DESIGN AND IMPLEMENTATION OF AUTOMATED DETECTION OF GAS CYLINDER LEAKAGES USING ARTIFICIAL INTELLIGENCE

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Abstract

The user's carelessness or incompetence, an outdated system, a broken cylinder, or its auxiliary parts are among the most prevalent causes of liquefied petroleum gas (LPG) leaks in households. The outcome is unanticipated leakages, which pose the risk of explosions. So, this research focuses on finding out how to build, test, and operate an electrically driven system that can automatically identify gas leaks with the use of a gas sensor module. In the event of a gas leak in the house, the electrical circuit will pick up the signal, translate it into screen-readable information, and then send an automated phone call to the user. As the minimal threshold value changed at different amounts of gas leakage, validation and testing of the proposed system demonstrated a high degree of sensitivity, detecting as low as 3000 ppm of gas leakage. In addition, the system's sensitivity is great, which is typical of systems designed to detect gas leaks.

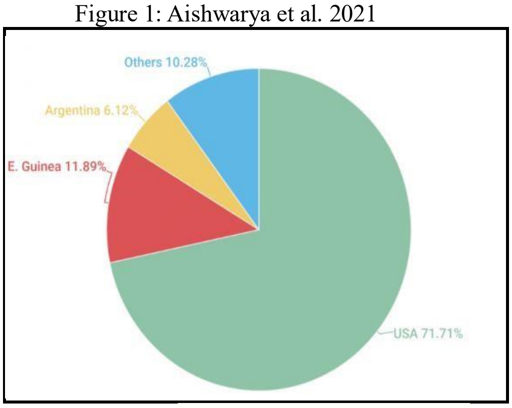
Graphical abstract

Keywords: *Liquefied Petroleum Gas (LPG), Leakages, Detection*

Introduction

One byproduct of the petroleum industry is liquefied petroleum gas (LPG), which is a volatile, colorless, and odorless substance. Among its many hydrocarbon components, butane and propane make up the bulk of its 70% and 30% composition, respectively. Because it vaporizes at ambient temperature and has a flash point of -156F (104oC), LPG, also called cooking gas, is highly combustible (Bauer, 1996). Liquified petroleum gas (LPG) has several potential applications, including heating, cooking, and lighting. The usage of LPG as a cooking fuel is on the rise, and 38 nations currently utilize it for automobile fuel. As can be seen in Figure 1, the demand for LPG has been on the rise worldwide. According to the Nigeria Midstream Downstream Petroleum Regulatory Agency (NMDPRA), this is also the case in Nigeria. In 2022, the country's consumption of LPG reached 1.4 million metric tons, and in 2023, the target is 3 million metric tons, while production in the country is only 600,000 metric tons. According to Figure 2, the top three countries supplying LPG to Nigeria are the US, Argentina, and Equatorial Guinea.

Figure 1: Aishwarya et al. 2021



Source: PPPRA Energy Report, 2019

Figure 2: Top suppliers of LPG to Nigeria

The use of liquid propane gas (LPG) as a cooking fuel is now trending upwards in popularity. There was less focus on LPG in 2017 compared to other sources such electric cooking, charcoal, kerosene, and firewood (figure 3). Table 1 shows that the danger of explosion is higher when using LPG as compared to other cooking energy sources, despite the fact that it is cleaner, quicker, and relatively cheaper than other conventional cooking fuels (Ajaja, 2019). There appears to be a correlation between the rising number of accidents and fatalities caused by LPG and its growing use, particularly in residential cooking. Figure 4 illustrates the numbers of gas-related accidents and fatalities in India from 2015 to 2018. Forjuoh (2006) states that an explosion can happen when a gas leak is coupled with an igniting source. In the years between 2010 and 2014, cooking cylinder explosions accounted for over 16% of all fatalities (Nidhi 2016). Many things can cause gas cylinders to explode, including operator error, broken or worn-out regulators, damaged valves, defective cylinders, exceeding fill capacity, and inexperience with the gas system (Okonkwo *et al*., 2020). Both residential and commercial buildings have been damaged or destroyed as a consequence of gas leaks (Ramya & Palaniappan 2012).

