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Original Article

SmartGuard: An Intelligent LPG Leakage Detection and Control System

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Abstract *- The increasing incidents of gas leakage have become an important concern for both domestic and industrial environments. Burners, pipes, and regulators are just a few examples of places where LPG leaks can happen. Installing a kit that can detect leakage of LPG is one of its preventative strategies for avoiding gas leakage incidents. Therefore, designing and developing a smart device for controlling LPG leakage has become necessary. The developed device aims to prevent hazardous situations by detecting gas leakage and shutting off the gas supply automatically. The device comprises sensors that can sense the level of LPG in the air and send signals to the microcontroller unit when the level is exceeded. The processing unit of the device processes the data and sends the signal to the control unit to shut off the gas supply. The system design is in a way that along with the immediate control over the gas supply, it also allows manual control. The device also includes an alarm system to alert the users of the leakage. The developed intelligent device offers a low-cost and real-time efficient solution to prevent gas leakage and associated hazards.*

Keywords *- Arduino UNO, Gas Sensor, LED light, LCD, Buzzer, LPG Leakage control.*

1. Introduction

Liquefied Petroleum Gas (LPG) is normally employed in households for cookery and heating purposes [1]. However, if not handled properly, LPG can pose a noteworthy risk to human life and property because of its flammable nature. The majority of accidents happen as a result of failure to turn off the regulator when there is a leakage. Various techniques of gas sensing technologies are used in all existing systems. However, it was discovered that there is not the best-automated system to prevent leaks by shutting off the regulator. Some experts recommended using an exhaust fan to manage the gas level in the surrounding area [2]. However, this strategy is not possible in every case and does not solve the issue at its base, which leads to significant accidents. Thus, it is vital to have a real system in place to detect and prevent LPG leaks. The developed device aims to prevent hazardous situations by detecting gas leakage and offers numerous benefits to users. One such benefit is increased safety in the home, specifically in regard to the detection and prevention of gas leaks. Numerous studies on the topic in question of LPG monitoring and gas leak detection have been conducted in the past. The findings from these studies offer significant perspectives on the development and execution of LPG leak detection systems, with the aim of safeguarding individuals and assets. There can also be major effects on air quality because of LPG leaks and explosions. Daily air quality reports are provided by the Air Quality Index. AQI focuses on the potential health effects of air pollution that may be experienced hours or days after breathing it. The higher amount of LPG in the air can affect the environment by releasing formaldehyde (HCHO), carbon monoxide (CO) and nitrogen dioxide (NO_2). If a leak occurs, the quality of propane and butane can affect the environment and air. Anyone can be affected due to reduced oxygen levels due to heavy butane and propane emissions.

This paper proposes a smart device for detecting and controlling LPG leakage. The device utilizes various sensors to sense gas leakage and trigger a response to mitigate the situation by turning off the gas supply. This system alerts the user about the leakage, shuts off the gas supply to prevent further leakage, and provides necessary alert information to emergency services. In order to test the developed system, a small quantity of LPG is supplied close to the MQ6 sensor module in real-time. The MQ6 measures the level of LPG in the air, and if it exceeds a certain threshold, it notifies the user

by SMS, turns on the buzzer, and displays a warning about a gas leak on an LCD screen. Furthermore, it switches off the regulator, which stops the gas flow.

1.1. Objectives of this Study

The primary goal of this research is to design a smart, potable and low-cost gas level monitoring and control system to examine the time-bound response of the gas sensor when it spots an accidental leakage of gas. The system records the gas sensor's response over time, allowing us to assess its efficiency and response time. The response time of the gas sensor was measured at regular intervals. The system was then observed to evaluate its performance and effectiveness.

The overall goals of the developed system are as follows:

- Monitoring the gas flow.
- Detection of gas leakage.
- Alert the user by sending an SMS for gas leakage.
- Controlling the gas leakage (If leakage spots, turn off the gas supply).

1.2. Paper Organization

The rest of the work is structured as follows. Section 2 narrates the problem statement. Section 3 includes the literature review. Section 4 includes the methodology followed by Section 5 which highlights the results along with discussions. Section 6 gives the significant outcomes of this research work. Section 7 showcases the limitations of this system, and finally, the conclusion is highlighted along with future work in Section 8.

