The 2nd International Conference on Multidisciplinary Engineering (2nd ICOMDEN 2024)

The 2nd International Conference on Multidisciplinary Engineering: 00031 (2024) https://doi.org/10.29103/icomden.v2.xxxx
Volume 2, 2024
eISSN: xxxx-xxxx
Research Original Article

Smart Fire Prevention: An IoT Approaceh To Detecting LPG Leaks And Fire Hazards

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Abstract

In this paper, we address the serious fire risks posed by Liquefied Petroleum Gas (LPG) leaks, which can lead to significant material damage and loss of life. These incidents are often caused by human error or the absence of effective early warning systems capable of timely leak detection. To tackle this issue, we have developed an automatic gas leak detection system integrated with the Internet of Things (IoT). The system utilizes the ESP32 microcontroller as the main control unit, along with an MQ2 gas sensor for detecting LPG leaks and a fire sensor for identifying fire hazards. Additional components include a fan to enhance air circulation in case of gas accumulation and an automatic water pump that activates upon fire detection, aiding in prompt fire extinguishment. The system is also equipped with an LCD to display real-time gas levels in the environment, providing visual feedback to users. For enhanced functionality, this system connects to the Blynk application, allowing remote monitoring and control via smartphone. This feature enables users to receive instant notifications upon detecting gas leaks or fires and to manually control the fan or water pump if necessary. The primary objective of this system is to provide early detection and automatic response to gas leaks and fire hazards, thereby reducing the risk of fire-related accidents. This IoT-based approach offers a reliable solution to enhance safety by ensuring rapid responses to gas leaks and fires, ultimately minimizing damage and protecting lives.

Keywords: Liquefied Petroleum Gas, Gas Leak Detection, Internet of Things, Fire Hazard, Automated Safety System.

Introduction

In recent years, the rapid advancement of technology, particularly the Internet of Things (IoT), has opened new avenues for enhancing safety and security through sophisticated monitoring systems. IoT enables sensor devices to connect via the internet, transmitting real-time data and providing early warnings of hazardous conditions. Within this context, gas leak detection represents a critical area where IoT offers effective solutions, allowing for quicker and more accurate monitoring and detection. Gas is one of the most commonly used energy sources in daily life, serving both household needs, such as cooking, and industrial applications [1]. Despite its many benefits, gas usage poses significant risks, particularly in the event of leaks. Gas leaks can lead to explosions, fires, and even fatal accidents, underscoring the necessity for early detection to prevent unwanted incidents.

Previous research has highlighted the potential of IoT-based gas leak detection systems to provide rapid early warnings. For example, systems utilizing MQ-2 gas sensors, integrated with microcontrollers, have been developed to detect the presence of gas and methane in the air. These systems connect to IoT networks to notify users promptly, demonstrating their effectiveness in detecting gas leaks and offering timely alerts.

This study focuses on the development of an IoT-based gas leak detection system, emphasizing user interface design. A mobile application has been created using Blynk, enabling users to monitor gas and fire conditions easily while receiving notifications in various formats, including text, images, and audio. Additionally, the importance of testing and validating the gas leak detection system is underscored through a series of trials to ensure reliability and accuracy in diverse environmental conditions.

Leveraging cloud technology within the gas leak detection system facilitates real-time monitoring of gas, fire, and movement from remote locations via a mobile application linked to the cloud. This capability allows users to continuously observe the environmental conditions of their homes or industries and respond swiftly to potential hazards [2]. Furthermore, this research aims to integrate various types of sensors into the gas leak detection system, combining gas, fire, and motion sensors to provide comprehensive detection capabilities. This integrated system has proven to deliver quicker and more accurate notifications to users and can automatically activate other safety devices [3].

Lastly, the development of home security systems equipped with IoT-based gas leak detection features is emphasized. These systems utilize gas sensors connected to mobile applications, alerting users in the event of a gas leak [4]. Additionally, there is a focus on the development of home security systems equipped with IoT-based gas leak detection features. This system uses gas sensors connected to a mobile application to notify users in case of a gas leak [6]. This research emphasizes the importance of IoT integration in improving home security, particularly in gas leak detection [5]. This highlights the critical role of IoT integration in enhancing home security, particularly in gas leak detection. The combination of advanced technology and practical applications in gas leak detection systems can significantly improve safety measures in both residential and industrial settings. Through the integration of IoT, cloud technology, and user-friendly interfaces, these systems not only provide timely alerts but also foster a safer environment for all.

