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An IoT-Based Remote-Controlled System for LPG Gas Leakage Detection and Cylinder Management

Enhancing Safety and Accessibility in LPG Usage: A Smart Gas Cylinder Management System

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Abstract: *In India, 62% of households used LPG as their primary cooking fuel in 202021, with 89% in urban areas and 49.4% in rural areas. However, gas leakage poses significant risks, causing over 5,122 accidents from 2017 to 2023. Elderly individuals face challenges with heavy cylinders and digital booking processes, exacerbating safety concerns. This project proposes a remote-controlled trolley with a self-closing nozzle and gas leakage detection system. Using an ESP32 microcontroller, gas sensors, solenoid valves, buzzers, GSM module, LCDs, ultrasonic sensors, stepper motors, and weight sensors, the system detects leaks, triggers alarms, shuts off gas flow, and sends alerts to homeowners. It also monitors cylinder levels and autonomously initiates booking via SMS when levels are low. The ESP32's Wi-Fi and Bluetooth modules enable remote control, aiding elderly users. This solution enhances safety, simplifies cylinder management, and addresses user challenges, contributing to a safer cooking environment in Indian households.*

Keywords*: Gas leakage detection, Liquefied Petroleum Gas (LPG), Safety, Remotecontrolled trolley, ESP32 microcontroller, Internet of Things (IoT), Cylinder management, Automatic cylinder booking, Household safety.*

1.INTRODUCTION

1.1 Motivation

With over 80% of Indian households relying on LPG, gas leaks pose a serious safety risk, often leading to accidents. Timely monitoring and automatic booking can prevent such hazards and significantly reduce the chances of catastrophic incidents. A personal experience underscored this urgency—while my mother was cooking, a valve malfunction caused uncontrolled gas leakage. A nearby lit lamp could have led to disaster, but my grandfather's quick action averted it. This incident highlighted the need for a reliable safety system that can detect leaks instantaneously and trigger immediate protective measures. Additionally, elderly individuals struggle with handling heavy cylinders and navigating digital booking platforms, further increasing risks [1]. The physical strain of cylinder management, combined with limited technological literacy, creates significant barriers to safety for this vulnerable demographic. For these reasons, enhancing LPG safety through smart automation becomes essential [2]. The proposed system integrates user-friendly interfaces and automated controls to address these challenges comprehensively, particularly for households with elderly residents.

1.2 Proposed Solution and Objectives

To address gas leakage and cylinder management challenges, we propose an IoT-based remote-controlled trolley system. This solution ensures real-time leak detection [3], automatic risk mitigation, and efficient cylinder replenishment. By integrating sensors and automation, it enhances safety, minimizes human intervention, and optimizes gas management for reliability and efficiency. The key objectives are to:

- Detect gas leaks instantly
- Trigger immediate safety actions
- Enhance safety through continuous monitoring and alerts
- Enable remote access and control for better user convenience

1.3 Technical Approach

This system integrates key components for real-time gas monitoring and safety:

- ESP32 Microcontroller – Controls operations and communication.

- Gas Sensor – Detects leaks with high precision.
- Solenoid Valves – Automatically shut off gas flow during leaks.
- Buzzer – Provides an audible warning in case of leakage.
- Ultrasonic Sensor – Ensures safe trolley navigation by detecting obstacles.
- Weight Sensor – Monitors cylinder weight and triggers automatic booking.
- LCD Display – Shows system status, gas levels, and booking updates.

