Smart LPG Shield: Intelligent Gas Safety & Monitoring

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Abstract:
Liquefied Petroleum Gas (LPG) is one of the most commonly used fuels for domestic, commercial, and small-scale industrial cooking due to its high energy efficiency and clean combustion. Despite its advantages, LPG presents serious safety risks because of its highly flammable nature. Gas leakage incidents often result in fire accidents and loss of life, particularly when leakage is not detected at an early stage.paper proposes SMART LPG SHIELD, an IoT-based LPG gas leakage detection and management system aimed at enhancing safety and operational reliability. The system integrates an MQ-2 gas sensor for leakage detection and a load cell with an HX711 module for continuous monitoring of LPG cylinder weight. An ESP32 microcontroller processes sensor data and activates alert mechanisms through a GSM module by sending SMS notifications during leakage detection or low-gas conditions. A buzzer provides immediate local alerts. The system is designed to operate independently of continuous internet connectivity, ensuring reliability even in remote locations.

Keywords: Liquefied Petroleum Gas (LPG) , Internet Of Things (IOT) , Global System For Mobile Communication (GSM)

I. INTRODUCTION:

Liquefied Petroleum Gas (LPG) has become an essential source of energy in households, hotels, restaurants, and industrial kitchens due to its portability, high calorific value, and ease of storage. However, LPG is highly inflammable, and even minor leakage can create hazardous conditions. Statistics related to domestic gas accidents show that a significant number of incidents occur due to undetected leakage or delayed response .

Traditional LPG safety measures rely mainly on manual inspection or simple gas alarms that provide only local alerts. These systems are insufficient in situations where users are not physically present at the location. Moreover, conventional systems do not provide information regarding the remaining gas level in the cylinder, which often results in unexpected gas exhaustion and operational disruption .

With advancements in embedded systems and IoT technologies, it has become possible to design intelligent safety systems that continuously monitor environmental parameters and automatically notify users during abnormal conditions. IoT-based safety systems improve response time and reduce dependency on human intervention . The objective of this project is to design and implement a smart LPG gas leakage detection and cylinder monitoring system that integrates sensing, automation, and reliable communication to enhance safety and convenience.

II. LITERATURE SURVEY:

A wide range of gas leakage detection systems has been developed over the years to improve safety in domestic, commercial, and industrial environments. Early research primarily focused on low-cost embedded solutions using microcontrollers such as Arduino in combination with gas sensors like MQ-2 or MQ-6. These systems were capable of detecting the presence of combustible gases and triggering local alerts through buzzers or visual indicators such as LEDs. Although these solutions were simple, affordable, and effective for basic leakage detection, they were limited to on-site alerts and failed to notify users when they were away from the monitored location, thereby reducing their effectiveness during emergencies.

To address the limitation of local alerting, researchers later introduced GSM-based gas leakage detection systems. These systems integrated GSM modules with gas sensors to transmit SMS alerts to predefined mobile numbers when leakage was detected. This approach significantly improved user safety by enabling remote notification and faster response.

However, most GSM-based systems were designed only for alert transmission and lacked advanced features such as continuous gas level monitoring, automation, and data analysis. As a result, these systems provided limited functionality beyond emergency notification.

With the advancement of Internet of Things (IoT) technologies, researchers proposed IoTbased gas monitoring systems using platforms such as ESP8266, ESP32, and NodeMCU.

These systems enabled real-time monitoring of gas concentration through mobile or web-based applications, offering improved visualization and user interaction. IoT-based solutions enhanced system scalability and allowed users to access sensor data remotely. Despite these advantages, many IoT-based systems rely entirely on continuous internet connectivity. In the absence of network availability, these systems fail to deliver critical alerts, making them unreliable in remote or low-connectivity areas.

Furthermore, a significant limitation observed in existing gas safety solutions is the lack of LPG cylinder weight monitoring and automatic gas booking functionality. Most systems focus solely on leakage detection and do not address the problem of unexpected gas depletion, which is a major inconvenience for users. Automatic cylinder booking based on real-time weight monitoring is an important feature that enhances user convenience and ensures uninterrupted gas supply, yet it remains largely unaddressed in existing research.

