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IOT-Based Gas Leakage and Fire Detection System with Automated Emergency Response for Industrial Safety

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Abstract - The flammable gas leakage and fire accidents in industrial environments leads to significant risks to the life of workers and the residents in surrounding areas. The proposed article aims to reduce these disastrous incidents with the help of IoT- based intelligent gas and fire leakage detection system that integrated with an automated emergency response mechanism. In this proposed system, an MQ-4 sensor is used to detect the emission of harmful methane gas. Depending upon the gas leakage percentage, an LED will glow as a white light for low leakage of methane gas and a red light for high leakage, along with an LCD display in both the inside of the industry area and a traffic signal for public alert. In case of any fire accident, a flame sensor will detect the fire, and safety measures such as a water dispenser are also added in this proposed system. This project gives a solution to enhance industrial safety, reduces human dependency and the incident prevention is provided by real-time data analysis

Key Words: MQ-4 Sensor, Liquid Crystal Display, Light-emitting diode, Gas leakage detection

1.INTRODUCTION

When hazardous gases accidentally escape from storage containers, pipes, or equipment in factories, manufacturing facilities, or refineries, this is referred to as gas leakage in industrial settings. These leaks may be from human error, defective equipment, insufficient upkeep, or unanticipated natural circumstances. Because they frequently involve toxic, flammable, or caustic compounds, industrial gas leaks are very dangerous [1].

In India, gas and chemical leakage accident count has increased significantly in the past decade, in 2013 the count was 13 accidents and 30 accidents found in the year 2023 [2]. The impact of gas leakage can be severe, causing fires, explosions, environmental damage, injuries, and even fatalities. Certain gases, like ammonia, chlorine, and hydrogen sulphide, pose significant health risks if inhaled, leading to respiratory issues, chemical burns, or even death in high concentrations. Additionally, leaks of flammable gases like methane or propane can lead to catastrophic explosions if ignited. The article aims to contribute to the development of a safer and more resilient industrial framework for handling hazardous chemicals [3].

2.LITERATURE REVIEW

The literature review provides a comprehensive overview of existing research related to gas leakage detection system in the recent years are discussed below.

2.1 Gas Leakage Detection and Smart Alerting System Using IOT

This proposed article developed the gas detection system, which is used to detect the gas in flats. The primary objective is to introduce a gas leakage detection system across the society, with each apartment equipped with a gas detection device. The buzzing sound is produced by the buzzer when the gas leakage is detected and an alert message is send to authorized person in the apartments [4].

2.2 LPG Gas Leakage Detection Using IOT

A new approach for finding an Arduino-based microcontroller that supports LPG discharge is presented in this research. In order to detect the discharge and prevent any unintended catastrophe, it is necessary to take certain precautions. An Arduino-based LPG gas detection is done using MQ-6 LPG detector is an associate degree accurate LPG sensing device that measures the strength of the signal. The non-inheritable electrical signal is efficiently quantized using an Arduino-based signal processing mechanism that is inexpensive and associate degree based. The LPG leakage intensity is divided into three categories based on square measure: LOW, MEDIUM, and HIGH. In this paper, the temperature and ratio are simultaneously displayed on the alphanumeric display [5].

2.3 Design and implementation of an IOT-based gas detection & fire extinguishing system.

This paper develops a design and implementation of an IOT-based gas detection & fire extinguishing system that breaks the circuit wire to prevent fire accidents when the gas is detected. This module turns off the nearby circuit when a gas leakage is detected using an H- bridge. This prevents the damage of electrical devices from fire and also turns on the ventilator fan for exhausting the gases [6].

2.4 Sensor-Based Gas Leakage Detector System

A technique for detecting gas leaks in industrial settings is presented in this research. When the gas is detected automatically, the buzzer will produce the buzzing sound to alert the people in the area; it sends the alert message to authorized people in the industry. It also provides automatic door and window opening using a servo motor so that the compressed gas can spread into the air freely. Hence a fire accident does not occur [7].

2.5 LPG Gas Leakage Detection System with Auto Cut-off Regulator

This paper discusses a system that detects various gases that are harmful to the surroundings. Once the sensor detects a gas leak, it transmits the signal to the Arduino for processing. The buzzer will produce a buzzing sound after it receives the signal from Arduino to alert the people in that area. It disconnects the power to the equipment through a relay and triggers the exhaust fans to ventilate and eliminate the hazardous gases from the surroundings [8].