Related Work

1. Internet Of Things

The Internet of Things (IoT) has significantly influenced the development of safety systems, particularly in the areas of gas leak detection and fire hazard management. Previous research has explored various IoT-based systems designed to monitor and mitigate the risks associated with gas leaks. Introduced a gas leak detection system utilizing the MQ-7 sensor integrated with an Arduino microcontroller. While effective in identifying gas leaks and sending SMS alerts, this system did not incorporate a comprehensive response mechanism or multiple sensor types, limiting its applicability in dynamic environments [7].

Our proposed system distinguishes itself by integrating various functionalities into a cohesive and automated solution. By utilizing the ESP32 microcontroller, we enhance processing capabilities and real-time monitoring of both LPG and fire hazards. The inclusion of an MQ2 gas sensor for LPG detection, a fire sensor for identifying fire risks, and automated responses such as a fan for air circulation and a water pump for extinguishing fires set our approach apart. Additionally, the integration with the Blynk application allows for remote monitoring and control, empowering users to receive instant notifications and manually operate the system as needed. This comprehensive and interactive solution not only addresses the unique challenges of gas and fire hazards but also significantly improves safety and user engagement, ultimately minimizing the risk of fire-related accidents.

2. Microcontrollers

Microcontrollers play a pivotal role in the development of Internet of Things (IoT) applications, especially in safety and monitoring systems. Among the various microcontrollers available, the ESP32 has gained prominence due to its comprehensive features and high performance. The ESP32 is the successor to the ESP8266 and incorporates dual-core processing capabilities, which allows for simultaneous management of WiFi and Bluetooth communication alongside the execution of complex applications. This dual-processing architecture enhances the efficiency and responsiveness of IoT systems, making it an ideal choice for safety-critical applications such as gas leak detection and fire hazard monitoring. Several studies have leveraged microcontrollers for similar purposes. Implemented an Arduino-based gas detection system using MQ-7 sensors, focusing primarily on gas leak detection. While the Arduino platform provides an accessible entry point for many developers, it lacks the advanced processing power and connectivity options offered by the ESP32. As a result, systems based on Arduino may face limitations in handling multiple sensors and performing real-time data processing effectively. Furthermore, they typically require additional components for Bluetooth connectivity, complicating the system architecture [8].

In our system, we utilize the ESP32 microcontroller to create a more integrated and efficient solution for detecting LPG leaks and fire hazards. By combining the capabilities of an MQ2 gas sensor, a fire sensor, and an automated response system that includes a fan and water pump, our design ensures a rapid response to hazardous conditions. The ESP32's ability to seamlessly connect to the Blynk application allows for real-time remote monitoring and user notifications, enhancing user interaction and system responsiveness. This multi-functional approach, coupled with the robust processing capabilities of the ESP32, sets our system apart from existing solutions, ultimately improving safety and minimizing risks associated with gas leaks and fires.

Figure 1. NodeMcu ESP32

3. MQ-2 Gas Sensor

The MQ-2 gas sensor is widely recognized for its sensitivity to various hazardous gases, including Liquefied Petroleum Gas (LPG), natural gas, carbon monoxide (CO), and methane. Its utility in detecting these gases makes it an essential component in safety systems aimed at protecting human health and the environment. Previous research has utilized the MQ-2 sensor in various configurations, particularly with microcontrollers like Arduino and Raspberry Pi, to create effective gas detection systems. Using MQ-2 gas sensor, we developed a gas leakage detection system employing the MQ-2 sensor in conjunction with an Arduino Uno. This system provided timely alerts through short message service (SMS), demonstrating the feasibility of using simple microcontrollers for safety applications [9]. However, the limited processing capabilities of Arduino Uno may hinder the complexity and scalability of such systems.

Table 1. Types of Gas Sensors

Types Of Sensor	Function
MQ-2	Detects the smell of methane, butane, LPG, and carbon monoxide.
MQ-3	Detects alcohol
MQ-4	Detects the smell of methane and CNG.
MQ-6	Detects the smell of LPG and butane.
MQ-7	Detects carbon monoxide gas.
MQ-135	Detects benzene, ammonia, alcohol, NOx, and smoke.