The proposed system aims to overcome these limitations by integrating LPG gas leakage detection, GSM-based SMS alerting, automatic gas booking using cylinder weight monitoring, and IoT-based real-time monitoring into a single unified platform. By combining multiple safety and management features with both GSM and IoT communication mechanisms, the system provides a more reliable, automated, and comprehensive solution for LPG safety and management.

III. SYSTEM ARCHITECTURE

The proposed system architecture is carefully designed to ensure accurate gas leakage detection, reliable alert delivery, and automated LPG management with minimal human intervention. The system follows a modular and layered approach, allowing seamless integration of sensing, processing, communication, and alerting components. At the core of the architecture is the **ESP32 microcontroller**, which functions as the primary processing and control unit. The ESP32 is responsible for acquiring real-time data from connected sensors, executing decision-making algorithms, and managing communication with external alert and monitoring modules.

The **MQ-2 gas sensor** is interfaced with the ESP32 to continuously monitor the presence and concentration of LPG gas in the surrounding environment. The sensor outputs an analog signal proportional to the detected gas concentration. This signal is continuously analyzed by the ESP32 and compared against a predefined safety threshold. When the gas concentration exceeds the threshold value, the system identifies the condition as a gas leakage event and immediately initiates alert mechanisms to prevent potential hazards.

In addition to gas leakage detection, the system incorporates **LPG cylinder weight monitoring** to enhance user convenience and operational reliability. A **load cell** connected through the **HX711 amplifier module** is used to measure the weight of the LPG cylinder with high accuracy. The weight data obtained from the load cell is processed by the ESP32 to estimate the remaining gas quantity. When the cylinder weight falls below a predefined minimum limit, the system automatically triggers a gas booking notification, ensuring uninterrupted gas supply and reducing manual dependency.

To ensure reliable communication under different operating conditions, the system employs a **dual communication strategy**. The ESP32's built-in **Wi-Fi module** is used to connect to the **Blynk IoT platform**, enabling real-time monitoring of gas concentration and cylinder weight through a mobile application. This allows users to remotely view system status and receive instant notifications. In parallel, a **SIM800L GSM module** is integrated to transmit SMS alerts during gas leakage detection or low-gas conditions. The GSM-based alert mechanism acts as a backup communication channel, ensuring that critical alerts are delivered even when internet connectivity is unavailable or unstable.

Additionally, a **buzzer** is incorporated into the system to provide an immediate local alert during gas leakage situations. This audible warning enables quick response from nearby occupants, further enhancing safety. The combination of sensor-based detection, dual communication channels, and local alerting mechanisms forms a **robust and fault-tolerant architecture**.

Overall, this multi-layered system architecture effectively integrates gas sensors, weight monitoring, GSM communication, IoT-based monitoring, and local alerting. The architecture ensures enhanced safety, real-time monitoring, automation, and high reliability, making the proposed system suitable for both domestic and commercial LPG applications.

IV. METHODOLOGY

The methodology of the proposed system describes the detailed step-by-step operational process involved in LPG gas leakage detection, continuous cylinder weight monitoring, and alert generation. The system is designed to function autonomously with minimal human intervention, ensuring safety, reliability, and automation throughout its operation.

Initially, the **ESP32 microcontroller** initializes all the connected hardware components and communication modules. These include the MQ2 gas sensor for leakage detection, the load cell with HX711 module for cylinder weight measurement, the SIM800L GSM module for SMS communication, the Wi-Fi interface for IoT connectivity, the buzzer for local alerts, and the Blynk IoT platform for remote monitoring. Once initialization is complete, the system enters continuous monitoring mode.

The **MQ-2 gas sensor** continuously senses the concentration of LPG gas present in the surrounding environment. The sensor generates an analog voltage proportional to the detected gas concentration. This analog output is read by the ESP32 and continuously compared with a predefined safety threshold value. If the sensed gas concentration remains below the threshold, the system continues normal operation. When the gas concentration exceeds the threshold, the system identifies this condition as a **gas leakage event**.

