCD and Blynk, primarily due to the time required for data transmission to Google Sheets, which affected response speed. For future development, it is recommended to utilize alternative data storage methods to enhance response time and reduce delay. Faster response is critical in early warning systems to enable more immediate and effective intervention.

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