Automatic Fire Extinguishing System Using Smoke Detector and Heat Detector Based on Programmable Logic Controller

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***Abstract*— Fire is a disaster that is often encountered throughout the year. This research aims to protect and mitigate the worst possibility of a fire disaster. A PLC automatically creates the work system of this tool, using it as the controller. This tool utilizes two sensors: a smoke detector and a heat detector. Two smoke detectors and one heat detector automatically make the system, each providing input to the PLC. The system splits into two parts: Alarms 1 and 2. If any of the three sensors send input to the PLC, Alarm 1 triggers a buzzer and a yellow light. Alarm 2 occurs if 2 or 3 sensors provide input to the PLC and provide output as the bell lights up, the flash lights up, and the solenoid opens to release Co2 into the room.**

Keywords— ***fire extinguishers, smoke detector, Heat detector, PLC.***

I. INTRODUCTION

Fire is a disaster that arrives unpredictably. Fires can cause loss of life and material losses [1]. Delays in firefighters' response can lead to material loss and death, thus necessitating a fire management system [2]. Improper and slow response to a building fire causes it to grow and spread to other rooms or buildings. It will also cause significant material losses and casualties. Because the more extensive the fire, the thinner the oxygen in the room. Delays in the arrival of firefighters can worsen the situation, increasing the risk of material loss and loss of life. Therefore, a structured and efficient system is needed to handle fires quickly and effectively. This system must not only be able to respond instantly but also prevent the spread of fire and minimize possible negative impacts.

In 2021, a large fire occurred in the CYBER 1 building. The CYBER 1 building is one of several companies' data center operator buildings, including PT Indomarco Prismatama. This incident caused the paralysis of several networks and applications and material losses due to fire disasters. This fire also claimed the lives of 3 people, 2 of whom died [3], [4]. The PT Indomarco Prismatama data center room in the CYBER 1 building created an automatic fire extinguishing system using CO_2 gas as an agent in response to a fire case. Equipment and objects in the data center space are not damaged by CO_2 gas, minimizing potential losses. In the data center space, it uses CO_2 gas to avoid damaging equipment and objects, reducing potential losses because the data center room has many electrical components such as servers, switches, etc.

Building a sophisticated and effective early warning system is necessary to overcome the challenges of unpredictable fires. Innovative connected fire sensor technology can detect early fire signals, enabling a faster response and reducing the risk of material loss and loss of life [5]–[8]. This system informs authorities and firefighters instantly, allowing them to respond quickly and efficiently. This tool uses two sensors: a smoke detector and a heat detector. The two sensors trigger CO_2 as an extinguishing medium. This tool also has a hold button feature to prevent CO_2 from spreading during the test.

II. METHOD

Before explaining the method, several supporting components in this research are as follows:

PM 2.5, also known as (PM 2.5) are particles in the air that are small or equal to 2.5 µm (micrometers). PM 2.5 is also applied to determine whether AC is safe in an area or house. PM 2.5 particles are dangerous for humans because they can cause respiratory problems. PM 10 is a particle in the air that is very small, smaller than 10 microns. These particles can also cause problems with the respiratory system. Therefore, Pm 10 and 2.5 have threshold values that are dangerous for humans [9]–[11].

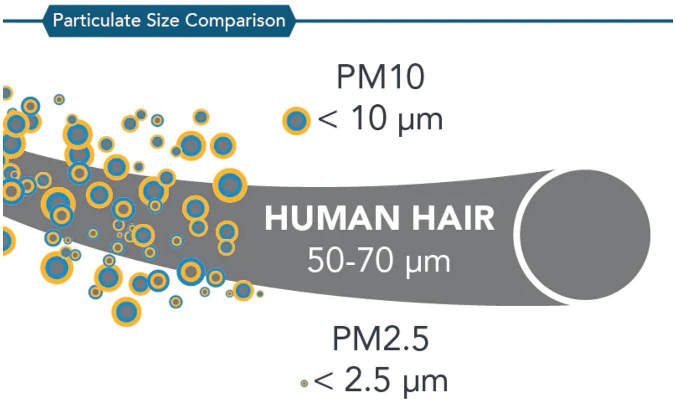

Fig. 1. PM 2.5 dan PM 10 Particle

A Heat Detector is a sensor that works based on a specific temperature or temperature and automatically detects fire based on the heat received. At the same time, temperature sensors are the oldest detectors. The basic principle is that a working alarm is triggered when the temperature in the detector chamber rises above a threshold. This heat detector is efficient when installed in a room with a high heat-producing area, for example, in a

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generator room, boiler room, kitchen, or by the detector specifications [12].