Disadvantage:

- In “Gas Leakage Detection and Smart Alerting System Using IOT System” implementing multiple sensors, H-bridge circuits, and actuators may increase system costs, making it less affordable for some applications.
- In “Design and implementation of IOT-based Gas detection & Fire Extinguishing System” Constant monitoring, sensor operation, and activating systems like fans and fire extinguishers can consume significant power, which may not be ideal for systems relying on battery-powered setups
- In “LPG Gas Leakage Detection System with Auto Cut-off Regulator System” if the signal transmission between the sensor, Arduino, and relay fails, the system may not perform as intended, leading to a delay in action or no action at all.
- In “LPG Gas Leakage Detection Using IOT System” continuous notifications could lead to alert fatigue, causing people to ignore or dismiss alarms.
- In “Sensor-Based Gas Leakage Detector System” while opening doors/windows is meant to vent the gas, it could potentially lead to further hazards, like the spread of gas to other areas or exposure to external environmental factors.

3. PROPOSED METHODOLOGY

The proposed system overcomes the drawback of all the above existing system

- Gas Leakage (Methane and natural gas) in the project is detected by MQ-4 sensor.
- When the gas leakage at 25% of configuration is detected, the RED light will illuminate and the buzzer will produce a buzzing sound.
- When the gas leakage at 50% of configuration is detected, the red LED will illuminate and the LCD will show the alert message “GAS DANGER” along with the buzzing sound.
- When the gas leakage at 75% of configuration is detected, the red LED will illuminate, the buzzer will produce the buzzing sound, and the LCD will display the alert message “GAS DETECTED AT EXTREME LEVEL” in industry as well as at traffic signals to alert the people who are in the surroundings.
- In case of, fire is detected A water dispenser is used for the rescue.

4.COMPONENT USED IN THE RESEARCH

4.1 Arduino Uno:

Datasheet The Arduino Uno microcontroller board is built on top of the ATmega328. It features a 16 MHz ceramic resonator, 6 analog inputs, 14 digital input/output pins (six of which can be used as PWM outputs), a USB port, a power jack, an ICSP header, and a reset button. These are required for microcontroller and the USB cable is used to connect to computer, battery o AC-to-DC adaptor. Since Uno not used the FTDI USB-to-serial driver chip it is set apart from all previous boards. Serial-to-USB convertor is configured by Atmega16U2/Atmega8U2 [9] [10].

4.2 MQ-4 Sensor:

This sensor is used to detect CNG and methane gas leakage. Because of its quick response time, this gas sensor can be adjusted using a potentiometer to meet sensitivity requirements. Similar to a compressed natural gas (CNG) sensor, this analog output sensor is a part of the MQ sensor series. This sensor uses 5V DC and generates 750 MW. The concentration range from 300 ppm to 10,00 ppm is set for gas leakage detection [11].

4.3 LCD:

The LCD display in our project plays a crucial role in providing real-time information about gas leakage and fire alerts. It shows the current gas levels, ranging from low to high, and displays warning messages like "Fire Alert" or "Evacuate" to ensure quick action during emergencies. This visual interface enhances user understanding and allows for immediate response, making the system more efficient and user-friendly. The LCD also aids in debugging and monitoring during setup or testing, showing system statuses like "operational" or "error." Additionally, it confirms the successful communication of fire alerts to nearby traffic signals, ensuring seamless coordination [12].

4.4 LED:

Due to its ability to provide effective, long-lasting, and highly visible lighting in vital locations, LED (light-emitting diode) technology is essential to industrial safety. LEDs can be used to show warning signs, notify staff of possible dangers, or direct employees to safety exits in the event of an emergency when it

comes to hazard identification and emergency response. Even in high-risk situations, their energy-efficient design guarantees continuous illumination, and their brightness and colour variations—such as green for safe zones or red for danger—make them immediately identifiable from a distance. Along with sensors and automatic alarms, LEDs are frequently included in safety systems to provide visual cues that improve general safety procedures, particularly in the event of a gas leak, fire, or other industrial hazard [13].

4.5 Buzzer:

A buzzer quickly alerts people about fire accident or gas leakage. It makes sure that the people, who are not physically watching the system, are informed when gas levels rise above acceptable bounds or when a fire is discovered. The loud noise instantly attracts attention and prompts swift action to limit damage or avert accidents. The buzzer enhances the LED's and LCD's by offering non visual alarm. This capability is particularly important in loud settings or in circumstances where it may be difficult to see visual cues [14] [15].

4.6 Water Dispenser:

In terms of industrial safety, a water dispenser is an essential tool made to give firefighters instant access to water in the event of an emergency, such as a fire or gas leak. The Water dispenser, which are positioned thoughtfully across industrial sites, can rapidly deliver water to help put out fires, cool heated surfaces or aid in the decontamination of dangerous chemicals. Water dispensers are essential for improving emergency response skills, lowering the danger of a fire escalation, and protecting the environment and employees by making sure that water is easily accessible in strategic areas. Together with sophisticated sensors and automated technologies, their incorporation into the safety system produces a more efficient, quick-reaction safety framework [15].