The ESP32's dual-core architecture allows for efficient handling of multiple sensor inputs and real-time data processing, enabling more sophisticated features such as simultaneous monitoring of gas and fire hazards. Additionally, the ESP32's built-in support for WiFi and Bluetooth facilitates seamless integration with mobile applications like Blynk, allowing users to monitor conditions remotely and receive instant notifications. This level of connectivity and functionality surpasses the capabilities of previous implementations, providing a more comprehensive safety solution.

Furthermore, while existing systems primarily focus on gas detection, our approach emphasizes the importance of automated response mechanisms. In addition to detecting gas leaks, our system incorporates a fan to improve air circulation during gas accumulation and an automatic water pump to extinguish fires upon detection. This multi-faceted response strategy not only enhances safety but also minimizes the potential for material damage and loss of life associated with gas leaks and fire hazards. By leveraging the strengths of the MQ-2 sensor in conjunction with the advanced features of the ESP32 microcontroller, our system represents a significant advancement in the field of gas detection and fire prevention.

Figure 2. MQ-2 Gas Sensor

4. Flame Sensor

Flame sensors play a critical role in fire safety systems by detecting the presence of flames and providing timely alerts to prevent potential disasters. These sensors are designed to detect infrared (IR) radiation emitted by flames, allowing for high-precision detection even from small sources of fire, such as a gas lighter. Various types of flame sensors are available, including ultraviolet (UV) and near-infrared detectors, each with its specific operating principles. For instance, the infrared flame sensor functions by capturing the IR light emitted by flames using a photodiode, which then converts the detected radiation into an electrical signal for further analysis by an operational amplifier (op-amp). If a flame is detected, the sensor generates a digital output indicating the presence of fire, enabling quick responses in fire safety systems [10].

Recent studies have explored the integration of flame sensors into comprehensive safety systems, demonstrating their effectiveness in various applications, including fire alarm systems and security monitoring. By implemented a fire safety system that combines gas sensors and flame sensors to control and monitor alarm systems in smart farming environments [10].

By integrating a flame sensor with the ESP32 microcontroller and an automated response mechanism. In addition to detecting flames, our system is designed to activate an automatic water pump for fire extinguishment and a fan for improved air circulation in case of gas accumulation. This comprehensive approach not only detects flames but also initiates immediate corrective actions, significantly reducing the potential for damage and injury. By incorporating both gas and flame detection within a single IoT-based framework, our system offers a robust solution for fire prevention, differentiating it from existing systems that typically focus on singular detection mechanisms without integrated response features.

Figure 3. Flame Sensor

5. Blynk Application in IoT Systems

The Blynk application serves as a versatile platform for developing Internet of Things (IoT) solutions, enabling users to control and monitor devices remotely through smartphones. It provides a robust infrastructure that includes a cloud server, libraries for various hardware platforms, and a user-friendly mobile interface. Blynk facilitates seamless communication between mobile applications and hardware components, allowing developers to implement IoT solutions with minimal effort [11]. The integration of Blynk with popular microcontrollers such as NodeMCU and ESP32 further enhances its usability, making it an ideal choice for projects requiring real-time monitoring and data visualization.

Our research advances the existing knowledge by combining the Blynk application with a comprehensive automatic response system for gas leak and fire detection. Our system not only leverages Blynk for remote monitoring and alerting but also incorporates functionalities such as automatic activation of a water pump for fire suppression and a fan to enhance ventilation in the event of gas accumulation. This integration significantly improves safety measures by providing immediate corrective actions alongside real-time monitoring, distinguishing our approach from previous studies. By utilizing Blynk's intuitive interface while implementing robust automated responses, our system offers a holistic solution for fire prevention and gas leak management, ultimately reducing potential hazards and enhancing overall safety.

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Figure 4. Application Blynk

This study presents the design and implementation of a Smart Fire Prevention system using an Internet of Things (IoT) approach, focusing on detecting LPG leaks and fire hazards. The hardware components utilized in this system include an ESP32 microcontroller, which acts as the main control unit, an MQ-2 gas sensor for the detection of LPG leaks, a flame sensor to identify fire hazards, and a PIR (Passive Infrared) sensor to detect human presence. Additional components included a 16x2 LCD display for real-time gas level feedback, a relay module to control external devices, LEDs for status indication, a buzzer for alarm signals, a 5V fan to enhance air circulation during gas accumulation, and a 5V water pump [12] to extinguish fires when detected. Power was supplied by a 9V battery, ensuring continuous operation.