Fig. 2. Heat Detector

A *smoke detector* is a detection device based on the amount of smoke collected. The task of this detector is to detect invisible and visible smoke particles. This detector can detect fire faster than conventional fire detectors. Smoke detectors are suitable for homes with many Class A fires that can produce smoke but are not suitable for gas/oil/oil fires [13], [14].

Fig. 3. Smoke Detector

A Programmable Logic Controller (PLC) is a microprocessor based control system that uses programmable memory to store instructions and perform functions such as logic, timing, calculations, and arithmetic. This device's PLC circuit defines an output program that allows users to enter control programs in a simple programming language. The working principle of a PLC and its functions are the same as other controllers, including receiving input signals from sensors, then processing them according to the data, and creating programs and output signals according to the program we created for the driving device [15], [16].

Fig. 4. Programmable Logic Controller

The following is an explanation of the Fire Detection System flow diagram is depicted in Figure 5.

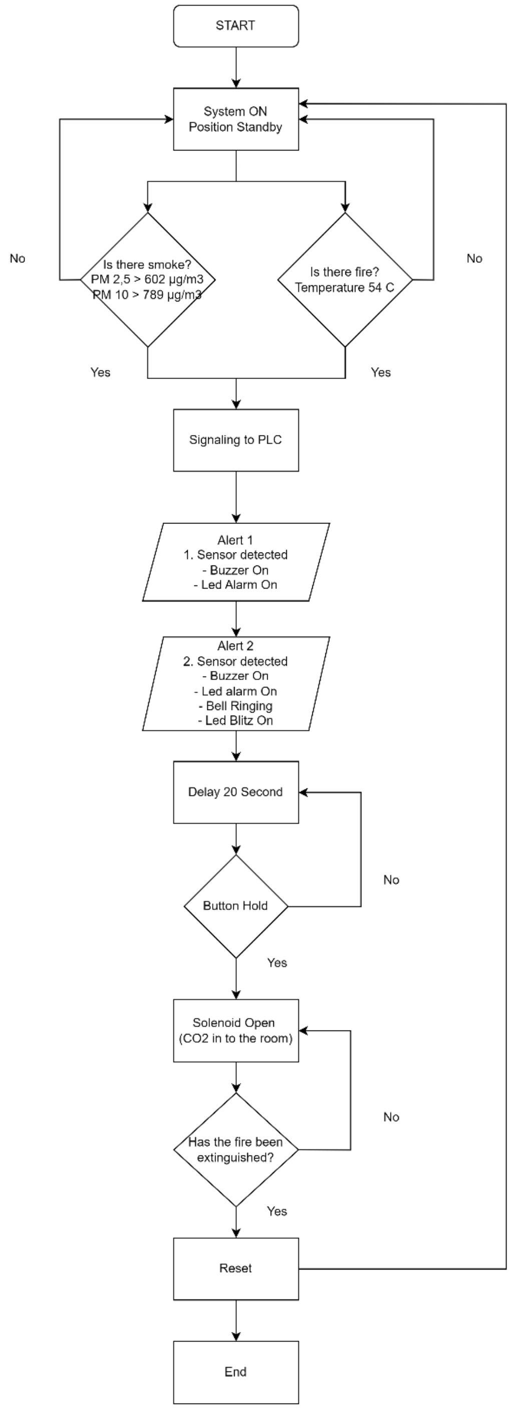

Fig. 5. Flowchart System

The following is an explanation of the Fire Detection System flow diagram:

1. Alarm 1 occurs if one of the three smoke or heat detector sensors turns on. When the alarm is activated, the buzzer will alert that smoke or fire has been detected in the room, and the yellow light will turn on as a sign that the system is still detecting smoke or heat. The system usually runs again after the smoke or Press the reset button to address the fire indication.

2. 2. Alarm 2 occurs if 2 of the three smoke or heat detector sensors are "ON." If alarm 2 is active, the system will count down for 20 seconds to release CO_2

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gas. If a fire occurs, it is necessary to save specific items. It creates a hold button to stop the countdown and release CO_2 gas. If the hold button is released or released, the time will return to 20 seconds. The system opens the solenoid valve and releases CO_2 gas into the room after calculating the time for 20 seconds.

