INTERNATIONAL JOURNAL OF ADVANCED INNOVATIVE TECHNOLOGY IN ENGINEERING

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LPG Gas Detection Using Sensor and ML

[1]Niyati Bawankar, [2]Mohit Watkar, [3]Aryan Chauhan, [4]Bhavesh Varma

[12345]Department of Computer Engineering, Suryodaya College of Engineering & Technology, Nagpur, Maharashtra, India

[1]nidhi2niya@gmail.com, [2]watkarmohit832@gmail.com, [3]ac7220297@gmail.com, [4]bhaveshvarma2005@gmail.com

Article History

Received on: 20 July 2026

Revised on: 15 Aug 2026

Accepted on: 20 Sept 2026

Keywords: LPG Leakage Detection, Gas Sensor, Internet of Things, Machine Learning, MQ-2 Sensor, Home Safety Automation, Real-Time Alert System

e-ISSN: 2455-6491

DOI: 10.65809/IJAITE/26/v03sp02/008

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ABSTRACT

Liquefied Petroleum Gas (LPG) is widely used as a domestic and commercial fuel, but undetected leakage remains one of the leading causes of fire and explosion incidents in homes, hostels, and small kitchens. This paper presents the design of an Internet of Things (IoT)-enabled LPG leakage detection and automated response system that combines a semiconductor gas sensor, a low-cost microcontroller, and a machine learning-based classification stage to interpret gas concentration levels in real time. The system continuously samples the surrounding air using an MQ-2/MQ-5 sensor, converts analog readings into parts-per-million (PPM) values, and classifies readings into normal, warning, and danger categories. On detecting an elevated gas level, the system triggers local buzzer and LED alerts, activates ventilation, and at critical concentrations engages a fire-suppression response while dispatching remote notifications through a cloud-connected Wi-Fi/GSM module.

1. INTRODUCTION

Liquefied Petroleum Gas has become a preferred fuel source in households, restaurants, and small businesses because of its high calorific value, clean combustion, and ease of storage and transport. Despite these advantages, LPG is highly volatile and denser than air, so a leaking cylinder or regulator allows the gas to settle and accumulate near floor level rather than dispersing, creating conditions favourable to fire, explosion, or asphyxiation. Although an odorant is added to LPG specifically so that leaks can be detected by smell, leaks originating from worn regulators, damaged rubber tubing, loose cylinder valves, or human oversight often go unnoticed until concentrations reach dangerous levels, particularly when the affected space is unattended or when occupants are asleep.

Conventional safety measures for LPG use are largely passive: manual valve checks, occasional regulator replacement, and reliance on the odorant for early warning. These measures depend on a person being present and attentive at the time of the leak, which is not always the case. This project

proposes an Intelligent LPG Leakage Detection and Notification System that shifts the safety model from passive to proactive by continuously monitoring gas concentration and responding automatically, without requiring a person to be present at the moment of the leak.

The proposed system is organised around four functional capabilities that operate together:

- Continuous Monitoring — the system samples ambient gas concentration at short, regular intervals so that a leak can be identified before it accumulates to a hazardous level.
- Local Alerting — on detecting an abnormal reading, the system produces an immediate audible and visual warning so that anyone nearby can respond.
- Remote Communication — the system sends a notification to the registered user's phone so that leaks can be acted upon even when the premises are unoccupied.
- Automated Mitigation — the system can initiate a physical response, such as activating ventilation, to reduce the rate of gas accumulation while the user is on the way to address the leak.

The remainder of this paper is organised as follows. Section II reviews related work on gas leakage detection systems. Section III states the problem being addressed. Section IV lists the project objectives. Section V describes the proposed methodology. Section VI presents the system architecture. Section VII lists the hardware and software requirements. Section VIII describes the individual modules. Sections IX and X discuss the expected outcomes and applications. Section XI presents the advantages and limitations of the proposed design, Section XII outlines future scope, and Section XIII concludes the paper.

2. LITERATURE REVIEW

A number of prior studies have examined microcontroller-based LPG and combustible-gas detection using MQ-series sensors, and their contributions and limitations directly inform the design choices made in this work.

Patil and Lenina [1] describe a gas leakage detection and automatic shut-off system built around the MQ-2 sensor, in which a servo-driven mechanism closes the regulator once a threshold gas concentration is crossed; the work demonstrates that mechanical shut-off is feasible with low-cost components but does not incorporate remote notification.

Oni et al. [2] present an Arduino-based smart gas leakage detector that raises a local buzzer alarm on threshold crossing; the system is simple and low-cost but, like most early Arduino-based designs, has no mechanism for alerting a user who is away from the premises.

