Chapter 14

Book Chapter

Safe Haven: Smart Gas Leakage Detection and Response System

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Abstract

The project's main goal is to create an Internet of Things (IoT)-based system for detecting and preventing gas leaks to improve safety in both home and commercial settings. The system uses an MQ-2 gas sensor to identify potentially dangerous gases and trigger several safety procedures. When the system detects a gas leak, it immediately turns off the power source to eliminate possible sources of ignition and activates an exhaust fan to disperse the gas. Additionally, the system sends an immediate distress message to the user via a Telegram bot, ensuring prompt notification. This integration of IoT technology provides an efficient and automated solution for preventing gas-related accidents, enhancing overall safety and peace of mind.

Keywords: IoT, MQ-2 Sensor, Arduino Module, GSM Networks, Gas Leakage Detection.

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1 Introduction

1.1 Background

The Internet of Things (IoT) represents a transformative evolution in technology, extending internet connectivity beyond traditional computing devices such as desktops, laptops, smartphones, and tablets to encompass a vast array of everyday objects. These IoT-enabled devices are embedded with sensors, software, and other technologies that allow them to connect and exchange data over the internet. This interconnected ecosystem facilitates enhanced communication, data collection, and control, thereby offering numerous opportunities for innovation and improvement across various domains. One of the critical areas where IoT technology has significant potential is in ensuring safety and security in both residential and commercial settings. Although, the oil and gas industry is one of the most significant industries where industrial and technological growth aims to provide a better living for the stakeholders as stated by Younes's (2019), Gas leaks, a common yet dangerous occurrence, typically arise from poorly fitted, badly maintained, or faulty appliances such as boilers, cookers, and heating systems. Even small leaks can gradually accumulate to reach hazardous concentrations, posing severe risks including fire, explosions, and health hazards due to toxic gas exposure.Each year, thousands of industrial gas leaks happen, many of which result in fatalities, serious injuries, damaged equipment, and terrible environmental effects. (Chraim, Erol, & Pister, 2016). This problem has been attempted to be solved numerous times, but with little success. The ability to detect and prevent gas leaks is, therefore, crucial for safeguarding lives and property.

As digital technology enters every field and is an integral part of our daily lives as mentioned by Gautam and Mittal's (2022), A Gas Leakage Detector can be created using Internet of Things technology. It has Smart Alerting features that allow it to notify people in advance of potentially dangerous situations by predicting them and using data analytics on sensor readings to send text messages, emails, and calls to the relevant authority.(Varma, Prabhakar, & Jayavel, 2017).

1.2 Objective

The objective of this research paper is to develop and implement a comprehensive IoT-based gas leakage detection and response system, known as SafeHaven. The primary goals include:

- Detection of Gas Leaks: Utilize the MQ-2 gas sensor to accurately detect the presence of hazardous gases such as methane, propane, and butane.
- Automated Safety Response: Design and implement automated safety protocols that are triggered upon the detection of a gas leak. These protocols include shutting off the

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power source, activating an exhaust fan, and sending immediate alerts to users.

- User Notification System: Develop a notification system using the Telegram bot to ensure users receive instant alerts about gas leaks, regardless of their location.
- Enhanced Safety and Prevention: Improve overall safety measures by providing an efficient, automated solution that reduces the risk of gas-related accidents in both residential and commercial environments.

2 Literature Survey

The literature survey provides a comprehensive review of existing research and developments in the field of gas leakage detection systems, highlighting various approaches, technologies, and innovations that have contributed to enhancing safety measures in residential and commercial environments. The focus is on IoT-based solutions, sensor technologies, and automated response mechanisms.

2.1 Historical Background

The evolution of gas leakage detection systems has its roots in early safety measures, initially relying on simple mechanical sensors and manual inspections. The development of semiconductor sensors in the 1970s marked a significant advancement, allowing for more reliable detection of gas leaks. By the 1990s, the integration of microcontrollers facilitated the creation of automated alert systems. The early 21st century saw the emergence of IoT and wireless technologies, which revolutionized gas leakage detection by enabling real-time monitoring and remote alerts. Recent advancements have incorporated machine learning and AI to further enhance the accuracy and predictive capabilities of these systems.