2. Problem Statement

Serious concerns have been expressed for both residential and commercial properties due to an increasing number of gas leak events. To successfully monitor and control gas leakage, especially in terms of promptly discovering leaks, a smart, portable, and reasonably priced system must be developed. This research bridges the knowledge gap by developing a system that can identify and control gas leaks by turning off the gas supply.

3. Literature Review

There has been some research done in the past on LPG monitoring and leakage detection systems. Maximum devices focus on identifying the LPG leaks only and send the signal right away to the system's central unit to start the alarm system. Although this kind of leakage can lead to a major accident, no adequate and precise control measures are being implemented. The majority of mishaps occur due to negligence in failing to turn off the regulator. The exhaust fan approach is not always practical and fails to highlight the underlying issue that leads to serious accidents. An overview of the present systems is given in this section. The authors of [3] suggested a device that uses a MQ6 gas sensor and a microcontroller to detect gas leaks directly.

Table 1. Present-day existing system features

	Existing Systems Features					
Ref	**Leakage Detection**	**Control Gas Flow**	**Alarm/ Buzzer**	**SMS / Call**	**Weight Monitor**	**Gas booking**
[6]	Yes	Yes	Yes	Yes	No	No
[7]	No	No	No	No	Yes	Yes
[8]	Yes	Yes	No	No	No	No
[9]	No	No	No	Yes	Yes	No
[10]	No	No	No	No	Yes	No
[11]	Yes	Yes	No	Yes	Yes	No

In addition to detecting leaks, this system notifies users by sending them an SMS when it detects gas leaks and by turning on the exhaust fan and buzzer to lower the amount of gas in the air. The authors of [4] developed a system where an intelligent system is used to detect LPG and, upon detection, notifies the users through SMS. In [5], the authors proposed an automatic LPG monitoring system and cylinder booking system based on WSN. When the system is monitoring the LPG level in the air, it will sound an alarm to notify the consumers if it detects any leaks. The authors proposed a system in [12] that included level monitoring along with leakage detection. It also offers the feature of automatic renewal. This system keeps an eye on the initial LPG level and identifies gas leaks throughout operation. In [2], the authors suggested an approach where the system would alert the user and allow for automatic cylinder booking when the cylinder's gas level drops below the minimal level. Furthermore, Table 1 presents a selection of products or approaches along with some of their existing features.

4. Materials and Method

Designing an intelligent LPG leakage detection and controlling system involves several steps, like identifying the requirements, selecting the right sensors, selecting the communication protocol, developing the software, prototyping and testing, and finally, deploying and monitoring the system. Additionally, to design an intelligent LPG leakage detection and control system, some specific kinds of hardware are required [12-16]. The details of the used hardware are highlighted in Section 4.1. Furthermore, Section 4.2 explains the steps that are executed in this system, and Section 4.3 explains the algorithm for monitoring and controlling LPG leakage, in Section 4.4, the technical specifications of the developed system. Finally, In Section 4.5 circuit diagram of the system is mentioned.

4.1. Hardware Components

The details of the used hardware components and specifications are highlighted below [12-16]:

4.1.1. Gas Sensor

It serves as the system's main component. It notices the leakage of LPG gas from the pipeline or cylinder.

4.1.2. Microcontroller

The complete system is controlled by a microcontroller. This type of system can be constructed utilizing microcontrollers such as Arduino or Raspberry Pi.

4.1.3. Control Valve/ Motor

It regulates the supply of LPG gas. During a gas leakage, the system will cut off the gas supply using the relay module.

4.1.4. Buzzer

A buzzer is employed to notify users about the gas leak.

4.1.5. LED

An LED is employed to display the status of the system. It will highlight whether the system is working properly or not.

4.1.6. Power Supply

A power supply module is necessary to power the system. Normally, this is made possible by using a 5V power supply system.

4.1.7. Breadboard or PCB

A breadboard or PCB is employed to connect all the components of the system.

4.1.8. Relay

Electric switches are known as relays. In a low-voltage battery circuit, a relay can be utilized to switch a 230V AC main circuit.

4.1.9. Jumper Wires

A jumper wire is an electrical line that is used to link far-off electric circuits on printed circuit boards.

4.1.10. Global System for Mobile Communications (GSM)

GSM modules and specialized hardware enable connections between electronic gadgets and the mobile network infrastructure. The GSM module has ten pins available in total. This module is frequently utilized in many different applications, including security systems, automobile tracking systems, Internet of Things (IoT) devices, and more when remote communication is necessary.