The software framework for the system was developed using the Arduino Integrated Development Environment (IDE), enabling programming of the ESP32 microcontroller to handle sensor inputs and execute control logic. The Blynk application was employed for remote monitoring and control, allowing users to receive instant notifications and manage the system via a smartphone interface. The integration of the Blynk app not only facilitates real-time data monitoring but also enhances user engagement by enabling remote interactions with the system [13] [14] [15] [16]. This combination of hardware and software provides a comprehensive approach to fire safety.

The methodology included a detailed process for integrating the various components into a cohesive system. Initially, schematic diagrams were created to visualize the connectivity among all hardware elements. The microcontroller was programmed to respond automatically to inputs from the gas, flame, and PIR sensors. When the gas level exceeded a threshold of 600 ppm, the system activated the buzzer, illuminated the red LED, and powered on the fan to disperse the gas. In case of fire detection by the flame sensor, the water pump was automatically activated, and notifications were sent to the Blynk app. The use of a block design model was critical in elucidating the flow of processes, making it easier to understand the system's operations from start to finish.

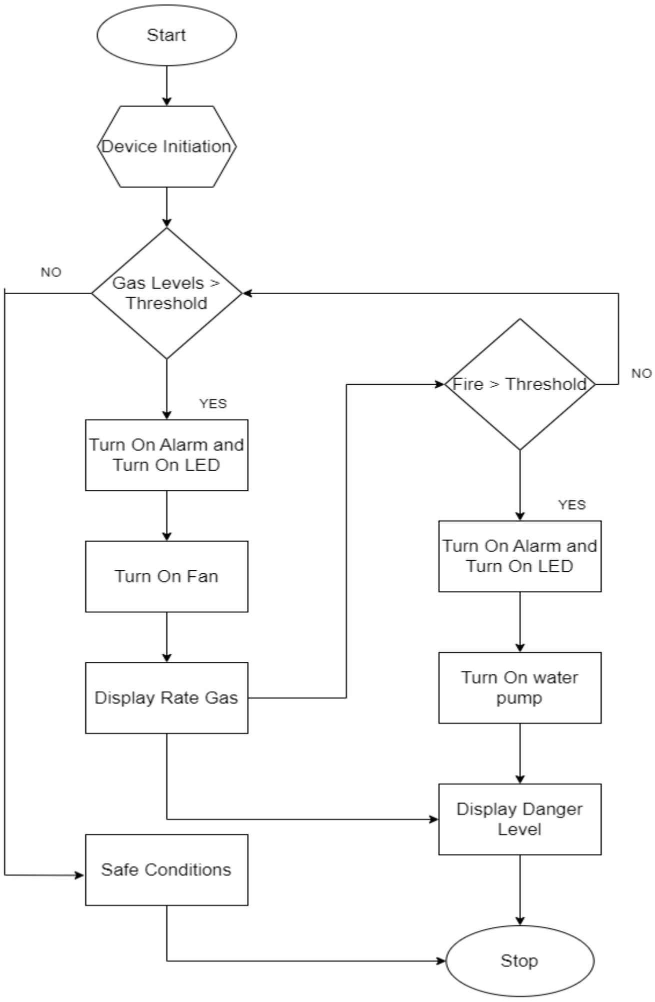

Figure 5. Design System

Rigorous testing was conducted to evaluate the performance of the Smart Fire Prevention system under various conditions, including simulated gas leaks and fire scenarios. The system's response times, accuracy of sensor readings, and reliability of notifications were closely monitored during these tests. This validation process ensured that the system met the intended safety objectives and provided effective early warning capabilities to prevent fire-related accidents.