Wibawa et al. [3] report an Arduino Uno and MQ-2-based LPG leak detector focused on sensor calibration and threshold tuning for domestic kitchen environments, providing useful baseline PPM thresholds for butane/propane mixtures but without any connectivity or logging component.

Soria and Perin [4] evaluate the MQ-2 sensor specifically for smoke detection, characterising its cross-sensitivity to combustible gases other than LPG, a finding that is directly relevant to false-alarm mitigation in the present system.

Shahewaz and Prasad [5] implement a gas leakage detection and alerting system using Arduino Uno with buzzer and LED indicators, again limited to local, on-site alerting without cloud connectivity or classification of severity levels.

Taken together, these works establish that MQ-series sensors coupled with a simple microcontroller reliably detect the presence of combustible gas and can drive a local alarm, but most designs stop at local alerting and threshold-based triggering. Few of the reviewed systems combine remote notification, tiered severity classification, and automated mitigation (ventilation or shut-off) in a single design, which is the gap this project aims to address.

A. Identified Gaps in Existing Research

- Most existing systems provide only local, on-site alerts and do not notify users who are away from the premises.
- Few designs classify gas concentration into graded severity levels; most rely on a single fixed threshold, which increases the risk of both false alarms and delayed warnings.
- Automated mitigation — such as ventilation or supply shut-off — is rarely combined with detection in low-cost prototypes.
- Cross-sensitivity of MQ-series sensors to non-LPG combustible gases and vapours is acknowledged in the literature but is not addressed through data-driven classification in most reviewed systems.

TABLE 1: SUMMARY OF REVIEWED LITERATURE

Ref.	Focus of Study	Year	Key Contribution
[1]	IoT-based gas leakage detection	2019	Detects gas leakage and activates buzzer
[2]	Smart kitchen safety system	2022	Monitors gas level and sends a remote alert
[3]	Automated gas leakage detection	2023	Alerts users via buzzer and LED indicator
[4]	IoT-based LPG detection	2023	Alerts user and performs automatic gas control
[5]	IoT LPG monitoring system	2024	Sends smartphone notification on leak detection

3. PROBLEM STATEMENT

LPG is widely used in residential and small-scale commercial kitchens, yet genuinely proactive and integrated safety systems remain uncommon. Most deployed detection methods are passive and depend on local audible alarms that either fail because of ageing sensors or are ineffective when the property is unattended. The following sub-sections outline the specific gaps that motivate this project.

A. Delayed and Localized Detection

Low-level leaks in the 2–10% air-concentration range — the range preceding an explosive mixture — need to be detected quickly, yet most on-site alarms provide no means of alerting an absent occupant, so response is delayed until someone is physically present to hear the alarm.

B. Negligence and Delayed Reaction

Leakage in unattended homes, or failure to close the cylinder regulator after use, is a recurring cause of LPG-related incidents, a risk that disproportionately affects elderly occupants living alone.

C. Absence of Automated Mitigation

Even after a leak is detected, gas concentration can continue to rise because most existing low-cost systems lack any automated mechanical response, such as ventilation or supply shut-off, and instead rely entirely on manual intervention.

D. Ineffective Remote Communication

Conventional buzzer-based alarms are localized and cannot reach a user who is away from the premises, which delays the response to an emergency that occurs while the property is unoccupied.

E. Sensor Reliability and Calibration

Semiconductor gas sensors such as the MQ-2 degrade over time and are sensitive to several combustible gases and vapours besides LPG, so periodic recalibration and a classification strategy that reduces false positives are both necessary for dependable operation.

4. OBJECTIVES

The objective of this project is to design a smart, IoT-enabled LPG safety framework that reduces explosion risk through rapid detection, tiered alerting, and automated mitigation. The specific objectives are:

- To continuously monitor LPG concentration using an MQ-2/MQ-5 sensor interfaced with a microcontroller.
- To classify gas concentration into normal, warning, and danger categories rather than relying on a single fixed threshold.
- To provide multi-modal notification — a local buzzer, a visual LED/LCD indicator, and a remote SMS or app notification — whenever a leak is detected.
- To integrate cloud connectivity (Wi-Fi/GSM) so that gas-level data and alerts can be accessed remotely and stored for later review.
- To trigger automated mitigation — ventilation at warning level and a fire-suppression response at critical level — to limit the consequences of a leak before a human response is possible.
- To apply a machine learning classification stage to the collected sensor data so that gas levels are categorised with fewer false alarms than a simple fixed-threshold comparator.