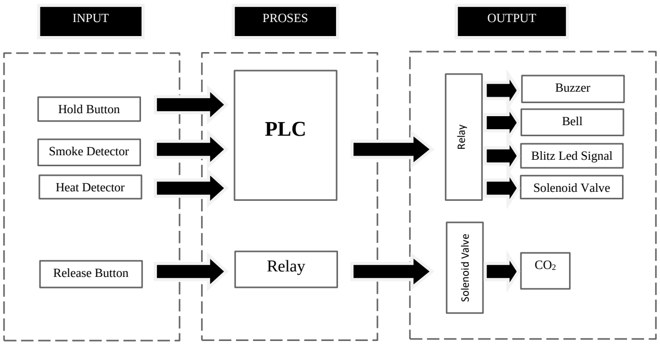

Fig. 6. Block Diagram System

The input section consists of 3 devices in the form of hardware, namely sensors that will provide a signal if smoke and the room detects hot temperatures. The signal will enter the processing circuit in the form of a PLC. In the PLC, the circuit processes the signal and produces an output. The output on the PLC will send a signal to the hardware in the output section to run an automatic system. The hardware at the output consists of relays, flashlights, buzzers, bells, and solenoid valves, which release CO_2 gas as a fire extinguishing medium are depicted in Figure 6.

III. RESULTS AND DISCUSSION

The hardware setup comprises heat and smoke sensors, a programmable logic controller (PLC), miniature circuit breakers (MCBs), a control panel box, push buttons, and illumination, all illustrated in Figure 7.

Fig .7. Hardware System

This research experimented by applying smoke from burnt paper to the smoke detector detector at 10 cm and 20 cm for 1 minute each to determine the gas value when the smoke detector was active.

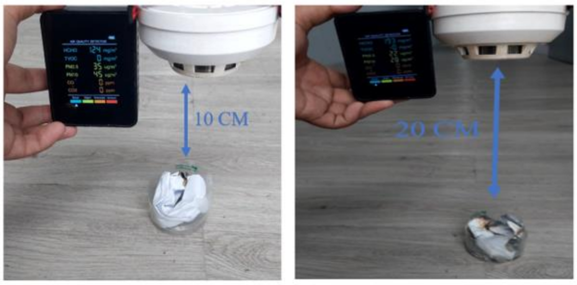

Fig. 8. Smoke Sensor Data Collection

This data collection will use a smoke detector by providing a smoke source at 10 and 20 cm from the top of the smoke. To find out the PM 2.5 and PM 10 values and the smoke response value, an experiment was conducted by giving smoke to the smoke detector and then taking the necessary data.

TABLE 1. ACTIVE RESPONSE DATA OF SMOKE DETECTOR

Data	0 Second	20 Second	40 Second	60 Second
PM 2,5 (10 cm)	26µg/m³	279µg/m³	566µg/m³	711µg/m³
PM 10 (10 cm)	34µg/m³	366µg/m³	742µg/m³	932µg/m³
PM 2,5 (20cm)	24µg/m³	188µg/m³	500µg/m³	659µg/m³
PM 10 (20cm)	31µg/m³	246µg/m³	656µg/m³	864µg/m³

In the measurement results, the smoke detector's active response is within 60 seconds (1 minute) in 10 cm. The figures obtained have increased from PM 2.5 values of 26µg/m3 to 711µg/m3 and PM 10 values of 34µg/m3 to 932µg/m3. The following graph shows the PM 2.5 and PM 10 measurement results. In the same measurement result in 20 cm, the figures obtained have increased from PM 2.5 values of 24µg/m3 to 659µg/m3 and PM 10 values of 31µg/m3 to 864µg/m3. The following graph shows the PM 2.5 and PM 10 measurement results.

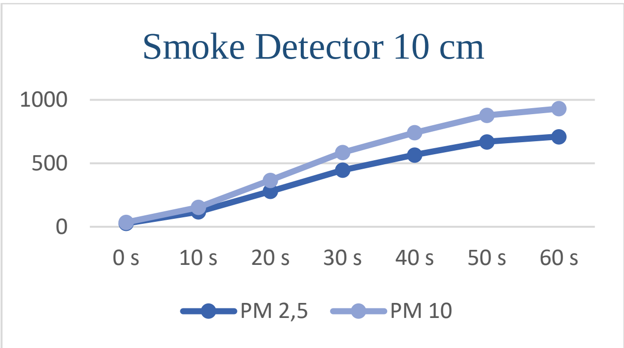

Fig. 9. Smoke Detector 10 cm Response

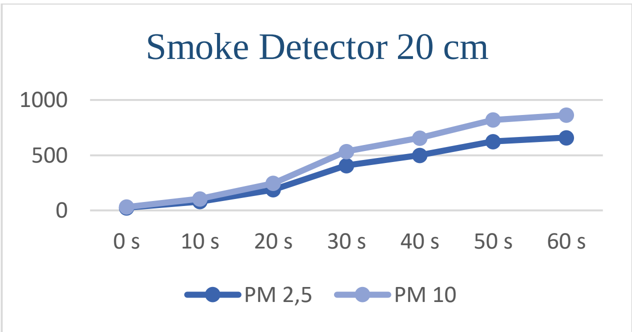

Fig. 10. Smoke Detector 20 cm Response

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This research experimented by applying fire from a candle to the heat detector at 10 cm and 20 cm for 1 minute each to determine the temperature value when the heat detector was active.