Upon detection of gas leakage, the ESP32 immediately activates the **buzzer** to provide a local audible warning, enabling nearby occupants to take quick preventive action. Simultaneously, the system sends an **alert SMS** to the registered mobile number using the GSM module, ensuring remote notification even if internet connectivity is unavailable. In parallel, a notification message is displayed on the **Blynk mobile application** through Wi-Fi connectivity, allowing the user to receive real-time updates regarding the leakage condition.

In addition to gas leakage detection, the system continuously monitors the **weight of the LPG cylinder** using a load cell interfaced through the HX711 amplifier module. The load cell converts the applied mechanical load into electrical signals, which are processed by the HX711 module and transmitted to the ESP32. The microcontroller analyzes this weight data and compares it with a predefined minimum weight limit corresponding to low gas availability.

When the cylinder weight falls below the defined threshold, the system identifies a **low gas condition**. In response, the ESP32 automatically sends a **gas booking SMS** to the gas agency using the GSM module, thereby automating the booking process and reducing user dependency. At the same time, the user is notified through the **Blynk IoT application** regarding the low gas level and booking status, ensuring transparency and convenience.

Throughout system operation, real-time sensor data such as gas concentration levels and cylinder weight values are continuously updated and displayed on the **Blynk IoT dashboard** using Wi-Fi connectivity. This allows users to remotely monitor system status, track gas usage trends, and receive instant alerts during abnormal conditions.

Flow chart:

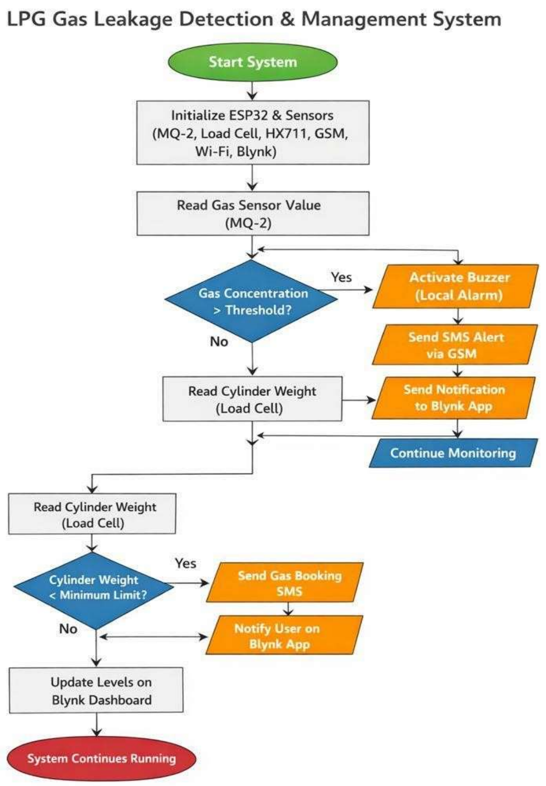

Fig. 4.1

V. RESULTS AND DISCUSSION

The experimental implementation of the proposed system demonstrates effective performance in detecting LPG gas leakage and ensuring timely alert generation. During testing, the MQ-2 gas sensor successfully identified the presence of LPG gas when the concentration exceeded the predefined safety threshold. Upon leakage detection, the system immediately activated the buzzer to provide a local audible alert, enabling nearby occupants to respond quickly and take preventive measures.

Simultaneously, alert messages were transmitted via the GSM module in the form of SMS notifications, ensuring that users were informed even when they were away from the installation site.

The cylinder weight monitoring module exhibited consistent and reliable performance throughout the experimentation. The load cell, interfaced through the HX711 module, accurately measured the LPG cylinder weight under different operating conditions. The ESP32 processed the weight data in real time and successfully identified low gas conditions when the measured weight dropped below the predefined threshold. In such cases, the system automatically initiated the gas booking process by sending a booking SMS to the gas agency, thereby reducing manual intervention and preventing unexpected gas depletion.

Real-time monitoring was achieved through integration with the Blynk IoT platform. The Blynk mobile application continuously displayed gas concentration levels and cylinder weight values, allowing users to remotely monitor system status. Notifications generated through the application provided immediate updates regarding leakage detection, low gas conditions, and booking status. This enhanced system transparency and improved user awareness.