2.LITERATURE REVIEW

2.1 Smart LPG Gas Level Detection and Safety System using IoT

- **Source:** Rohith Naidu V, Prathapa, Rakshith S Gowda, Ashwini D S (2020). Smart LPG Gas Level Detection and Safety System using IoT. *International Journal of Engineering Research and Technology (IJERT)*, NCCDS – 2020 (Volume 8 – Issue 13).
- **Objective & Limitations:** The study presents an IoT-based gas leakage detection and monitoring system for household safety. However, its reliance on a mobile app for safety actions may cause dangerous delays during emergencies, potentially rendering it ineffective when immediate intervention is crucial [4]. Its dependence on a stable internet connection limits reliability in rural areas, where 65% of India's population resides, leaving millions vulnerable.
- **Proposed Enhancements:** This project strengthens safety by introducing:
  - Autonomous Gas Shut-Off: A solenoid valve instantly stops gas flow upon detection.
  - Remote-Controlled Trolley: An ultrasonic sensor ensures safe cylinder handling and navigation.
  - Real-Time Alerts: Instant notifications via a mobile app provide timely warnings to users.
  - Predictive Maintenance: Advanced data analysis anticipates potential failures, enabling proactive system maintenance to enhance reliability and safety.

These improvements enhance reliability, minimizing risks and response delays.

3.METHODOLOGY

The methodology includes circuit diagrams and flowcharts illustrating component integration, providing technical insights. User survey data highlights practical challenges, design and functionality of the proposed system.

3.1 Flowchart

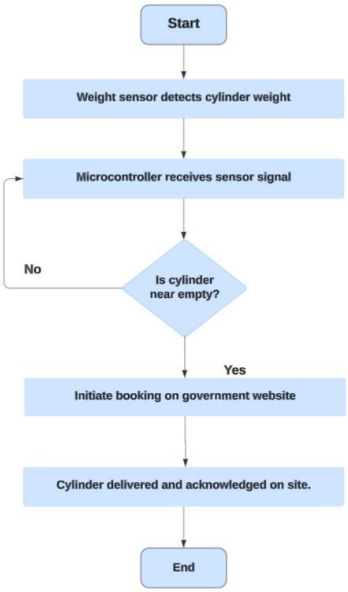

Figure 1: Flowchart for gas booking

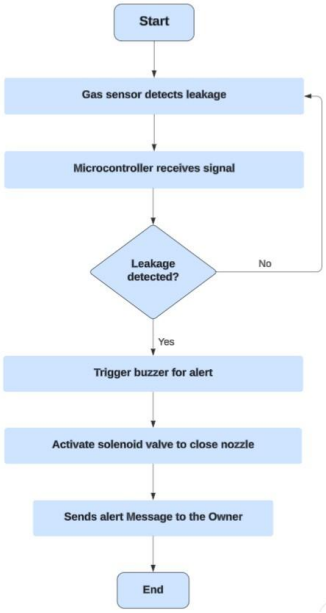

Figure 2: Flowchart for gas leakage detection

3.2 Circuit

This section details the integration of key components in the gas leakage detection system. The ESP32 microcontroller processes sensor data, controls actuators, and updates system status, ensuring reliability and user safety.