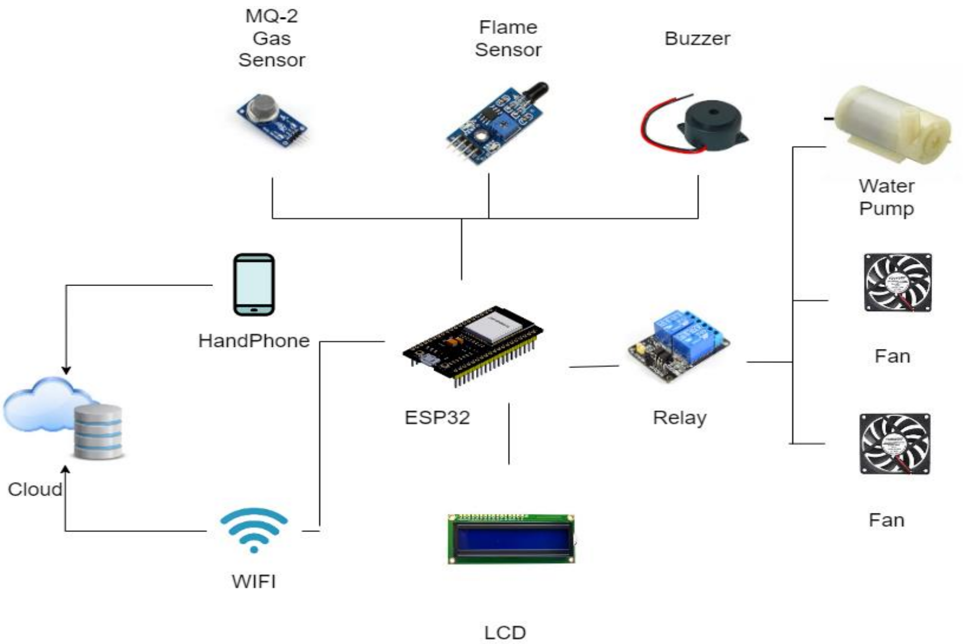

Figure 6. Design Model

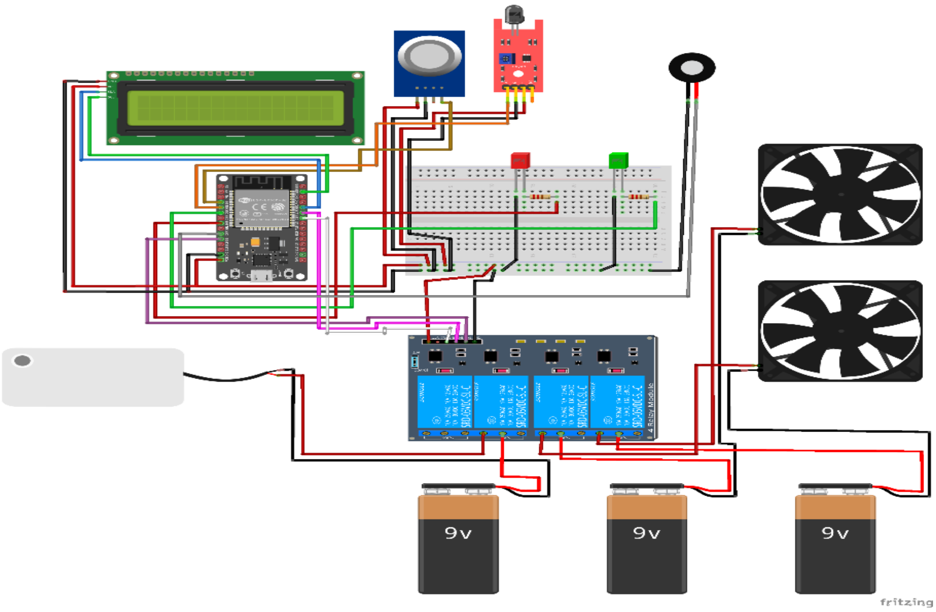

Figure 7. Circuit Schematic

The key advantage of this study lies in its integrated approach to safety, combining gas detection, fire detection, and automated emergency responses within a single IoT framework. Unlike previous works that often focused on singular aspects of safety, this research offers a holistic solution that enhances user interaction and engagement through the Blynk application. By providing real-time monitoring, automated responses, and remote access, the Smart Fire Prevention system significantly improves the safety landscape, minimizing the risks associated with LPG leaks and potential fire hazards. This innovative approach not only enhances property protection but also prioritizes the preservation of human life.