The dual communication approach adopted in the system significantly improved reliability. While Wi-Fi connectivity enabled IoT-based real-time monitoring and visualization, the GSM module ensured that critical SMS alerts were delivered even during internet failure or network unavailability. This redundancy in communication proved effective in maintaining system functionality under varying connectivity conditions.

Overall, the experimental results confirm that the proposed system provides accurate gas leakage detection, reliable cylinder weight monitoring, and timely alert delivery. The combination of local alerts, GSM-based messaging, and IoT-based monitoring enhances system robustness and ensures improved safety for both domestic and commercial LPG applications.

VI. LIMITATION:

Although the proposed system provides effective gas leakage detection and automated LPG management, certain limitations are associated with its current implementation. The operation of the GSM communication module is dependent on a stable and continuous power supply. Any interruption or fluctuation in power may affect the timely transmission of SMS alerts, which can impact system performance during critical situations.

The IoT-based monitoring functionality relies on the availability of a stable Wi-Fi connection. Since the Blynk mobile application operates over the internet, real-time monitoring and notification services may be temporarily unavailable in the event of network failure or poor connectivity. However, the presence of GSM-based alerting ensures partial system functionality under such conditions.

Additionally, the MQ-2 gas sensor used for LPG detection requires periodic calibration to maintain measurement accuracy. Environmental factors such as temperature, humidity, and longterm sensor aging can influence sensor sensitivity, potentially leading to false alarms or reduced detection precision if calibration is not performed regularly.

VII. FUTURE SCOPE:

The proposed system can be further enhanced by integrating an automatic gas valve shut-off mechanism. In the event of LPG leakage, the system could automatically close the gas supply, thereby preventing further leakage and significantly reducing the risk of fire accidents and explosions. This enhancement would improve overall safety by enabling immediate corrective action without requiring human intervention.

Future versions of the system may incorporate advanced communication technologies by using GSM modules with internet capabilities or hybrid communication architectures that combine GSM and IoT. Such integration would allow both SMS-based alerts and cloud-based real-time monitoring, improving system reliability and ensuring uninterrupted alert delivery under varying network conditions.

The system can also be extended to support cloud-based data logging and analytics. By storing historical data related to gas concentration levels and cylinder usage patterns, advanced analytical techniques can be applied to predict gas consumption, detect abnormal usage trends, and enable preventive maintenance. This enhancement would make the system more intelligent and data-driven.

Additionally, the integration of a dedicated mobile application with enhanced user interfaces and features such as voice call alerts, push notifications, and remote configuration can further improve user interaction and emergency response. These future enhancements would make the system more scalable, user-friendly, and suitable for large-scale deployment in both domestic and commercial LPG applications.

VIII. CONCLUSION

The proposed LPG gas leakage detection and management system presents an effective, reliable, and low-cost solution for enhancing safety and operational efficiency in both domestic and commercial environments. By integrating gas leakage detection with continuous LPG cylinder weight monitoring, the system addresses two critical challenges associated with LPG usage, namely accident prevention and uninterrupted gas availability. The combination of sensing, automation, and communication technologies significantly reduces dependency on manual monitoring and improves overall system responsiveness.

The use of GSM-based alerting ensures that critical notifications such as gas leakage alerts and low-gas warnings are delivered to users even in the absence of internet connectivity. At the same time, IoT-based real-time monitoring through the Blynk platform provides continuous visualization of gas concentration levels and cylinder weight, enhancing user awareness and convenience. This dual communication approach improves system reliability and ensures uninterrupted alert delivery under varying network conditions.

Experimental observations confirm that the system is capable of accurately detecting gas leakage, monitoring cylinder weight, and automatically initiating gas booking when the gas level falls below a predefined threshold. The integration of local alerts through a buzzer further strengthens safety by enabling immediate on-site response. Overall, the system successfully achieves its primary objectives of safety enhancement, automation, and real-time monitoring.

In conclusion, the proposed system demonstrates strong potential as a practical and scalable LPG safety solution. With future enhancements such as automatic gas shut-off mechanisms, cloudbased data analytics, and advanced mobile application support, the system can be further developed into a comprehensive smart LPG management platform suitable for widespread adoption.

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