4.1.11. Wi-Fi

The hardware that allows devices to connect to wireless networks is called a WiFi module, sometimes referred to as a WiFi adapter or WiFi chip. It is usually built in accordance with IEEE 802.11 certification criteria. A radio transceiver, an antenna, and firmware for controlling network connections are among the parts required for wireless communication that are included in these modules. The developed system automatically controls gas detection. The control module will switch off the gas flow when the system detects gas leakage. It also has various functions to alert the user through a buzzer and SMS.

The developed system comprises three different modules, as mentioned below:

- Leakage Monitoring Module
- Leakage Detection Module
- Leakage Controlling Module

1. The gas level in the atmosphere is monitored by the Leakage Monitoring Module.
2. The Leakage Detection Module is in charge of identifying any LPG leaks.
3. Controlling the gas flow to prevent mishaps is the responsibility of the Leakage Controlling module.

Two other modules, the GSM module and the Wi-Fi module, are also connected to this system. They are in charge of internal communications and all SMS notifications, respectively.

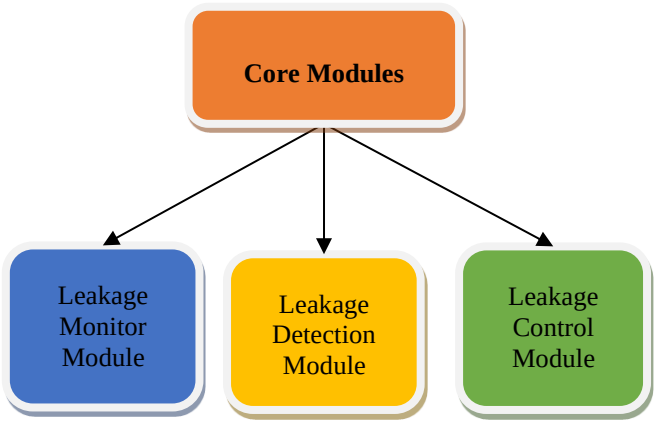

Fig. 1 Individual modules of the system

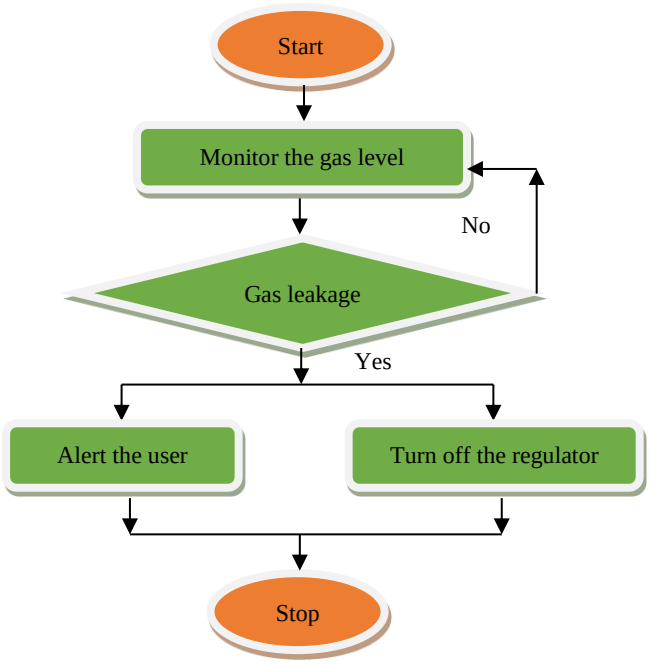

Fig. 2 System workflow

4.2. Workflow Flow of the System

The system uses a gas sensor to detect the amount of gas in the air as soon as it is turned on. In order to stop any more mishaps during this operation, it instantly triggers the alert and turns off the regulator anytime it detects a high level of LPG in the air. Until the system is turned off, this process will keep going.

4.3. Proposed Algorithm

This proposed algorithm highlights the working principle of the developed system.

Step 1: Set a threshold value (Tv) of LPG level
Step 2: Current gas level (CGL) monitoring
Step 3: if CGL >= TV, then
Set Flag = 1
else
Set Flag =0
Step 4: if Flag == 1
Start Alarm and Control the Gas flow
Step 5: Repeat the steps 2 and 3

The system alerts the control unit as soon as it detects a gas leak by changing the Flag value to 1. As soon as the control unit received the leakage message, the control valve available within the control unit shut down the LPG supply to prevent any accidents.