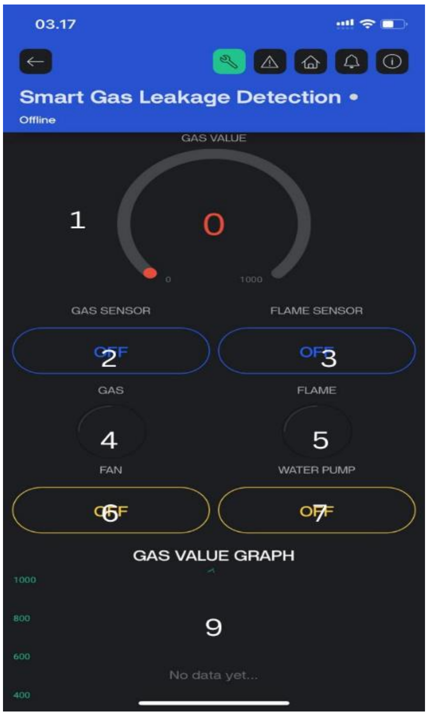

Figure 8. Application Program Design

The formula to determine the value of ADC, voltage, and gas PPM:

1. To determine the voltage value:

$$\text{Vout} = \frac{5xADC}{4096}$$

2. Determining the sensor constant value

$$\text{X} = \frac{Range\ (ppm\ MQ - 2\ Sensor)}{Total\ bits}$$

3. Determining the gas concentration in PPM

$$\text{ADC Konvert to PPM} = \text{X x} \frac{Vin}{Vref} x\ 4096$$

Information:

ADC = Analog-digital converter value on sensor readings

Range = On datasheet sensor 300-10000 PPM

X = Determine the sensor constant

Vin = Input voltage

Vref = Reference voltage

Bit = 0 – 4096

Results and Discussion

The testing phase was crucial for ensuring the proper connectivity and functionality of each component within the Smart Fire Prevention system. The performance of the MQ-2 sensor was evaluated in terms of its ADC (Analog to Digital Converter) readings, voltage outputs, and gas concentration measurements expressed in parts per million (PPM). The ESP32 microcontroller, with its 12-bit ADC capability, produces a range of 0 to 4095, allowing for precise detection of gas concentrations within the specified range of the MQ-2 sensor, which operates between 300 and 10,000 PPM. During the tests, the sensor demonstrated accurate readings, confirming its reliability for gas leak detection.

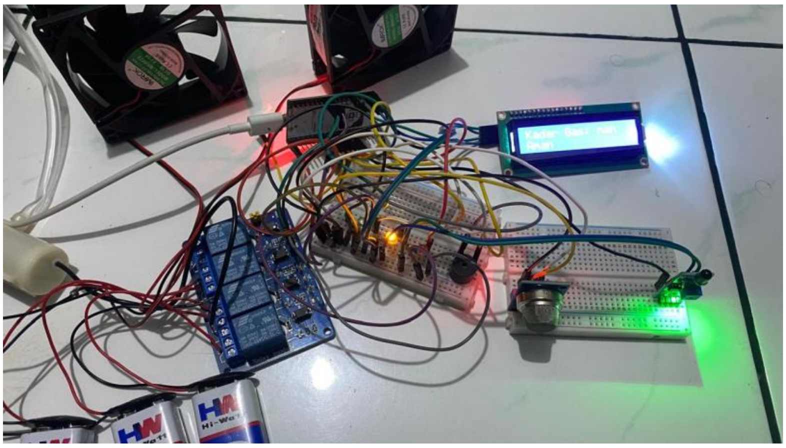

Figure 9. System Hardware Prototype Design

Table 2. Sample MQ-2 Sensor Data

testing to -	ADC	Voltage
1	257	0,2
2	501	0,3
3	577	0,4
4	656	0,7
5	734	0,8
6	889	1,43
7	1170	1,9
8	2119	2,54
9	3991	4,87
10	4096	5

Table 3. MQ-2 Sensor Testing

testing to -	ADC	Voltage	PPM	Response
1	257	0,2	386	Buzzer off, LED off, Fan off
2	501	0,3	579	Buzzer off, LED off, Fan off
3	577	0,4	773	Buzzer off, LED off, Fan off
4	656	0,7	1,353	Buzzer on, LED on, Fan on
5	734	0,8	1,546	Buzzer on, LED on, Fan on
6	889	1,43	2,764	Buzzer on, LED on, Fan on
7	1170	1,9	3,673	Buzzer on, LED on, Fan on
8	2119	2,54	4,910	Buzzer on, LED on, Fan on
9	3991	4,87	9,415	Buzzer on, LED on, Fan on
10	4096	5	9,666	Buzzer on, LED on, Fan on

In addition to gas detection, the flame sensor's performance was rigorously tested to determine its effective detection range. Using a gas lighter as a flame source, the sensor successfully detected the flame, providing digital output signals indicative of its operational status—either high (1) when a flame was detected or low (0) when absent. This binary output enabled immediate feedback to the system, allowing for swift responses to potential fire hazards. The results indicated that the flame sensor operated effectively within the expected parameters, reinforcing its integration into the overall safety framework of the system.