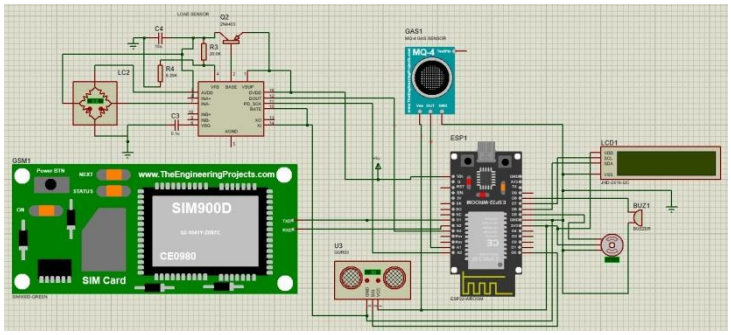

Figure 3: Circuit for Gas-Leakage detection

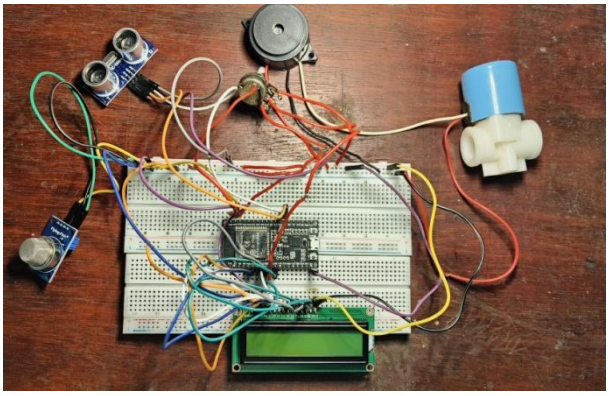

Figure 4: Gas-Leakage Detection Hardware Setup

Component	Model	Purpose
SIM900D GSM Module	SIM900D	GSM Communication
MQ-6 Gas Sensor	MQ-6	LPG Gas Detection
Ultrasonic Sensor	HC-SR04	Distance Measurement
LCD Display	JHD-2X16-I2C	Data Display
Buzzer	BUZZ1	Audible Alerts
Motor Driver	L298	Motor Control
Motors	Generic DC Motors	Rotational Motion

Table I: COMPONENT SPECIFICATIONS

3.3 Operation

The system operates through ESP32, which processes data from various sensors. The MQ-6 gas sensor detects LPG leaks and triggers safety measures, including closing the solenoid valve, activating the buzzer, and sending SMS alerts via the SIM900D module. The weight sensor monitors gas levels and books a new cylinder when the weight drops below 2 kg, displaying the OTP on the LCD. For navigation, an ultrasonic sensor detects obstacles, while the ESP32 regulates movement through the L298 motor driver, ensuring smooth trolley operation via DC motors. This circuit integrates various sensors and control modules to provide a comprehensive gas leakage detection and response system.

3.4 Design of trolley

3.4.1 System Components and Design

The gas cylinder trolley comprises three sections—upper, middle, and lower—each with distinct functions. Their integration ensures an efficient management system, enhancing safety and user convenience.

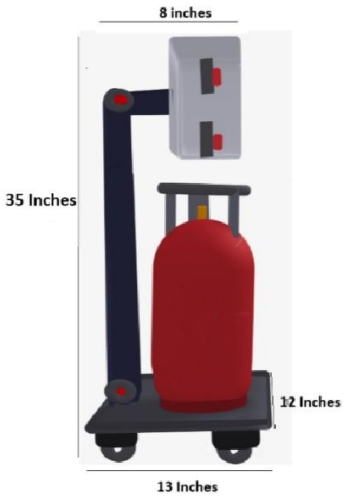

Figure 5: Design of a cylinder when it is connected to the cylinder

3.4.2 Upper Section

This section houses essential components for gas leak detection and response:

- **Solenoid Valves:** The primary valve shuts off gas flow during a leak, while the secondary valve acts as a backup. Both are joined and rotatable for easy maintenance [5].
- **Cuboid Structure:** Encloses the gas sensor, GSM module, and buzzer, with the sensor extending outward for air monitoring.
- **LCD Display:** Mounted below the gas sensor, displaying system status, gas levels, and OTP from the GSM module.

3.4.3 Middle Section

This section bridges the upper and lower parts, featuring an adjustable joint that allows rotation and facilitates cylinder shifting. It ensures secure positioning and houses the ESP32 power source.

3.4.4 Lower Section

The lower section houses key components for operation:

- **ESP32 Module:** Controls the ultrasonic sensor, weight sensor, and stepper motors, with Wi-Fi and Bluetooth for wireless communication.
- **Ultrasonic Sensor:** Detects obstacles to ensure safe trolley navigation [6].

- **Weight Sensor:** Measures cylinder weight and signals the ESP32 when levels drop below 2 kg [7].
- **Stepper Motors:** Facilitate precise trolley movement, controlled via Bluetooth.

3.4.5 Operation and Control

The system continuously monitors LPG levels using a gas sensor, automatically triggering a buzzer, solenoid valve shutoff, and SMS alert upon detecting a leak, ensuring immediate response and safety [8], [9]. Additionally, a weight sensor tracks gas consumption, sending an SMS booking request and displaying an OTP when the cylinder reaches 2 kg, preventing supply disruptions [10]. An ultrasonic sensor enhances operational safety by detecting obstacles, while Bluetooth-controlled stepper motors enable smooth and precise movement for efficient cylinder handling and transportation.