4.7 Flame Sensor:

A flame or fire in particular area can be detected by flame sensor. It's commonly used in safety systems, fire alarms, or automated systems where detecting a flame is essential to prevent accidents, such as in industrial applications, home safety, or IoT-based fire detection systems. Flame sensors that detect infrared radiation rely on the fact that flames emit a specific range of infrared radiation. These sensors are particularly useful for detecting flames in environments, where other sources of infrared radiation might interfere. Some flame sensors combine both UV and IR detection to increase sensitivity and reliability. These sensors are ideal in environments, where a wide range of flame detection is required, such as in industrial settings [15].

The block diagram of proposed project is shown in figure 1.

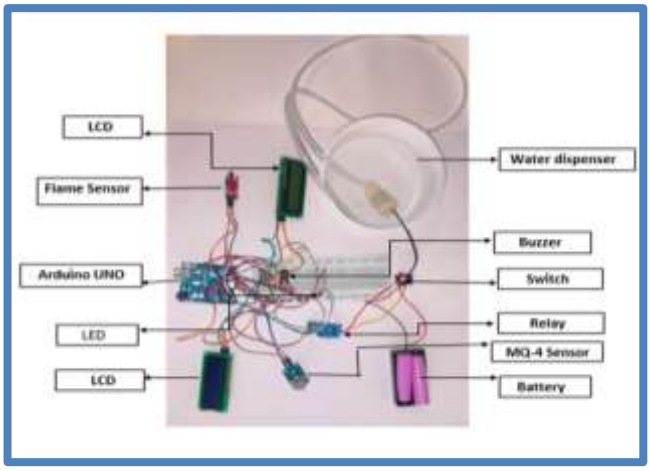

Fig -1: Block Diagram

5.RESULT AND DISCUSSION

This research concentrates on five modules:

- Methane Detection
- Gas leakage monitoring and alert system
- LCD display for worker alerts
- Traffic sign integration for external alerts.
- Fire detection system

5.1 Methane Detection:

The sensor used for to detect the methane are displayed in methane detection shown in figure 2.

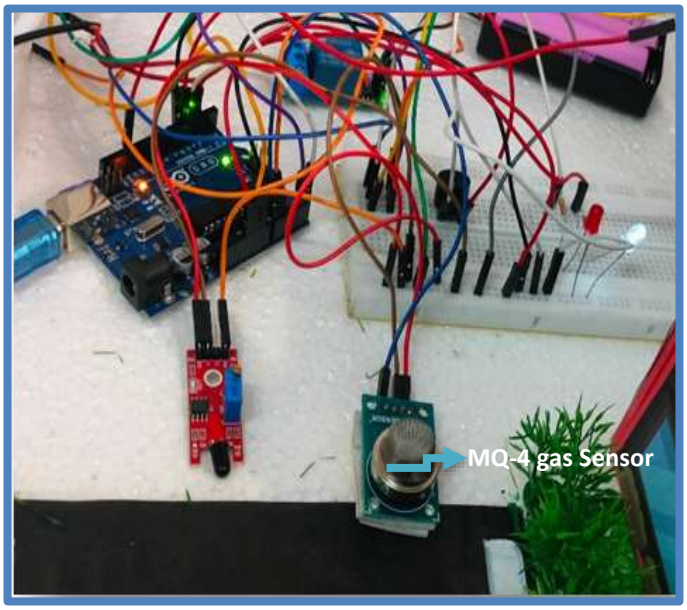

Fig -2: Methane Detection

This module is responsible for detecting methane gas concentrations in the air. The MQ-4 gas sensor is specifically designed to detect methane gas levels. The normal exposure level of methane is 1000 ppm that does not affect the environment. Methane can be used as fuel in a range of manufacturing processes and is created during the production of several chemical

compounds. In this research, methane concentration in the air is continuously measured using MQ-4 sensor. When the gas leakage is detected, the following precautions will be taken.

5.2 Gas Leakage Monitoring and Alert System

This Module enhances the basic detection capability by providing a comprehensive alert system, ensuring immediate action is taken when hazardous Methane levels are detected. When gas leakage is detected at 25% of configuration, the red LED will illuminate and the buzzer will produce a buzzing sound to alert the people in the industry. When the gas leakage is detected at 50% of the configuration, the red LED will illuminate and the buzzer will produce a buzzing sound. Along with that, an alert message will be displayed on the LCD in the industry to alert the workers in the industry. When the gas leakage is detected at 75% of configuration, a red light will illuminate, buzzing sound will be produced. Alert message will be displayed on LCD in the industry as well as traffic signal to alert the people in the industry as well as people around 100 meters.