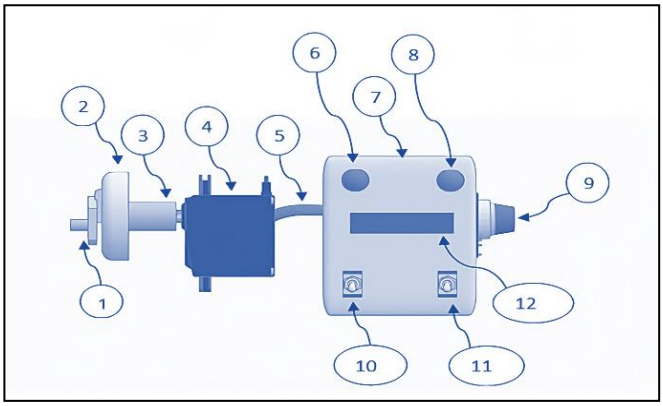

Fig. 3 Sample design of the developed System

Additionally, this system notifies the user by turning on the buzzer and sending a message. Once the gas level in the air becomes normal or less than the threshold value, the flag becomes 0. The system continuously executes this process.

4.4. Sample Design and Technical Specifications of the Developed

In this section, Figure 3 showcases the basic design of the system along with its hardware components. Additionally, Table 2 highlights the technical specification or functioning of each hardware component attached to the system.

4.5. Circuit Diagram of the System

A circuit diagram graphically represents an electrical circuit that includes various devices. It illustrates how various electrical devices are actually connected to one another. The design, building, and maintenance of electrical and electronic equipment for a given system are only a few of the many uses for circuit diagrams. Figure 4 depicts the circuit drawing of the developed system.

5. Results and Discussions

An intelligent system that can mechanically block the LPG supply when a leakage is detected would greatly improve safety in homes as well as additional facilities that use LPG. The system will be more useful if the system also allows manual control over the gas supply. In this research, a functional system prototype has been established, with all individual units performing as per the desired requirements.

In this system, the gas sensor is capable of detecting the incidence of LPG in the air as well as immediately stopping the gas flow through the employment of a control valve upon gas leakage. The system design is in a way that, along with the automatic control over the gas supply, also allows manual control. This could be achieved through the utilization of a switch or button that is located in a convenient location, such as the kitchen or utility room. When the switch is activated, the system will shut off the gas supply in a manner similar to that of the automatic detection system.

Table 2. Technical specification of the system

Sl No	Name of the Hardware	Uses
1	Regulator knob	Control the gas flow.
2	Regulator knob holder	Hold the regulator knob to perform the switch on or off operations.
3	Shaft	Transmit the movement and force from one component to another.
4	Motor	Control the movement regulator knob.
5	Wire connector	Connect different modules within the system.
6	Green indicator light	Indicate the current status. The green light indicates no leakage happened.
7	Red indicator light	Indicate the current status. Red light indicates leakage happens.
8	Sensing and Controlling unit	Perform and monitor the overall sensing and controlling operations.
9	Gas Sensor	Sense the gas level in the air to notice the leakage.
10	Turn on or Reset Switch	Turn on or reset the switch.
11	Turn Off switch	Turn off the switch.
12	LCD Display	Display the current status of the system.