3.4.6 Safety Mechanisms

The ESP32 ensures safety by detecting LPG leaks and triggering countermeasures, including solenoid valve shutoff, buzzer activation, and SMS alerts [11]. Real-time monitoring enables swift response, while an ultrasonic sensor prevents collisions by adjusting trolley movement [12]. To maintain gas supply, the system automates cylinder booking when levels drop below the threshold [13]. The integrated trolley design provides an efficient gas cylinder management system, enhancing both safety and user convenience.

3.5 Survey Analysis

A survey of over nearly 200 participants across Tamil Nadu was conducted to assess LPG usage and safety perceptions. The key findings are as follows:

Do you feel safe while cooking with LPG gas?: Responses:

- Yes: 84.4%
- No: 15.6%

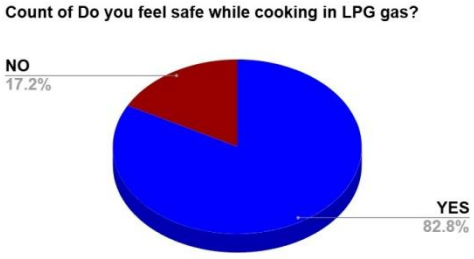

Figure 6: Survey responses regarding feelings of safety while cooking with LPG gas

Analysis: Although 84.4% of respondents feel safe using LPG, concerns from the remaining 15.6% highlight the need for enhanced safety measures. Given the rise in gas-related accidents, strengthening safety protocols is essential to maintaining user confidence.

Have you experienced any gas leakage in your environment?: Responses:

- Yes: 37.5%
- No: 62.5%

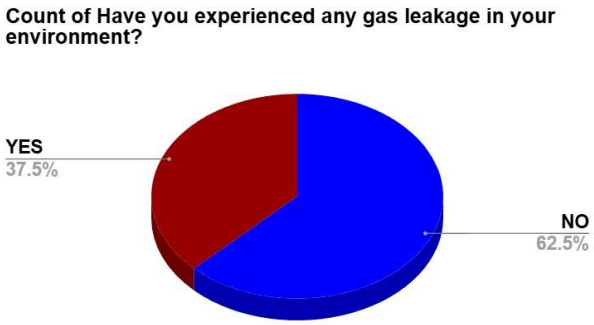

Figure 7: Survey responses regarding experiences with gas leakage in respondents' environments

Analysis: Nearly 38% of respondents have experienced gas leakage, underscoring the need for effective detection systems. While 62.5% have not faced leakage, the unpredictability of such incidents puts everyone at risk, making safety a priority for all users.

Do you know how to book a cylinder?: Responses:

- Yes: 70.3%
- No: 29.7%

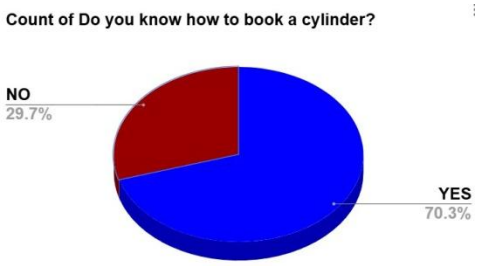

Figure 8: Survey responses regarding knowledge of how to book a gas cylinder

Analysis: While 70.3% of respondents know how to book a cylinder, a notable 29.7% lack this knowledge, especially in remote areas and among older adults. This knowledge gap can cause delays in accessing LPG, particularly in emergencies, underscoring the need for educational initiatives and more accessible booking options.

Survey Conclusion: A survey across Tamil Nadu highlights gaps in LPG safety and usage. While most users feel secure and know the booking process, many struggle with safety awareness and cylinder handling. Reports of gas leaks emphasize the need for enhanced safety measures, better education, and ergonomic solutions for improved user convenience.

4.RESULTS

Objective: Ensure a swift and automated response to gas leakage by promptly closing the solenoid valve and issuing alerts to prevent hazards and ensure user safety.