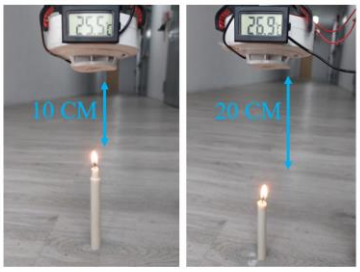

Fig. 11. Heat Sensor Data Collection

This data gathering process will involve utilizing a heat detector, with a smoke source being placed at a distance of 10 cm from the top of the fire. To determine the temperature readings, an experiment was carried out by igniting the heat detector and subsequently collecting the required data.

TABLE 2. ACTIVE RESPONSE DATA OF HEAT DETECTOR

Jarak	0 s	20 s	40 s	60 s
10 CM	25,8°C	38,8°C	46,3°C	56,6°C
20 CM	26,9°C	35,5°C	45,8°C	55,1°C

In the measurement results, the active response of the heat detector at a distance of 10 cm resulted in a value of 25.8°C to 55.6°C for 60 seconds. Altering the distance to 20 cm achieves a value of 26.9°C to 55.1°C in 60 seconds.

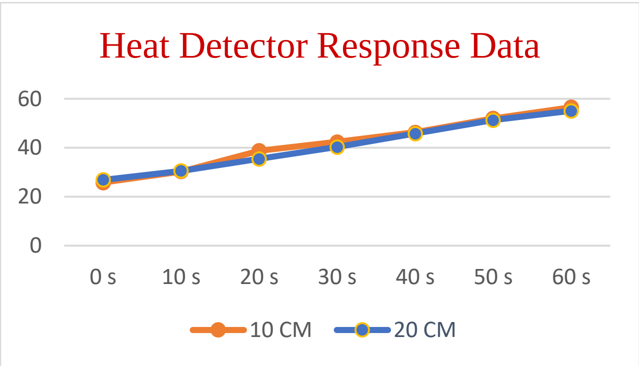

Fig. 12. Heat Detector 10 and 20 cm Response

In the negative test results, by trying to turn off one of the sensors, the results were:

1. In the 1st experiment with active smoke and heat detectors, alarms one and two can be lit by smoke or heat.
2. In the second experiment, with both smoke detectors active and the heat detector inactive, alarms one and two can be lit only by smoke to activate the smoke detector.
3. In the third experiment, only one active smoke detector and an active heat detector are present. Heat or smoke can activate alarm one, while smoke and heat must activate alarm two.
4. In the 4th experiment, with just one active smoke detector and an active heat detector, heat or smoke can activate alarm one, while both smoke and heat must activate alarm two.
5. In the 5th experiment, only one smoke detector was active; therefore, it could only activate alarm 1 with smoke because alarm 2 required two active sensors.
6. In the 5th experiment, only one smoke detector was active. Therefore, it could only activate alarm 1 with smoke because alarm 2 required two active sensors.
7. In the 5th experiment, only the heat detector was active. Therefore, it could only activate alarm 1 with smoke because alarm 2 required two active sensors.

No	Smoke Detector 1	Smoke Detector 2	Heat Detector	Alarm 1	Alarm 2
1	ON	ON	ON	√	√
2	ON	ON	OFF	√	√
3	ON	OFF	ON	√	√
4	OFF	ON	ON	√	√
5	ON	OFF	OFF	√	x
6	OFF	ON	OFF	√	x
7	OFF	OFF	ON	√	x

IV. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. An automatic extinguisher system integrating smoke and heat detectors is automated by incorporating two smoke detectors and one heat detector, each connected to the PLC. The system divides into two parts: Alarms 1 and 2. Alarm 1 activates when any one of the three sensors sends input to the PLC, triggering a buzzer and a yellow light. Meanwhile, Alarm 2 activates if two or three sensors signal the PLC, lighting up the bell, activating the flash, and opening the solenoid to release CO2 into the room.
2. How the smoke detector works. If a fire occurs or smoke is detected (PM 2.5> 602 ug/m3 and PM 10> 789 ug/m3) in the room, the smoke detector will enter an alarm position with a red LED light on. Then, it will provide the output to the PLC. Meanwhile, the heat detector becomes an alarm position if the temperature reaches 54°C.

Recommendations

In further research, the author provides suggestions for innovating tools to improve their performance by providing new improvements.

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