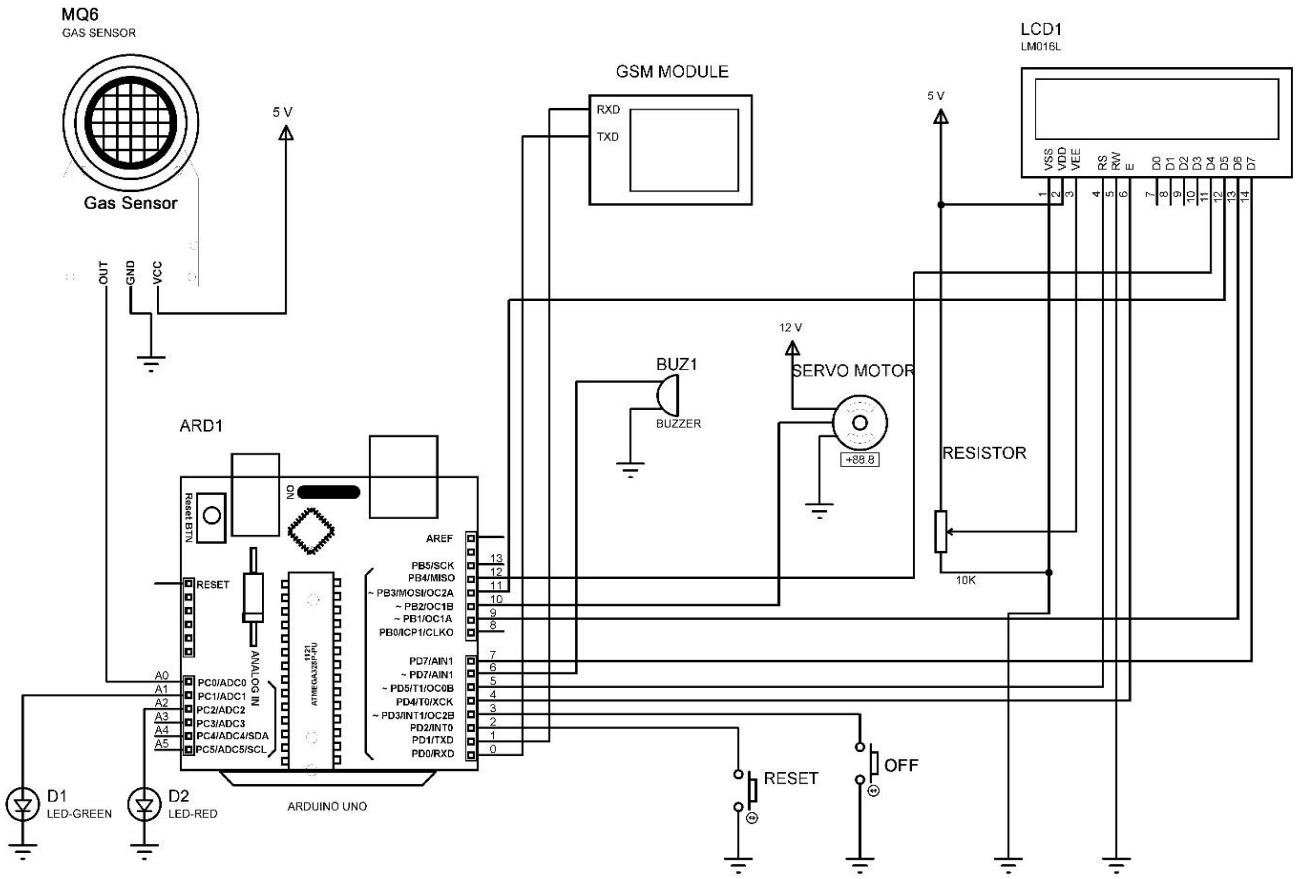

Fig. 4 Developed system circuit diagram

Similarly, using the reset switch, the user can turn on the gas supply. Additionally, the system displays information about the gas leakage on an LCD screen, sends an SMS to the user, and activates an alarm to ensure that appropriate action is taken. These measures are crucial in preventing any potential danger from gas leakage. The variation of the gas sensor response time is highlighted in Figure 5.

This figure represents a comparison of the gas sensor output reading (current) vs time where the X-axis carries the time values (in seconds), and Y-axis carries the gas sensor output reading (current) values, providing valuable insight into the gas sensor's behavior during the leakage period. The graph depicts how the gas sensor reading changed over time, indicating the presence and concentration of the leaked gas.

The gas sensor reading increases steadily when the leakage happens, at its highest when the sensor senses the highest gas occurrence. It also gradually decreases when the gas concentration decreases after the gas supply is turned off. According to the findings of the graph, the average response time of the developed system, starting from the detection of gas leakage to turning off the gas supply, is almost 5 to 10 seconds, and the average total time required to become the gas level normal is 15 to 20 seconds.

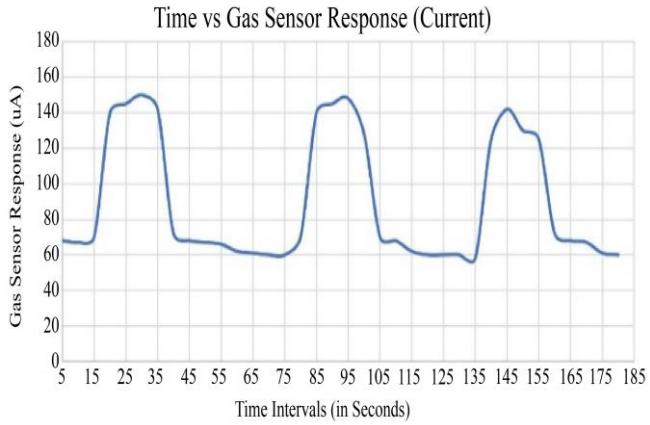

Fig. 5 Gas sensor response vs Time

The device was installed in a room that included a gas cylinder in order to monitor any potential leaks. The system keeps track of the amount of gas in the atmosphere, and it promptly cuts off the gas supply and alerts the users to any gas leaks it detects. The leak details were displayed on the connected monitoring system as well. Some experiments are conducted to verify the functionality and effectiveness of the suggested system. Module-wise examples of these experiments are included here:

5.1. Leakage Monitoring Module

This module begins monitoring the gas concentration in the air as soon as it is powered on. The monitoring system continuously performs the sensing operation. Since there isn't any gas leakage, the system displays the message "Gas Level Normal" on the LCD display, as shown in Figure 6.

5.2. Leakage Detection Module

When there is a gas leak, the module's results are explained in Figure 7. The device detects gas leaks instantly and flashes the message "Gas Level Exceed" on the LCD screen. The snapshots captured from the user's mobile device are displayed in Figure 8 when the system's integrated GSM module sends an SMS to the registered mobile device in the event of a gas leak. For this implementation, any mobile device that supports SMS can be utilized.

5.3. Leakage Controlling Module

When there is a gas leakage, the detection module sends the information to this controlling module. As a result of this, the controlling module switches of the regulator automatically to stop the gas flow. The module's results are explained in Figures 9 and 10.

Fig. 6 Monitoring module

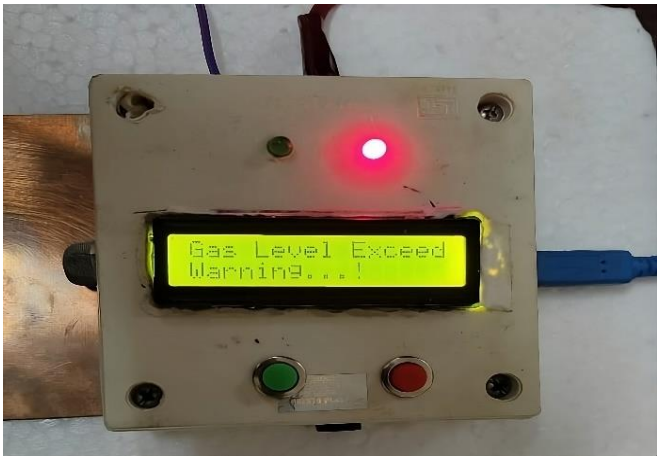

Fig. 7 Gas Leakage detects

Fig. 8 SMS notification

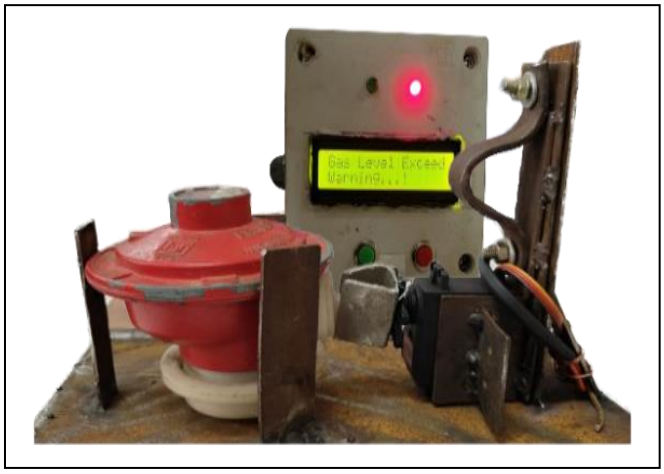

Fig. 9 Leakage controlling system

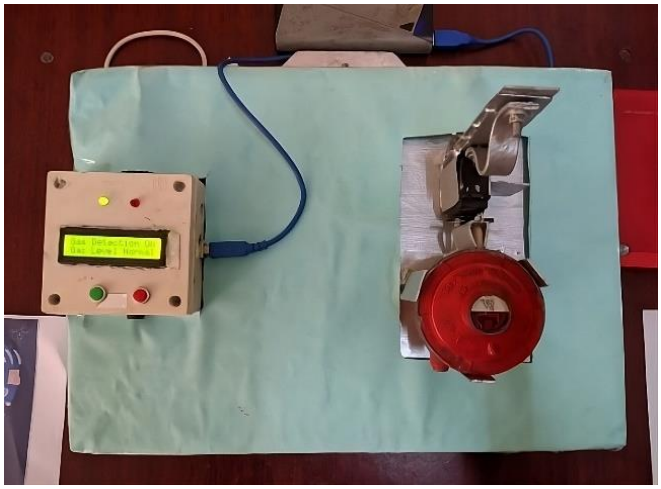

Fig. 10 Developed system top view

The developed system has many advantages over existing systems. In order to detect leaks instantly, the system combines real-time monitoring with advanced sensor technology to provide a higher level of security. Unlike existing models that only notify the user after the leakage occurs, this system both detects the gas leaks and prevents the leak from occurring by cutting off the gas supply.

It is also user-friendly, affordable and designed to be used in homes or similar workplaces. This advanced approach to detecting and preventing gas leakage increases safety. It reduces the potential for dangerous incidents, which sets it apart from other systems that focus mostly on the detection of gas leakage without integrated control mechanisms.

6. Significant Outcomes of this System

The significant outcomes of this system could include:

6.1. Enhanced Accuracy and Efficiency

An intelligent automatic gas leakage monitoring along with a controlling system replaces the requirement for human monitoring and intervention. In order to ensure perfect data collection, the system uses sensors to detect gas levels in the air correctly in real-time. This automation increases productivity, lowers the possibility of human error, and offers more dependable gas leakage monitoring and management.

6.2. Enhanced Safety Measures

The automatic system with smart capabilities displays gas levels continually and sends out alarms in a timely manner in case of abnormal levels or leakage. By taking a proactive stance, dangerous events like gas explosions or leaks that could endanger public health are avoided. The device increases safety for both residential and industrial applications by quickly identifying and reacting to irregularities in gas levels.

6.3. Instantaneous Notifications and Alerts