2.2 Foundational Concepts

The foundational concepts of gas leakage detection systems encompass a variety of technologies and methodologies aimed at improving safety and response times. These include sensor technologies, which form the core of any gas leakage detection system. Praveen Sharma et al.'s (2023) proposed a cloud-based Internet of Things (IoT) gas leak detection system that is affordable and effective for use in commercial, industrial, and residential settings. The system consists of a MQ 2 gas sensor, a Wi-Fi module, and an Arduino Uno microprocessor. IoT integration enables devices to communicate over the internet, allowing for real-time data collection, monitoring, and remote control, which is crucial for timely alerts and automated responses. Automated response mechanisms are designed to automatically shut off gas supply valves, trigger alarms, and send notifications to users and emergency services, thereby minimizing the risk of explosions and fires. Additionally,

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advanced data analytics, including machine learning algorithms, enhance the predictive capabilities of gas leakage detection systems by analyzing sensor data to detect patterns and predict potential leaks.(B. Deepika et al., 2024).

2.3 Major Advancements

To improve the provision of services to its residents, every country needs to organize itself and make sure that emerging technologies like artificial intelligence (AI) are strategically integrated. (Mittal & Gautam, 2023). Further, Digital transformation of governments is required to serve digital societies and economies. (Mittal, 2020). It is anticipated that sensors will actively look for leaks and notify consumers of any possible dangers. A single installation may experience gas leaks at several different places. A microcontroller is used to receive and evaluate a large number of sensor values. The created data is delivered to the base via the internet of things link, where another microcontroller decodes and views it after it has been encoded in the wireless module. The gadget gives an acoustic and visual alert when a leak is detected, and because high-speed processing limits the detection period, leakage situations are contained with little to no impact. It is an affordable and dependable method of reducing the risk of leaks. (Shukur & Al-Adilee, 2021).

The field of gas leakage detection has undergone significant advancements, particularly with the integration of IoT and AI technologies. One key development is the creation of low-cost sensor solutions, such as a cost-effective detection system using MQ-6 semiconductor sensors and an Arduino microcontroller. This approach emphasizes affordability and reliability, making it accessible for widespread residential use. Additionally, IoT-based detection and response systems have been introduced, which not only detect gas leaks but also automatically cut off the gas supply and alert users, exemplifying real-time monitoring and automated safety measures. Comprehensive surveys and reviews have highlighted the importance of continuous monitoring and quick response mechanisms, showcasing the continuous innovation required to enhance these systems.

Shrestha, Krishna Anne, and Chaitanya's (2019) designed an IOT-based smart gas management system with fire and gas leak detection capabilities. The automatic reservation of a gas cylinder is additionally made possible by the load sensor. Whenever a load cell determines that the weight of a gas cylinder has fallen below a threshold value, a notification is sent to the booking agency to make a reservation for a gas cylinder. The user will receive a notification when the gas cylinder runs out at the same time.

Advanced AI integration has also been proposed, combining deep learning and IoT to achieve highly accurate gas detection and real-time monitoring, representing a significant leap forward in system reliability. Furthermore, smart alerting systems using IoT and wireless sensor networks provide real-time notifications via mobile apps and SMS, emphasizing the importance of user-friendly interfaces and remote monitoring capabilities.

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Finally, the integration of IoT and cloud computing has been explored, emphasizing scalable and efficient data processing. Cloud-based analytics enhance the ability to monitor and predict gas leaks, providing a robust framework for large-scale deployment.(Khan, 2020)