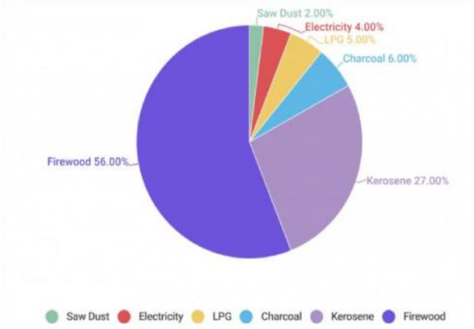


Figure 3: Showing Nigerian Cooking gas consumption (National Gas Policy, 2017)

Table1: Cooking energy sources and explosion chances

Cooking source	Diagrammatic representation	Chances of explosion
Charcoal		Low
Firewood		Low
Kerosene		Average
Gas		High
Electric		Average

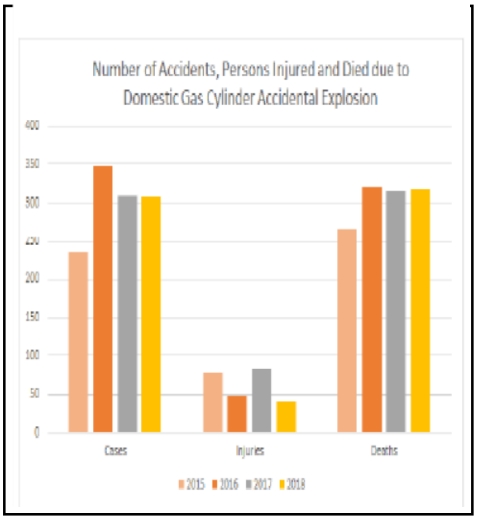


Figure 4: Statistics showing Number of accidents and persons injured due to domestic gas cylinder leakage in India (Kalpesh 2020, Un-natural causes of accident 2015-2018)

Also, a strategy to lessen the occurrence of gas explosions and accidents has to be put in place. According to Shingan *et al*. (2017), Georgewill and Ezeofor (2016), and others, this is the impetus for the idea of a gas leakage detecting system that is essential for preventing harm and maximizing safety. Researchers have found a way to alert consumers ahead of time of any potential event. The automated gas detection system, which primarily consists of the electrical component and the sensor section, has increased early warning. In order to monitor and detect gas leaks, Unnikrishnan *et al*. (2017) used the cylinder's weight as a strategy. In order to detect gas cylinder leaks, whether full or empty, the created system integrated a MQ6 sensor with the IoT. In the meanwhile, a system was created by Nithia and Ullas (2018) to measure and detect levels of carbon dioxide, oxygen, nitrogen, and cooking gas in homes. If these levels were to rise above the safe range, an alarm would go off. Similarly, Hariharan (2010) suggested an instrumentation system that could track pollutants like NO2, SO2, CO, dust, and hydrocarbons. Using a microcontroller, Suma et al. (2019) built an automated system that could detect low cooking gas levels, monitor gas leaks, and deliver SMS to consumers. The system could also send text messages to the gas agency using wifi. Along with the present-day trend in research, Adsul *et al*. (2016) introduced a system for detecting leaks that makes use of several sensor systems, such as those for hearing, temperature, pressure, gas leakage, and data transmission via a zigbee wireless module. The notion that the equipment was outdated was that gas leaks happened because of that. Additionally, smoke from cigarettes and cooking, ranging from 200 to 10,000 parts per million of LPG, was detected using the MQ6 sensor module. As for the sensors, they were a 40 kHz ultrasonic module, a 40 kHz ultrasonic receiver, and a 20 kHz microphone. The results showed that the system was running at peak efficiency.
The majority of LPG leaks occur in the house, and the users either aren't aware of the problem or don't have the

tools to check for the leak. A white cloud close to the leaking site, a hissing or whistling noise, and an odor are the physical indicators to watch out for (Luo, 2018).