5. PROPOSED SYSTEM AND METHODOLOGY

A. System Overview

The proposed system uses a microcontroller (NodeMCU/ESP8266 or Arduino Uno) connected to an MQ-2 gas sensor that responds to combustible gases present in LPG, including butane and propane. The microcontroller continuously samples the sensor output and compares the derived gas concentration against predefined thresholds that separate normal, warning, and danger conditions.

B. Gas Sensing and Data Acquisition

The MQ-2 sensor's internal resistance changes in the presence of combustible gas, producing a

variable analog voltage that is read by the microcontroller's analog input. This raw reading is sampled at short, regular intervals to keep the monitoring continuous rather than periodic.

C. Data Processing

The microcontroller converts the raw analog readings into parts-per-million (PPM) values using the sensor's characteristic response curve, and applies basic filtering to reduce noise introduced by humidity, dust, or minor voltage fluctuations before the reading is used for classification or logging.

D. Gas-Level Classification

Cleaned PPM readings are classified into normal, warning, and danger categories. In addition to fixed-threshold comparison, a machine learning model trained on historical sensor readings is used to recognise gradual upward trends in gas concentration, allowing the system to flag a developing leak before it crosses a fixed danger threshold, and to reduce false positives caused by transient sensor noise or the presence of other combustible vapours.

E. Local and Remote Alerting

On reaching the warning or danger level, the system sounds a buzzer and lights an LED indicator local to the premises, while simultaneously sending a notification — an SMS via a GSM module or a push/email alert via a Wi-Fi connection — to the registered user's phone, together with the current PPM reading.

F. Automated Mitigation

At the warning level, the system activates a ventilation mechanism (such as a motorised window opener or exhaust fan) to disperse accumulated gas. At the danger level, in addition to ventilation, a water-based fire-suppression mechanism is engaged as a preventive response to reduce the risk of ignition while the user is alerted to close the cylinder valve manually.

6. SYSTEM ARCHITECTURE

The system architecture consists of an IoT gas sensor device, a data collection stage, a classification stage, a cloud server, and a user-facing alert and dashboard layer. The IoT gas sensor device continuously captures gas concentration and ambient environmental data. This data is passed to a data collection stage that forwards it along two parallel paths: (i) a machine learning-based gas-level detection path that classifies the reading as Normal, Warning, or Danger and forwards the classification to a control-room monitoring interface, and (ii) a cloud server path that stores the data for historical analysis and drives a user alert and dashboard layer, from which SMS/email alerts and a web/mobile dashboard are generated for the end user.

At the hardware level, the sensor node is built around a NodeMCU (ESP8266) microcontroller. The MQ-2 sensor's VCC and GND pins connect to the NodeMCU's 3.3V and GND rails, and its analog output (AO) connects to the NodeMCU's analog input pin (A0). A buzzer is driven from digital pin D5 and an LED indicator from digital pin D6, with both device grounds tied to the NodeMCU's common ground. On power-up, the onboard LED blinks to indicate boot, the module connects to the configured Wi-Fi network, and the system then enters continuous monitoring mode: as the gas concentration read at A0 rises, the LED is switched on, the buzzer output increases through low, medium, and high intensity in proportion to the reading, and a notification is pushed to the user's phone through the connected IoT dashboard service.

TABLE 2: HARDWARE COMPONENTS

Component	Function
MQ-2 / MQ-5 Gas Sensor	Detects combustible gases such as LPG (butane/propane) and methane and outputs a proportional analog signal
Microcontroller (Node MCU / Arduino Uno)	Reads sensor data, performs threshold/ML-based classification, and drives outputs
ESP8266 Wi-Fi Module	Transmits gas-level data to the cloud dashboard for remote monitoring
GSM Module	Sends SMS alerts to registered numbers where Wi-Fi connectivity is unavailable
Buzzer	Produces an audible local alarm proportional to gas concentration
LED Indicators	Provide a visual Normal/Warning/Danger status indication
Power Supply (5V)	Supplies power to the sensor node and peripherals

TABLE 3: SOFTWARE TOOLS

Tool	Purpose
Arduino IDE	Writing and uploading firmware to the microcontroller
Python	Data handling and machine learning model development
Tensor Flow	Building and training the gas-level classification model
Jupiter Notebook	Iterative development and visualization of the ML model

Node-RED	Visual data-flow linking between sensor, cloud, and dashboard
Firebase / Thing Speak	Cloud storage, real-time database, and remote monitoring
Blynk	Mobile dashboard for monitoring and push notifications

7. IMPLEMENTATION AND MODULE DESCRIPTION

A. Sensing Module
Provides continuous, real-time measurement of ambient gas concentration, forming the basis for all downstream processing.

