Enhancing Domestic Safety through Integrated LPG Leak and Weight Monitoring Systems

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Abstract — Liquefied Petroleum Gas (LPG) is considered to be the most widely used domestic and commercial energy source, yet it has two critical challenges: the risk of leaks which are undetected and the need for continuous supply monitoring. This project aims to design and develop an integrated IoT based smart system which combines real-time LPG leak detection with accurate cylinder weight monitoring, that addresses both safety and efficiency in operation. The system consists of a gas sensor which is used to detect leakage and a load cell with HX711 amplifier, controlled by ESP32 microcontroller and a SIM800L GSM module for automatic SMS or call alerts. After the sensor detects leaks or low cylinder weight it triggers the alert system and provides reminders to the user. This dual approach provides a scalable and cost-effective solution that enhances safety, optimizes gas management and reduces manual checks. The prototype therefore provides a cost-effective, user-friendly safety enhancement that can be implemented in domestic and small- scale commercial environments.

Keywords — GSM Module, IoT System, Load Cell, Gas Sensor, Microcontroller, LPG safety

I. INTRODUCTION

Liquefied Petroleum Gas (LPG) is a widely used fuel for domestic, industrial, and commercial purpose due to its efficiency and easy storage. But due to the high flammability of LPG it's important to handle the cylinders with proper care and avoid leaks to prevent incidents such as fires, explosions, and health risks. The leak detection traditionally was done by simple alarms or manual observations which often failed to provide real-time monitoring. Due to this the users also face inconvenience and interruptions in their daily activities due to unexpected depletion of gas cylinders. Recently many advancement were done using sensors combined with IoT connectivity, these have opened many ways for improving the system safety and efficiency. In this paper we have presented the design and development of smart leak detection and weight monitoring system which integrates an MQ sensor, a load cell and GSM module for alerts. This system is controlled by ESP32 microcontroller which process the sensor data and activate the local alerts system when the weight of cylinder falls below a certain defined level or a leak is detected. This system ensures user safety by alarming early leak detection and also provides timely notifications for cylinder refilling, this reduces manual monitoring efforts. On addition to this the integration of IoT connectivity allows the system to be extended for remote monitoring and making a way for future smart home integration. This paper explains the methodology, hardware and software implementation, testing results and potential improvements to show the feasibility and effectiveness of the developed system.

II. LITERATURE REVIEW

As the use of Liquefied Petroleum Gas (LPG) continues to grow in both homes and diligence, there's a rising demand for dependable systems that can descry leaks and track operation to ensure safety and avoid unanticipated force dearths. To meet this need, numerous experimenters have developed smart results that use IoT- grounded technologies for better control and robotization. Balogun et al. (1) designed a compact system that brings together several detectors, including a cargo cell for measuring weight, an MQ135 detector for detecting gas leaks, and a DHT22 to cover temperature and moisture. All factors are managed using a NodeMCU and housed within a mobile charger. The system collects and sends data to the pall, giving druggies real- time access through a mobile app. It can also track gas operation and automatically record a cache when demanded. Satyanarayana et al. (2) worked on a analogous setup, aimed at creating a smarter kitchen. Their system can descry gas leaks, dears, and indeed cover LPG situations. It uses an MQ- 2 gas detector, honey detectors, a cargo cell, and a NodeMCU microcontroller. The Blynk app is used to notify druggies through emails and mobile cautions whenever unsafe conditions arise or gas is running low. Another result was offered by Jayashree et al. (3), who dived the common issue of gas cylinders getting empty without advising. Their design keeps an eye on the gas position continuously and can place an order for a new cylinder on its own grounded on the stoner's settings. This makes diurnal life easier by reducing interruptions caused by an empty tank. In a different approach, Neha (4) developed a cost-effective leakage discovery system that could be used in homes or manufactories. Her design includes an MQ- 2 gas detector and an Arduino Nano. However, the system turns on a buzzer, starts an exhaust addict if a leak is set up. It also displays gas attention situations on an TV screen. Eventually, Babu et al.(5) proposed a more advanced system where detector data is pushed to Microsoft's Azure IoT mecca. Their setup uses a NodeMCU and MQ- 2 detector to descry leaks. When a problem is set up, it can automatically shut off a solenoid stopcock and notify the stoner via SMS or dispatch. Testing showed the system could respond to leaks snappily and directly. [6] Ahmad and Bello both together designed a gas leakage detection system which is an alarming system that during unexpected gas leakage situation automatically detects the leakage, alerts and control the gas leakage. MQ-5 sensor is used to detect gass leaks, which triggers the buzzer alarm and activates exhaust fan to remove the gas concentration. An LCD displays the current system status, while LEDs indicate the gas level with two color- green means safe with no leakage and red means leakage detected. This system is controlled by Arduino uno. [7] Hotur and Prianka presented a smart LPG monitoring system prioritizing enhanced safety with leakage detection. Gas leaks has been the cause of serious accidents, and since LPG is highly flammable, detecting leaks is a crucial step for safety. This project uses a load cell to track gas level, gas sensor for gas leaks, and uses a GSM module to alert users about low gas levels or leaks, and activates alarms and an exhaust fan for safety.[8] Zakaria et al. proposed a safe and effective way to detect LPG levels without coming into direct contact with gas or liquid gas by using an ultrasonic sensing technique which enables real-time monitoring while overcoming the drawbacks of methods like weight-based measurements.[9] Satyanarayana et al. presented a solution by integrating IoT to enhance safety and efficiency in domestic cooking. This system continuously checks the weight of an LPG cylinder with help of load cell sensor. This data is processed by a microcontroller and sent through Wi-Fi to notify the user about the low gas level. This also had other features like flame detection to avoid fire hazard. [10] El Barkani et al. proposed an end-device ("edge") LPG-leak detector that embeds a TinyML convolutional neural network in an ESP32-S3 MCU. The model is trained on MQ-6 sensor data augmented with temperature and humidity readings, allowing on-device inference with high accuracy. The device raises local alarms and transmits MQTT messages over WiFi for cloud logging.