In the event of significant variations or abnormalities in the gas level in the air, the system is intended to instantly notify users or certain staff. This makes it possible to act quickly and take essential measures, such as turning off the gas or leaving the area. Accidents are avoided, and possible risks are reduced thanks to the system's timely notifications.

6.4. Energy and Cost Savings

The system aids in optimizing gas use by precisely monitoring gas levels and offering effective management. It guarantees that gas is only used when necessary and avoids waste. Users in the home and business sectors save money and energy as a result.

Overall, the "Smart LPG Leakage Detection and Controlling System" has resulted in increasing safety, providing real-time warnings, remote accessibility, and data analysis for precise decision-making.

7. Limitation of the System

Despite all of the benefits, the LPG system has certain drawbacks. These include:

7.1. Dependency on Power

Sensors are used by the LPG leak detection and control system to identify LPG leaks. Power is needed for these sensors to function. A source of electricity must be available to power the sensor and continuously monitor for any signs of emissions. In case of a power outage, the system will not work as expected.

7.2. Extreme Environmental Situations

LPG leakage detection and control systems may be less effective in some extreme environmental situations, such as extremely high or low temperatures, because these variables may impair the functionality of sensors or other system components.

7.3. Coverage Range

The sensitivity of the sensor determines how well such a device can identify leaks. A larger capacity of the sensor corresponds to a wider coverage area.

8. Conclusion

The intelligent device for controlling LPG leakage is a significant step towards enhancing safety in households and industries that use LPG as a fuel. The system is designed to detect and control gas leakage effectively, making it a reliable and efficient solution for preventing potential hazards. The system's gas sensor notices the excess LPG presence in the air and immediately stops the gas flow by using a control valve. The system design is in a way that, along with the automatic control over the gas supply, also allows manual control. Furthermore, the system has an LCD display, SMS notifications, and an alarm, which ensures that the user is notified of the gas leakage and prompted to take necessary measures. In summary, this intelligent device for controlling LPG leakage is a reliable and efficient solution that can help prevent potential gas leakage hazards, thereby increasing safety measures and ensuring peace of mind for users. LPG gas leak detection and control systems have a significant potential to improve safety and prevent accidents in both residential and commercial settings. Technological developments present chances to improve detection efficiency and accuracy. The integration of AI and machine learning technologies can strengthen the identification of hazards and the activation of responses. Linking the equipment to a centralized monitoring platform also enables real-time remote management. Additionally, the user can be informed about when to refill the cylinder by incorporating a weight measurement device in addition to gas leak detection.

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