3 Architecture

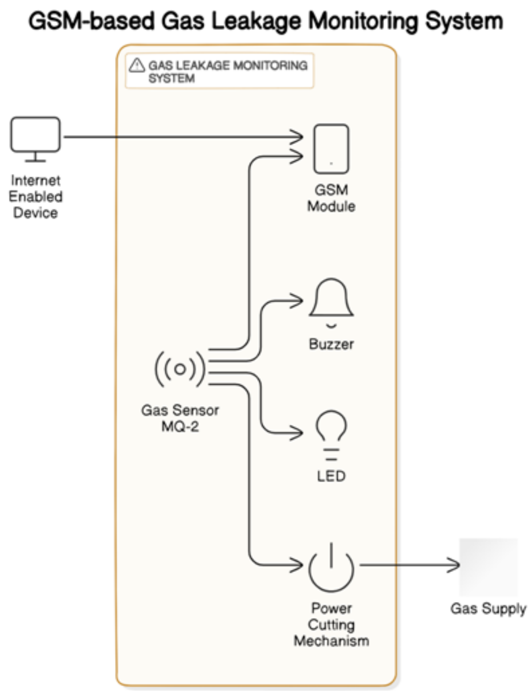

Figure 1. Architecture Flow

The GSM-based gas leakage monitoring system is designed to detect gas leaks and alert users immediately, leveraging a combination of sensor technology, GSM communication, and automated safety mechanisms. This system aims to enhance safety measures in residential and commercial environments by providing real-time notifications and automatic responses to gas leak incidents.

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3.1 System Architecture

The architecture of the GSM-based gas leakage monitoring system is depicted in the schematic diagram.(see figure 1). The system comprises several key components, each playing a crucial role in the detection and alert process:

1. Gas Sensor (MQ-2): The MQ-2 gas sensor is a semiconductor sensor that detects the presence of gases like propane, methane, and butane. It outputs an analog signal proportional to the gas concentration.

2. GSM Module: The GSM module enables communication between the gas leakage monitoring system and external devices via the Global System for Mobile Communications (GSM) network. It sends alerts and notifications to users' internet-enabled devices.

3. Buzzer: The buzzer serves as an audible alarm that activates when the gas concentration exceeds a predefined threshold, providing an immediate warning to anyone nearby.

4. LED Indicator: The LED provides a visual indication of a gas leak, complementing the audible alarm to ensure the alert is noticeable even in noisy environments.

5. Power Cutting Mechanism: This mechanism is connected to the gas supply and is triggered to shut off the gas flow automatically when a leak is detected, thereby preventing potential hazards such as explosions or fires.

6. Internet-Enabled Device: Users receive notifications on their internet-enabled devices (e.g., smartphones, tablets) through the GSM module, allowing for remote monitoring and prompt response.

3.2 Operation

The operation of the GSM-based gas leakage monitoring system can be summarized in the following steps:

1. Detection: The MQ-2 gas sensor continuously monitors the air for the presence of gas. When the gas concentration exceeds a predefined threshold, the sensor outputs a signal.

2. Alert Activation: Upon detecting a high concentration of gas, the system activates the buzzer and LED indicator to provide immediate auditory and visual alerts.

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3. Communication: Simultaneously, the GSM module sends an alert message to the user's internet-enabled device. This message includes details about the gas leak, allowing the user to take appropriate action remotely.

4. Safety Response: The power cutting mechanism is engaged to shut off the gas supply automatically, minimizing the risk of fire or explosion.

4 Methodology

The flowing diagram represents the working of the system:(see figure 2)