III. METHODOLOGY/EXPERIMENTAL

A. *Materials/Components*

A.1 Load sensor

Fig-1: Load Cell

A load sensor is a transducer, which measures weight and has a capacity of 40kg. It converts mechanical forces such as load, tension, compression or pressure into electrical output signals which can be measured. The electric reaction is proportional to the force. The load cell sensor measures the weight of cylinders continuously and sends sensor data to the microcontroller interface port when the weight of the cylinders drops to a known parametric level and the data is thereafter processed. By linking to the microcontroller, changes in load cell resistance are able to be detected and also interpreted after relevant calibration processes.

A.2 ESP32S Microcontroller

Fig-2: ESP32S

The ESP32S is a microcontroller, which has integrated Wi-Fi and dual mode Bluetooth. It consists of 38 digital input/output pins, USB, enable and boot pins, a jack with a power source, and is used in various applications in IoT. The device has two CPU cores which can be either independently controlled or energized. Its frequency of operation is around 80 MHz to 240 MHz. The ESP32 can be connected with a wide range of peripheral devices such as touch sensors, low noise sense amplifier, Ethernet, SD card interface, , UART, I2C and I2S.

A.3 HX711 Module

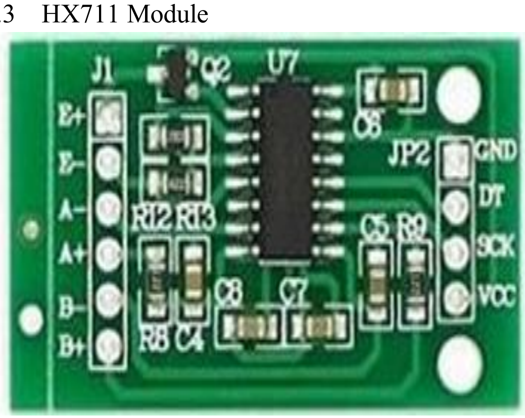

Fig-3: HX711

The HX711 is an amplifier which is integrated into the load cell. It also transforms electrical voltage of load cells into measurable weight values. This amplifier is used to convert an analog signal which is captured by load cells to a digital signal that can be processed by the microcontroller.

A.4 SIM800L GPRS GSM Module

Fig-4: GSM Module

The SIM800L is a small cellular module which allows transmission of GPRS, SMS functionality along with voice calls. It is cheap, small in size, and has the capability of working with quad band frequencies. This makes it a perfect solution to projects that need a long range of connectivity.

A.5 LM2596 2A Buck

Fig-5: LM2596 2A Buck

This module constitutes an LM2596 2A Buck Step-down Power Converter that transforms DC input voltages from 4V to 40V into DC output voltages between 1.3V to 37V. It integrates an in-built voltmeter display and advanced microcontroller for improved capacity of operation. The high-precision multi-turn potentiometer simplifies the process of adjustment of output voltage to any required value within the operational parameters, preventing the requirement for external voltage measurement equipment. The module demonstrates exceptional flexibility and efficiency of operation.

B. Method

The proposed LPG safety monitoring system integrates hardware and software components to continuously monitor the weight of an LPG cylinder and detect potential gas leaks. The system is designed for both domestic and industrial applications, aiming to enhance safety and operational efficiency. The methodology involves the following phases:

1. System Design & Architecture
The system consists of MQ-2 gas sensor for leak detection, and the load cell with HX711 amplifier to monitor the weight, both these units are integrated with ESP32 microcontroller which is the main controller of the system. The SIM800L GSM module is used to make phone calls in case of leak detection or send SMS alert when low gas level is detected.
2. Component Integration
The load cell is connected to an HX711 amplifier module, that converts the analog signal into a digital format which is read by the ESP32 microcontroller. The gas sensor is directly integrated with the ESP32 microcontroller via an analog input pin. The SIM800L module is interfaced with the ESP32 via a UART serial connection using voltage-level shifting to ensure compatibility.
3. Mechanical Setup
To evenly distribute the weight a strong mechanical frame was created to put the LPG cylinder over the load cell.
To reduce the vibration and outside disturbance the load cell is secured between the base plate and the cylinder platform. For accurate leak detection, the gas sensor is placed near the LPG cylinder's valve or nozzle area.
4. Calibration and Testing
To get the right scaling factor for precise gas level estimation, the load cell is calibrated using known weights. In a similar way, the threshold voltage level for leak detection is determined by testing the gas sensor with controlled gas exposure. The empty cylinder weight is taken into consideration by implementing tare functionality.
5. Software Implementation
The program is integrated with Arduino IDE, which is applicable to ESP32 microcontroller. The program constantly takes the reading of the load cell and gas sensor it then processes, the data and compares it with the predefined values. The ESP32 microcontroller sends data to the SIM800L in case of a leak or low gas detection, which then causes the phone call or an SMS alert to be sent to the registered mobile number. Other options can be added like an OLED display or Blynk IoT dashboard for real time monitoring.
6. Alert Mechanism
The SIM800L module is structured to dial a predefined mobile number or make an SMS when a gas leak is detected or when the weight of LPG is dropped below the set value. This guarantees instant notification, thus increasing user safety and avoiding accidents. It is a cost-effective and scalable methodology which is practical in the real world and applicable in homes, restaurants, and in industrial kitchens.

IV. RESULTS AND DISCUSSIONS

This integrated prototype was simulated and tested on both subsystems, which are the weight measurement and the gas- leak detecting.
A. load cell calibration: This calibration test involved the use of known weights between 1kg and 15kg. The readings were nearly linear with regression coefficient R2=0.998. The table given below displays the results obtained after the calibration.

True weight (kg)	Measured weight	Error (kg)	% Error
1	1.02	+0.02	2.0%
2	1.99	-0.01	0.5%
5	4.97	-0.03	0.6%
10	9.94	-0.06	0.6%
15	14.92	-0.08	0.5%

Table 1: Load cell calibration

The mean absolute error was 0.036 kg (approx. 0.46%) which is very good considering the low cost of sensors. The standard deviation of a repeatability test at 10 kg was 0.03 kg (coefficient of variation 0.3%).

B. Leak Detection: The MQ-2 sensor response was tested under controlled exposure. It took a mean response time of 3.2 s (± 0.6 s) and a recovery time of 12.5 s (± 2.1 s).

Condition	Detections	False alarm	sitivity (%)	Specificity (%)
Leak present (15 attempts)	13-True 2-False	-	93.6	-
No leak (15 attempts)	-	2	-	86.4

Table 2: Efficiency of leak detection

The MQ-2 sensor worked well in detecting 13 out of 15 cases. There were two false alarms when there was no leakage that occurred due to fumes of cooking near them. The resultant sensitivity was approximately 94% percent and specificity approximately 86% which is good for low cost sensor used in domestic setups.

C. GSM Alert Test: The GSM module was able to send SMS alerts in all simulated experiments with a mean delay of 5.6 s (±1.5) to send the alert.
These results shows that the system can reliably detect LPG leaks, monitor cylinder level, and issue remote alerts. Small variations in readings were mainly due to vibration and environmental noise.

Overall, the designed system is cost-effective, easy to install improving LPG safety by providing timely alerts. Future improvements could include mobile app integration and real-time graphical monitoring.

V. FUTURE SCOPE

For domestic purposes, the performance of the system can be further bettered by uniting a robot to turn off the cylinder controller. The buzzer system can be replaced with a speaker for a wider range of the alert system. It's possible to further enhance the monitoring system by transferring alert dispatches to the stoner via Bluetooth rather of GSM, which would enable another real- time operation to be supported. It's possible to develop mobile robots that are able of detecting multiple gas attention in the vicinity for artificial purposes.
Mobile robots that can detect multiple gas attention can be produced for artificial applications. Temperature detectors, in addition to gas detectors, can be used to detect
Moreover, incorporating artificial intelligence or machine learning algorithms could help predict consumption trends and automatically recommend optimal refill times, contributing to better resource planning for households and commercial kitchens. Finally, with appropriate industrial packaging and ruggedization, the system can be commercialized for widespread use in households, restaurants, and even distribution centers, contributing to smarter energy management and improved consumer safety on a larger scale.

VI. CONCLUSION

This system is a smart and practical way to integrate LPG leak detection and weight monitoring into a single compact IoT platform. The system will enhance user awareness and safety by installing the weight tracking, gas leak alarm and automated warning, thereby diminishing accidents. Weight monitoring by means of the load cell provides accurate measurements of the level of gases, whereas the MQ-2 sensor responds to gas leakage in 3 seconds. This system is a dependable solution to users across various sectors because of its cheapness and ease of installation.
The suggested system will properly fill the gap between safety, convenience, and automation, minimizing risks and maximizing gas use. As it evolves and improves, the given IoT-based LPG monitoring solution can become the new standard of kitchen and industrial safety.

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