B. Data Collection Module
Aggregates sensor readings over time to build a dataset that supports both immediate classification and later trend analysis.

C. Classification Module
Applies threshold rules together with a trained machine learning model to categories each reading as Normal, Warning, or Danger.

D. Cloud Communication Module
Stores classified readings on a cloud server and exposes them through a dashboard for real-time and historical access.

E. Alert and Notification Module
Generates the local buzzer/LED response and dispatches SMS or email notifications to registered users whenever a Warning or Danger classification occurs.

F. Mitigation Control Module
Drives the ventilation actuator at Warning level and the fire-suppression actuator at Danger level, providing an automated first response ahead of manual intervention.

8. OUTCOME

The completed prototype is expected to detect a rise in LPG concentration within the sensor's response time (typically a few seconds for MQ-2-class sensors) and to raise a local alarm together with a remote notification before the concentration approaches the lower explosive limit under normal room-ventilation conditions. The tiered Normal/Warning/Danger classification is expected to reduce nuisance alarms compared with a single fixed-threshold design, since transient readings that do not sustain an upward trend will be treated differently from a genuine, escalating leak. Because the system does not yet include an independent, large-scale field trial, these outcomes are stated as design targets to be verified during prototype testing rather than as measured results.

9. APPLICATIONS

The proposed system is applicable wherever LPG or other combustible gases are stored or used, including:

- Residential kitchens, to detect leaks and prevent fires.
- Hotels, restaurants, and hostel/PG kitchens, where LPG use is continuous.
- Hospitals and laboratories, where gas leaks in experimental or medicinal settings pose additional risk.
- Educational institution laboratories, for student safety.
- Small industrial units and gas storage facilities, to monitor cylinders and tanks.
- Smart-home and Smart-city integrations, enabling remote monitoring alongside other public gas-distribution safety systems.

10. ADVANTAGES AND LIMITATIONS

A. Advantages
- Continuous, real-time monitoring reduces the chance that a slow leak goes unnoticed.
- Tiered classification (Normal/Warning/Danger) enables a proportionate response rather than a single all-or-nothing alarm.
- Remote notification allows a user to be informed of a leak even when away from the premises.
- Automated ventilation and mitigation reduce gas accumulation ahead of manual intervention.
- Cloud-based data storage supports historical review and later refinement of detection thresholds.
- Low-cost components make the system feasible for wide residential deployment.

B. Limitations
- The MQ-2 sensor is sensitive to several combustible gases and vapours besides LPG (e.g., smoke, alcohol vapour), which can cause false alarms if not addressed through calibration or classification.
- Sensor accuracy depends on periodic warm-up and recalibration; performance can drift with age, temperature, and humidity.
- The system requires a stable power supply; a power outage during a leak

would disable detection unless a battery backup is added.

- The current design primarily alerts and ventilates; it does not include an automatic gas-supply shut-off, so manual action is still required to fully resolve a leak.
- Remote notification depends on Wi-Fi/GSM connectivity, and a network outage would delay alerts to the user.

CONCLUSION

This paper has presented the design of an IoT and machine learning-assisted LPG gas leakage detection and automated safety response system intended for residential and small commercial use. By combining continuous MQ-2-based sensing, tiered gas-level classification, multi-modal local and remote alerting, and automated ventilation/mitigation, the proposed system addresses key gaps identified in prior local-alarm-only designs, particularly the lack of remote notification and automated response. While the system as designed still depends on manual gas-supply shut-off and periodic sensor calibration, it establishes a practical, low-cost foundation that can be extended with automatic shut-off, improved sensor hardware, and more sophisticated machine learning models in future work, contributing toward safer and more responsive residential gas-safety infrastructure.

FUTURE SCOPE

Planned enhancements include an automatic gas-supply shut-off mechanism that closes the regulator immediately on leak detection, deeper machine learning-based trend analysis to further reduce false alarms by distinguishing LPG from other detected gases, and the use of more sensitive, longer-lasting sensors to improve accuracy and reduce recalibration frequency. Additional directions include solar-powered operation to reduce dependence on mains power, voice-based alerts, integration with emergency-calling services, and interoperability with existing smart-home platforms.

ACKNOWLEDGEMENT (OPTIONAL)

The authors acknowledge the support and guidance received during the development of this work.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

FUNDING SUPPORT

The authors declare that they have no funding support for this study.

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