Method: The solenoid valve dynamically adjusts its position (0°, 45°, 90°) based on real-time gas concentration levels. The system continuously monitors and logs gas values, corresponding valve positions, and alert statuses to ensure accurate functionality and responsiveness.

Results: Data from the serial monitor validates the system's efficiency in accurately detecting and effectively responding to varying gas concentrations. The solenoid valve promptly adjusts its position based on detected leakage levels, automatically triggering the necessary alerts and safety mechanisms to enhance overall reliability.

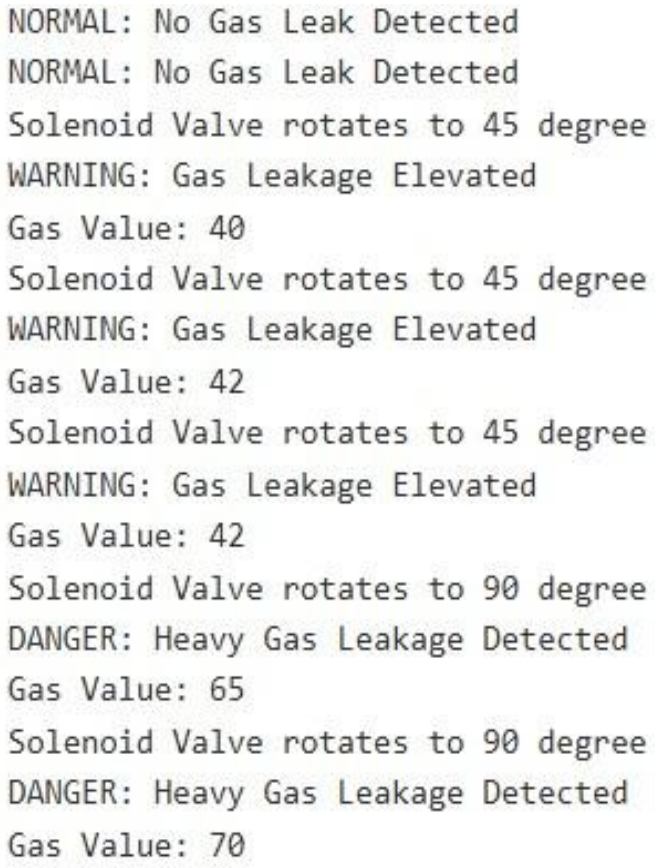

Figure 9: Serial Monitor Output Showing Solenoid Valve Response

Gas Value	Valve Position	Status
63	90°	Alert: Gas leakage detected!
66	90°	Alert: Gas leakage detected!
67	90°	Alert: Gas leakage detected!
47	45°	Warning: Gas levels elevated.
47	45°	Warning: Gas levels elevated.
47	45°	Warning: Gas levels elevated.
47	45°	Warning: Gas levels elevated.
33	0°	Normal
31	0°	Normal
31	0°	Normal

Table II: SOLENOID VALVE RESPONSE TO GAS LEAKAGE

Sensor Data Conversion:

The gas sensor utilized in this study generates a 10-bit ADC value (0-1023) corresponding to gas concentration in ppm. To streamline data processing and enhance readability, these raw values are normalized to a 0-100 scale using:

$$\text{Gas Value} = \left(\frac{\text{raw value}}{1023}\right) \times 100 \quad (1)$$

This transformation simplifies interpretation, representing gas concentration as a percentage of the sensor's maximum detection capacity. By converting the readings into a standardized format, the system ensures efficient threshold-based decision-making and real-time monitoring of gas levels.

Interpretation:

- Gas Value $\geq$ 60: The solenoid valve rotates to 90°, signaling a critical leak and triggering an alert.
- 30 $\leq$ Gas Value $\leq$ 60: The solenoid valve rotates to 45°, indicating a moderate leak and issuing a warning.
- Gas Value $\leq$ 30: The system remains in normal operation with no action required.