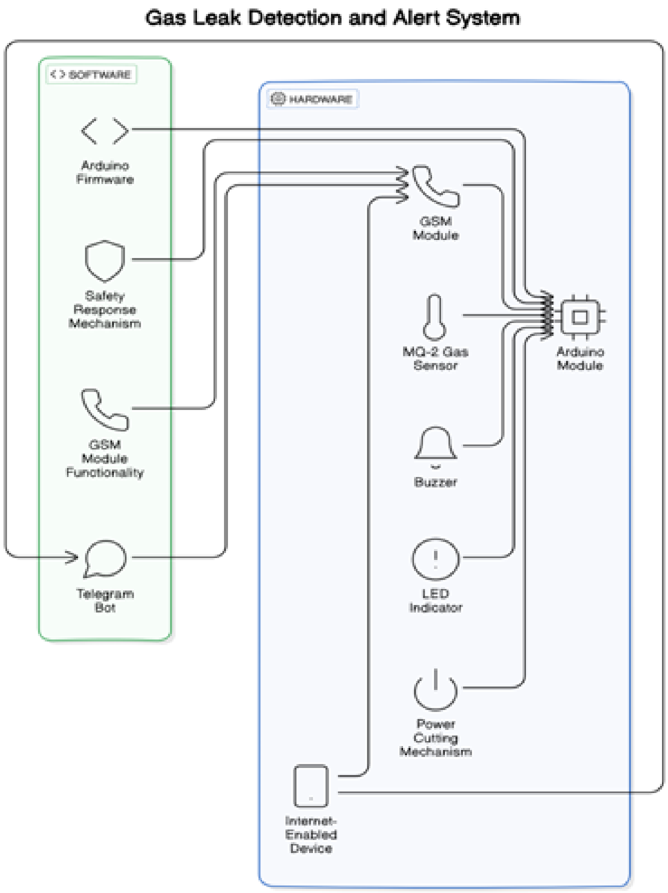

Figure 2. Workflow of Model

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1. Hardware Setup:
   - Acquire necessary hardware components including an MQ-2 gas sensor, Arduino module, GSM module, buzzer, LED indicator, power cutting mechanism, and internet-enabled device.
   - Connect the MQ-2 gas sensor to the Arduino module to enable gas detection capabilities.
   - Integrate the GSM module with the Arduino to establish communication over the GSM network.
   - Connect the buzzer and LED indicator to the Arduino for audible and visual alerts.

   Install the power cutting mechanism in the gas supply line to enable automatic gas shut-off.

2. Software Development:
   - Arduino firmware to read data from the MQ-2 sensor and interpret gas concentration levels.
   - Implement logic to activate the buzzer and LED indicator when gas concentration exceeds a predefined threshold.
   - Integrate GSM module functionality to send alert messages to users via SMS or internet-based platforms such as Telegram.
   - Code the safety response mechanism to trigger automatic gas shut-off upon detecting a gas leak.

3. System Integration:
   - Combine hardware and software components to create a cohesive system.
   - Test the integrated system to ensure proper communication between modules and accurate gas detection and alerting.

4. Telegram Bot Implementation:
   - Develop a Telegram bot to facilitate instant notifications to users.
   - Integrate the bot with the GSM module to receive alert messages and forward them to users' Telegram accounts.
   - Enable two-way communication, allowing users to interact with the bot for additional functionalities such as system status inquiries.

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5 Results

Figure 3. Output- result

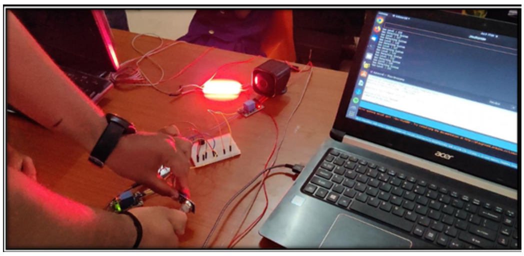

Figure 4. Work Procedure

The proposed IoT-based gas leakage detection and prevention system, SafeHaven, was successfully implemented and tested in both controlled and real-world environments. (see figure 3). The results demonstrate that the system is capable of accurately detecting the presence of hazardous gases and effectively triggering the necessary safety responses. (see figure 4).

Key outcomes include:

1. Detection Accuracy: The MQ-2 gas sensor was able to detect methane, propane, and butane gases with high sensitivity. Calibration tests showed that the sensor consistently detected gas concentrations above the predefined safety threshold.

2. Automated Safety Response: Upon gas detection, the system promptly initiated the automated safety protocols. The power source was successfully shut off, and the

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exhaust fan was activated to disperse the gas. This immediate response minimizes the risk of ignition and potential hazards.

3. User Notification: The integration of the Telegram bot ensured that users received real-time notifications about gas leaks. During tests, the bot sent alert messages within seconds of gas detection, allowing users to take prompt action regardless of their location.

4. System Reliability: The system operated reliably over extended periods of continuous monitoring. There were no false positives or missed detections during the testing phase, highlighting the robustness of the solution.

5. Ease of Integration: The system components, including the MQ-2 sensor, Arduino module, GSM module, and Telegram bot, were seamlessly integrated. The hardware setup and software development processes were straightforward, making the system scalable and adaptable for various environments.