Table 4. Flame Sensor Testing 3 cm

Distance	Experiment to-			output conditions	response
	1	2	3		
10 cm	✓	✓	✓	Very stable	Buzzer on, LED on, Water Pump on
30 cm	✓	✓	✓	Stable	Buzzer on, LED on, Water Pump on
60 cm	X	X	X	-	Buzzer off, LED off, Water Pump off
90 cm	X	X	X	-	Buzzer off, LED off, Water Pump off

Table 5. Flame Sensor Testing 6 cm

Distance	Experiment to-			output conditions	response
	1	2	3		
10 cm	✓	✓	✓	Very stable	Buzzer on, LED on, Water Pump on
30 cm	✓	✓	✓	Very stable	Buzzer on, LED on, Water Pump on
60 cm	✓	✓	✓	Stable	Buzzer on, LED on, Water Pump on
90 cm	X	X	X	-	Buzzer off, LED off, Water Pump off

Table 6. Flame Sensor Testing 9 cm

Distance	Experiment to-			output conditions	response
	1	2	3		
10 cm	✓	✓	✓	Very stable	Buzzer on, LED on, Water Pump on
30 cm	✓	✓	✓	Very stable	Buzzer on, LED on, Water Pump on
60 cm	✓	✓	✓	Very stable	Buzzer on, LED on, Water Pump on
100 cm	✓	✓	✓	Stable	Buzzer on, LED on, Water Pump on

The unique advantage of this research lies in its comprehensive integration of gas leak detection, flame monitoring, and automated emergency response capabilities within a single IoT framework. Unlike existing systems that focus solely on either gas detection or fire hazards, this approach combines multiple safety features into one cohesive unit, enhancing overall user safety. Furthermore, the incorporation of the Blynk application for remote monitoring and control distinguishes this system from traditional methods, as it empowers users with real-time data access and the ability to respond to emergencies promptly. This holistic design not only improves the reliability of fire safety measures but also significantly reduces response times during critical situations, ultimately safeguarding lives and property from the devastating effects of gas leaks and fires.

Conclusions

In conclusion, the Smart Fire Prevention system presented in this study demonstrates a significant advancement in the detection and management of LPG leaks and fire hazards through the innovative use of IoT technology. By integrating multiple sensors, including the MQ-2 gas sensor and a flame sensor, with the ESP32 microcontroller, we have developed a comprehensive solution that not only detects gas leaks and flames but also facilitates an automated response to potential threats. This approach effectively addresses the critical issue of fire safety, which is often exacerbated by delayed human intervention.

The key advantage of our system lies in its real-time monitoring capabilities, enabled by the Blynk application, which allows users to receive instant notifications and control system components remotely. This feature enhances the overall user experience by ensuring that individuals can act swiftly in emergency situations, thus significantly reducing the risks associated with gas leaks and fires. Additionally, the combination of automated features—such as the activation of a fan for gas dispersion and a water pump for fire extinguishing—further elevates the system's responsiveness, ensuring that safety measures are enacted even in the absence of immediate human action.

Overall, this research contributes to the field of fire safety by providing a reliable, integrated solution that combines the latest IoT advancements with essential safety protocols. Unlike conventional systems that may focus on singular aspects of safety, our approach encompasses a holistic strategy that effectively enhances the protection of lives and property. Future work may focus on refining the system's capabilities, exploring additional sensor integrations, and conducting field tests to validate performance under various environmental conditions, thereby continuing to advance the safety landscape in residential and industrial settings.

For future improvements, adding features to enhance the PIR sensor and integrating a DHT22 sensor could significantly improve the device's functionality. Upgrading the PIR sensor could expand its detection range and enable it to distinguish between human movement and other types of motion, thereby improving the system's accuracy. Incorporating a DHT22 sensor would enable real-time monitoring of temperature and humidity levels, which would be valuable for detecting early signs of overheating or fire risks. Developing a web-based interface would also allow users to monitor data and control the device remotely from any internet-connected device. These enhancements would increase the system's reliability and versatility, making it an even more effective IoT-based safety solution.

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