These results confirm the system's effectiveness in accurately detecting and mitigating gas leaks by providing real-time alerts, triggering immediate safety measures, and ensuring a swift response to potential hazards, thereby enhancing overall reliability and user safety.

4.1 Result Conclusion

Data Visualization

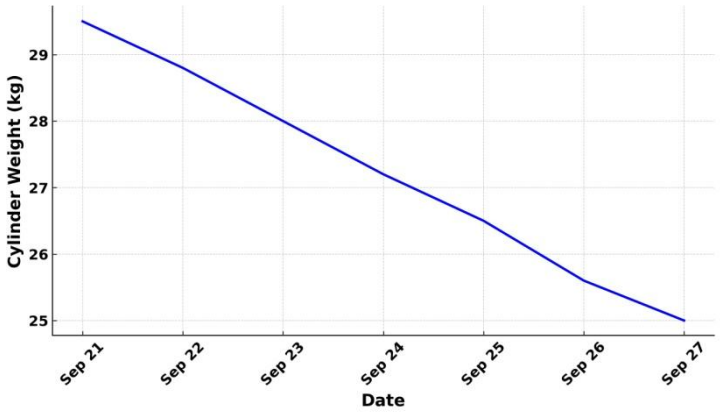

Figure 10: Daily monitoring of gas cylinder weight over one week

The graph illustrates a gradual decrease in LPG cylinder weight from 29 kg to 25 kg over a week, highlighting the system's precision in tracking gas consumption. This accurate monitoring ensures timely alerts for replacement, preventing unexpected shortages and enhancing user convenience.

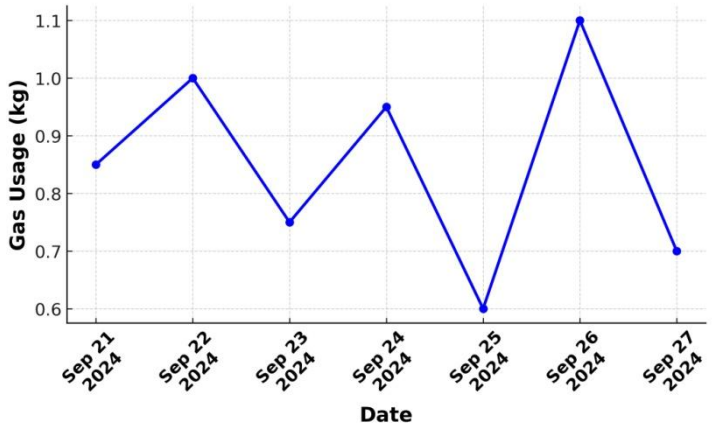

Figure 11: Daily monitoring of gas usage over one week

The graph shows daily gas usage fluctuations between 0.7 kg and 1.1 kg, forming the basis for predicting consumption and optimizing refill. The system ensures safety through leak detection and automatic valve closure. Future work will integrate automated cylinder replacement and weight monitoring, enhancing LPG management for both safety and convenience.

5.CONCLUSION AND FUTURE WORK

This study demonstrates an IoT-based LPG safety and monitoring system that enhances household safety and convenience. By integrating a remote-controlled trolley, self-closing nozzle, and gas leakage detection, the system effectively detects leaks, automates cylinder booking, and assists users, particularly the elderly.

Leveraging the ESP32 microcontroller and multiple sensors, the system ensures realtime gas monitoring and response. Wi-Fi and Bluetooth connectivity enable seamless remote control, while the solenoid valve promptly prevents accidents. User feedback confirms its efficiency in mitigating gas leakage risks and simplifying cylinder management.

Future Work: Enhancements will focus on automating cylinder replacement and refining weight tracking. The ESP32-controlled stepper motor will enable precise trolley navigation via WiFi/Bluetooth, with an ultrasonic sensor ensuring obstacle avoidance.
Additionally, weight sensors will continuously calculate gas levels using:

$$\text{Gas Weight} = \text{Measured Total Weight} - \text{Tare Weight}$$

These improvements will further enhance system accuracy and user convenience, advancing IoT-driven home safety solutions.

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