6 Conclusion

Gas leakages resulting into fatal heck has become a serious problem in household leading to financial loss as well as human injuries and deaths. A solution to such those problems is this project which ensure safety with very low cost can detects gas leakage along alert system such as send message to the user. .Gas leakage leads to server accidents resulting in material losses and human injuries. Gas leakage occurs mainly due to poor maintenance of equipment and inadequate awareness of the people .Hence, LPG leakage detection is essential to prevent accidents and to save human lives.

This paper presented gas leakage detection and alerting system. This system triggers LED and buzzer to alert people when LPG leakage is detection. This system is very simple yet reliable. This paper aimed at monitoring and detection system to meet the safety standards and to avoid free accidents due to the leakage .The system detects gas in the atmosphere and will be continuously update and display the gas value ,the value can be seen by the user, through the mobile app easily. This system provides a quick response rate and the diffusion of the critical situation can be made faster than the manual methods. The system alerts and responds quickly in case leakage with help of alerting and by sending SMS to concerned authority.

In this paper we use IOT technology for enhancing the existing safety standards. While Making this prototype has been to bring a revolution in the field of safety against the leakage of harmful and toxic gases in environment and hence nullify any major or minor hazard being caused due to them. We have used the IOT technology to make a Gas Leakage Detector for society which having Smart Alerting techniques involving sending

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text message to the concerned authority and an ability performing data analytics on sensor. This system will be able to detect the gas in environment using the gas sensors. This will prevent form the major harmful problems related to gas leakages.

7 Future Scope

The current gas leakage detection and alert system has proven to be a reliable and straightforward solution for identifying and notifying individuals about LPG leaks. However, there are several areas for future enhancement and development that could significantly improve the system's performance, user experience, and overall reliability.

1. Extended Battery Life and Power Management
   - Objective:To enhance the system's operational duration and reliability by integrating a more robust power supply.
   - Approach: Utilize a larger, rechargeable battery to sustain the gas detection module for extended periods. Implement a power management system that alerts users when the battery is running low, ensuring continuous operation and timely maintenance.
2. Detection of Gas Concentration Levels
   - Objective: To provide users with more detailed information about the severity of the gas leak.
   - Approach: Incorporate sensors capable of measuring the concentration of gas in the environment. Display the concentration levels in real-time, allowing for a better assessment of the situation and more informed decision-making.
3. Enhanced User Interface and Alert Mechanisms
   - Objective:To improve user interaction with the system and ensure that alerts are effective and actionable.
   - Approach: Develop a more user-friendly interface that provides clear visual and auditory alerts. Integrate the system with mobile applications for remote monitoring and notifications. Allow for customizable alert settings to accommodate different user preferences and environments.
4. Integration with Smart Home Ecosystems
   - Objective:To create a more comprehensive safety and automation solution.
   - Approach:Integrate the gas leakage detection system with existing smart home platforms (e.g., Google Home, Amazon Alexa). This integration will enable coordinated responses, such as automatically shutting off gas valves and venting systems when a leak is detected.

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5. Machine Learning and Predictive Analytics
   - Objective:To enhance the accuracy and predictive capabilities of the gas detection system.
   - Approach:Implement machine learning algorithms to analyze sensor data and identify patterns that precede gas leaks. This predictive capability can provide early warnings and help prevent potential leaks before they become critical.
6. Cost Reduction and Miniaturization
   - Objective:To make the system more affordable and accessible to a broader range of users.
   - Approach:Focus on cost-effective materials and manufacturing processes to reduce the overall system cost. Additionally, work on miniaturizing the components to make the system more compact and easier to install in various environments.
7. Environmental and Safety Standards Compliance
   - Objective:To ensure the system meets the highest safety and environmental standards.
   - Approach:Conduct thorough testing and obtain certifications from relevant authorities to guarantee that the system complies with industry standards. This compliance will increase user confidence and promote wider adoption.

By addressing these areas, the gas leakage detection and alert system can be significantly improved, providing users with a more reliable, efficient, and user-friendly solution for gas leak detection and prevention.

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