There are restrictions with all of these, particularly for those who are deaf or hard of hearing. Leakage detecting systems for LPG should thus be installed in houses across Nigeria. With the increasing sophistication and safety of using LPG in the house, this is more important than ever to prevent accidents and damage (Georgewill & Ezeofor, 2016). This is in line with the development of more contemporary technology, which offers an early warning system to let people know when a gas odor, especially from LPG gas, is present (Georgewill & Ezeofor, 2016; Nag *et al*., 2016; and Vasantakumaar, 2018). Hence, our research suggests an inexpensive device that can identify certain extremely flammable gases—LPG cookers in particular—and notify the user through an audio alarm, hazardous information display on the LCD, power off, and a phone call to the user's location, regardless of where they happen to be.

Methodology

Description of the developed system

Using pre-existing parts, we were able to design and build a gas leakage detection system. One component, the sensor unit, detects the trace amounts of LPG in the surrounding air thanks to the gas sensor module. Figures 5 and 6 demonstrate how the user is automatically notified by phone call and how the signal is converted to readable information by the electrical circuit. This information is then exhibited on the LCD screen. If the system detects that the LPG level is too high, an automated system that makes use of artificial intelligence will not activate the system; in such cases, the user will be notified by phone. Table 2 provides a detailed description of each component and its purpose.

Table 2: Description of component parts

NO	ITEM	UNIT	DESCRIPTION
1	AT 328P microcontroller	1	Main chip responsible for collecting sensor data and initiating calls
2	Buzzer	1	Device for sounding alarm to warn home users
3	Red led	1	Used for indication out of threshold range
4	Green led	1	Used for indication within threshold (Normal) range
5	GSM module (SIM800L)	1	For initiating emergency call protocol to remote user
6	Resistors	2	For resisting the flow of current
7	Power module	2	For converting 12volts dc to 5volts dc.
8	DC female jack	1	Plugs to power adapter that provides main DC voltage to the system
9	Printed Circuit Board (PCB)	1	Holds all components in place and connects them as well
10	Enclosure casing	1	To box the entire system
11	LCD screen	1	Displays information to users
12	MQ2 gas sensor	1	Responsible for detecting gas leaks
13	Capacitor	2	Used for storing currents

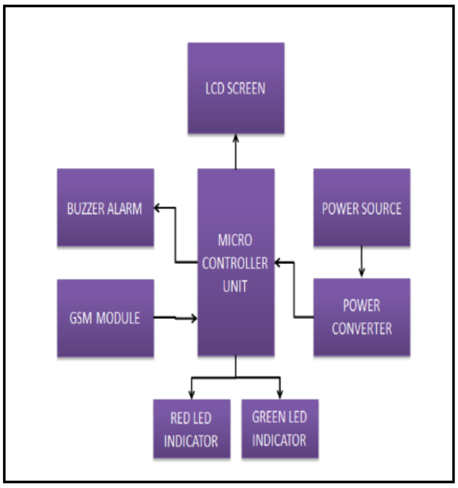
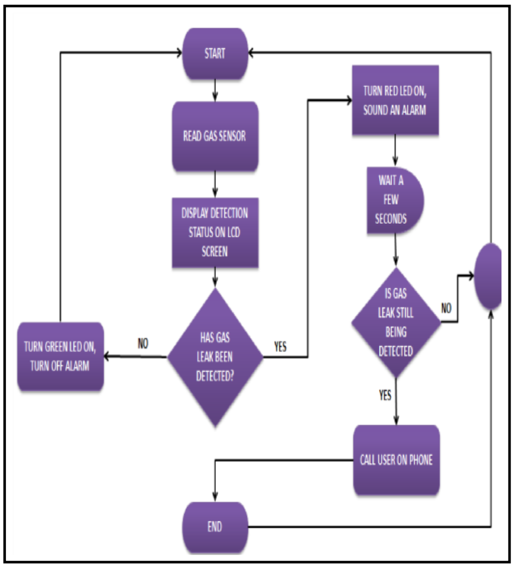