The working process for alert system are defined as shown in the figure 3.

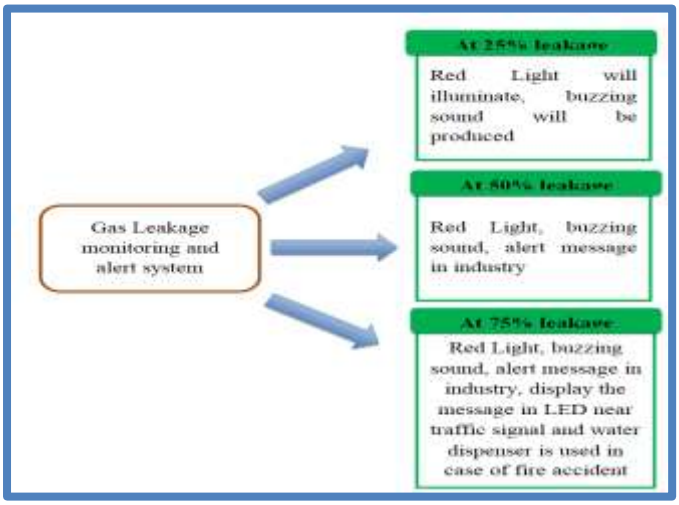

Fig -3: Working Process for Alert System

5.3 LCD Display for Worker Alerts:

The component used to give alerts for workers are displayed in LCD display alert shown in figure 4.

Fig -4: LCD display alert

This module serves to provide visible information to workers regarding the safety status of the industrial environment. The LCD display will be used to show real-time information about the gas levels, fire incidents, and any necessary alerts. When methane concentration reaches hazardous levels (50% or 75%), the LCD will display an alert message, indicating the level of danger and providing guidance to workers. It may also display any fire-related alerts when the flame or temperature sensor detects a fire. In emergency situations, this display acts as a central point for workers to quickly understand the situation and act accordingly.

5.4 Traffic Sign Integration or Public Alerts:

If gas leakage is at higher concentration the alert message will be displayed on LCD to protect people around 100 metres as shown in the figure 6.

Fig -6: Traffic Alert

This module ensures that the surrounding environment, such as traffic and nearby areas, is informed about hazardous situations within the industrial setting. If a critical gas concentration (75%) is detected or a fire accident occurs, an LCD screen in the traffic signal will display an alert message to warn nearby residents or commuters. The traffic signals can be adjusted to indicate danger, possibly even triggering red lights or special warning signals to prevent vehicles or people from entering the hazardous zone. This module ensures that both the internal workers and the external public are warned about potential hazards. By activating special warning signals or red lights, this module reduces unnecessary movement in and around the hazardous zone. This limits the chances of further accidents or contamination and prevents additional people from entering the area, potentially contributing to the spread of the hazardous situation.

5.5 Fire Detection System

If flame sensor detects fire the system will activate the water dispenser. This module detects any fire accidents in the industrial environment, ensuring that appropriate fire-fighting measures can be triggered automatically. Temperature and flame sensors detect abnormal temperature increases or the presence of a flame in the industrial area. When a fire is detected, the system activates the water dispenser, automatically triggering a water flow to suppress the fire and prevent it from spreading. The fire detection system can also work in conjunction with other components, such as the gas detection system, to ensure both hazards are addressed simultaneously. Early detection and suppression of fire help minimize exposure to harmful smoke, toxic gases, and extreme heat, which could cause serious harm to workers' health and safety. Industries that implement automated fire detection and

suppression systems may benefit from lower insurance premiums, as they are seen as reducing the risk of major fire-related claims.

6. CONCLUSIONS

The successful deployment of this methane gas detection and fire safety system marks a major step forward in enhancing safety protocols in industrial environments, especially within pharmaceutical industries that utilize methane gas. The integration of the MQ-4 sensor to detect methane emissions ensures timely alerts for workers at different stages of gas leakage. Arduino successfully sends the information to the components that are connected for the necessary precautions. When the gas leakage is detected, the buzzer provides the buzzing sound without fail. LED illuminates based on the level of gas leakage. Alert messages are successfully displayed on LCDs in industry as well as on traffic signals. The water dispenser is activated on time as soon as the flame sensor detects the fire. All the components are functioning properly, leading to the expected outcomes. The future work is to include voice commands, Multi-gas sensors which can detect a wide range of gases including natural gas, propane, carbon monoxide, and methane, sensors to monitor environmental parameters including air quality, humidity, and temperature and also to include GSM module to give alert message to authorized people, the fire station and the nearby police station, which reduces risk.

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