Figure 5: Gas Leak Detection Block Circuit Diagram



FiguGas Leak

Experimental procedure

As seen in Figure 7, a planned experiment was designed and executed to validate the established system. The 8-and 10-kilogram gas cylinders were outfitted with the leakage detecting technology to do this. Weighing the gas and cylinder together on a digital scale gave us the starting weight of the gas in the cylinder. The amount of gas released for each observation was controlled by attaching a regulator to the gas cylinder. Quick detection was achieved by positioning the designed gas sensor immediately above the regulator's release valve. The sensor system's electrical components were hardwired into the power supply so that signals could be sent and read out on the LCD panel. In cases when the gas detection system did not detect any gas leakage or when the regulator did not release gas or when the quantity of gas detected was insufficient, the user would not receive a call warning, as illustrated in figure 8. Additionally, as illustrated in figure 9, the system will automatically initiate a call notifying the user and the LCD will display a gas leakage detected when the regulator releases a variable quantity of gas enough for the sensor to pick up the signal and transmit it through the system. We repeated this process three times for every part per million of gas that was emitted, and then we took the average.

Figure 7: Automatic gas detection set up

Figure 8: Automatic gas detection system showing no leakage detected

Figure 9: Automatic gas detection system showing gas leakage detected

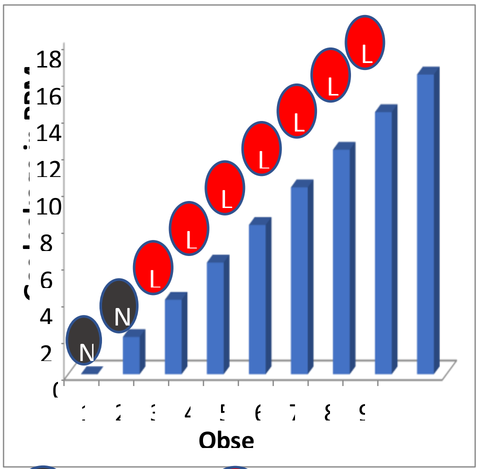
Results and discussion

As shown in Table 3.1, the designed automated gas detection system was tested at various gas leakage levels. The devised apparatus failed to detect or notify at 0 ppm (or 2 grammes) of cooking gas leakage or 2002.28 ppm (or 2 grammes). The reason behind this is because the amount of gas that can be detected by the sensor is insufficient inside that volume of air. At the same time, the system started sending out prompts and signals to let the user know when the gas leakage level reached 4 grams, which is 4004.57 parts per million. This indicates that a detection threshold of around 4004.57 ppm is necessary. The gas detection system responded with a further decrease to a 3000 ppm leakage, but it did not detect anything at 2000 ppm. According to Evalina and Azis (2020), the minimum value needed for detection is 2500 ppm, whereas the system's real minimum value is 3000 ppm. The experimental design demonstrated that at 6 grams, 8 grams, and 16 grams, which are comparable to 6006.85, 8009.14, and 16018.28 ppm, respectively, a similar detection and reaction were noted. Additionally, it was noted that the device will keep detecting gas leaks even after the 16018.28 ppm leakage limit has been exceeded. As the gas leakage value in parts per million (ppm) increases, figure 10 depicts a steady gas detection signal, which is the graphical depiction of gas leakage detection.

Table 3.1: Gas leakage level and signal response

Grams	PPM	Signal
0	0	No gas leakage detected
2	2002.284606	No gas leakage detected
4	4004.569212	Gas leakage detected
6	6006.853818	Gas leakage detected
8	8009.138424	Gas leakage detected
10	10011.42303	Gas leakage detected
12	12013.707636	Gas leakage detected
14	14015.992242	Gas leakage detected
16	16018.276848	Gas leakage detected

1 ppm = 1 mg per liter = mg/Liter



N Represents L eakage detected

Figure 10 System

Conclusion

By connecting all the individual components, the automated gas leakage detecting system was designed and developed. Each component's roles were emphasized. In the event of a gas leak, the gas detector will promptly detect the signal, transform it, and send it on its way as electrical impulses, which will trigger an automated notification to the user. In the controlled environment, we were able to determine the lowest gas concentration at which the system would initiate a phone call to the user. The system was designed to detect gas leaks at a minimum level of 3000 parts per million (ppm) and warn the user in the event of a gas leak at home.

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