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Analysis Empowering Home Safety in Underserved Regions: Introducing a Smart Gas Leakage Management System for Internet-Deprived Remote Area

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ABSTRACT
This work provides a self-monitored safety device that gives a complete solution to household LPG gas leakage utilizing smart sensing and control action that prevents any accident in remote regions lacking consistent internet connectivity. In the present market view, this is obvious to find a device capable of gas leak detection with a warning alarm. But through this work an integrated device is developed with its accident prevention system by introducing far more precise technology. Unlike the marketed gas leak detection device, it not only detects the gas leakage proficiently but also can stop further leakage by operating a quick responding valve regulator which is driven by a low voltage brushless DC (BLDC) electric motor as well as by starting the exhaust fan also.

KEYWORDS

LPG Leakage;
SGAS711/ MQ-6 Gas Sensor;
Arduino UNO R3;
BLDC Motor-Operated Fan;
Control Valve;
GSM Module (SIM300).

1. INTRODUCTION

Liquefied Petroleum Gas (LPG) is produced during natural gas processing and crude oil refining process. Its composition is primarily propane(C_3H_8), butane(C_4H_{10}), isobutane(iC_4H_{10}), butylene(C_4H_8), propylene(C_3H_6) and mixtures of these gases, which are the components of LPG and all with different LPG properties. Domestic LPG cylinders are painted in red color for easy identification and are available in 5Kgs and 14.2 Kgs the price of the cylinder is determined by different oil marketing companies running by different states, crude oil prices in the International Market and the currency exchange rate [1]. According to the latest National Statistical Office (NSO) survey report conducted all over India in 2018, LPG is used for domestic cooking purposes by about 61% of total households. The percentage of users of LPG in rural areas is 48.3%, in urban areas 86.6% and the rest of the population uses firewood, crop residue, and chips as primary fuels for their domestic cooking. That is reported by the NSO's 76th round survey based on "Drinking Water, Sanitation, Hygiene and Housing Condition". For Indian households, primary fuel for cooking i.e., LPG connection has increased 76% from 140 million to 247 million for the corresponding financial year of 2014. By introducing Pradhan Mantri Ujjwala Yojana (PMUY), a fundamental change has been observed in the case of primary fuel for household cooking i.e., LPG gas instead of wood-oven and kerosine stove from 2016 to the current financial year [2]. It has been observed that with the increase of LPG users, the number of LPG leakage accidents is also hiking day by day. A report on household fire accidents is presented in Figure 1.by taking the data from the National Crime Records Bureau (NCRB) survey [3]. Like various accidents we usually face in our daily restless life, LPG leakage is one of the most life-risky accidents and it is mostly used in household applications. Bhopal gas tragedy in December 1984 is one of the biggest industrial disasters [4]. The uncertainty of accidents is increasing day by day due to substandard cylinders, old valves, cracked rubber regulator pipes, damaged ovens, no regular checking of expired gas cylinders, worn-out regulators, and a lack of awareness of handling gas cylinders [4], [5]. So, people are becoming more aware of avoiding such life-threatening hazards with the helping hand of technology where modern technology introduced us to life-saving equipment to ensure better safety and security i.e., LPG Leakage Detectors. There are some LPG leakage detectors available on online platforms that are either capable of monitoring leakage or controlling leakage, not both. Most of the detectors only detect the gas and provide visual and audible alarms when the gas concentration crosses the pre-set alarm level without any control over it. Few of them have the facility to stop the supply from the cylinder but none of them is designed to cut off the flow when the oven is not flamed by keeping the control knob open mistakenly. So, this type of system is only capable of controlling the leakage from the cylinder not from other parts (regulator, pipe, oven etc.). There has been so much research works on inflammable gas i.e., LPG leakage detection using different types of MQ-sensors like MQ-2, MQ-3, MQ-7, MQ-8 [6] and methods and researchers are consistently working on it to make it more reliable and efficient with proper precautions [4-28]. In this said work, the effectiveness of existing sensor-based LPG gas detectors has been served outputs with 85 % to 100 % efficiency in preventing accidents by detecting gas leakages [7], [8]. In most cases, the system directly provides alarm through SMS to users by using GSM modules and instant signaling through LED, buzzer, and LCD or based on a Wi-Fi Module or any other IoT platform [4-24]. Besides those leakage detections, some works of literature use load cells to monitor the weight of gas cylinders for automatic booking when the weight goes below a critical value by sending a notification to the booking agency as well as the house owner [17-20]. Acknowledging daily incidents, detection and warning is not enough to get rid of an accident, there are some emergency quick steps to control the situation, especially

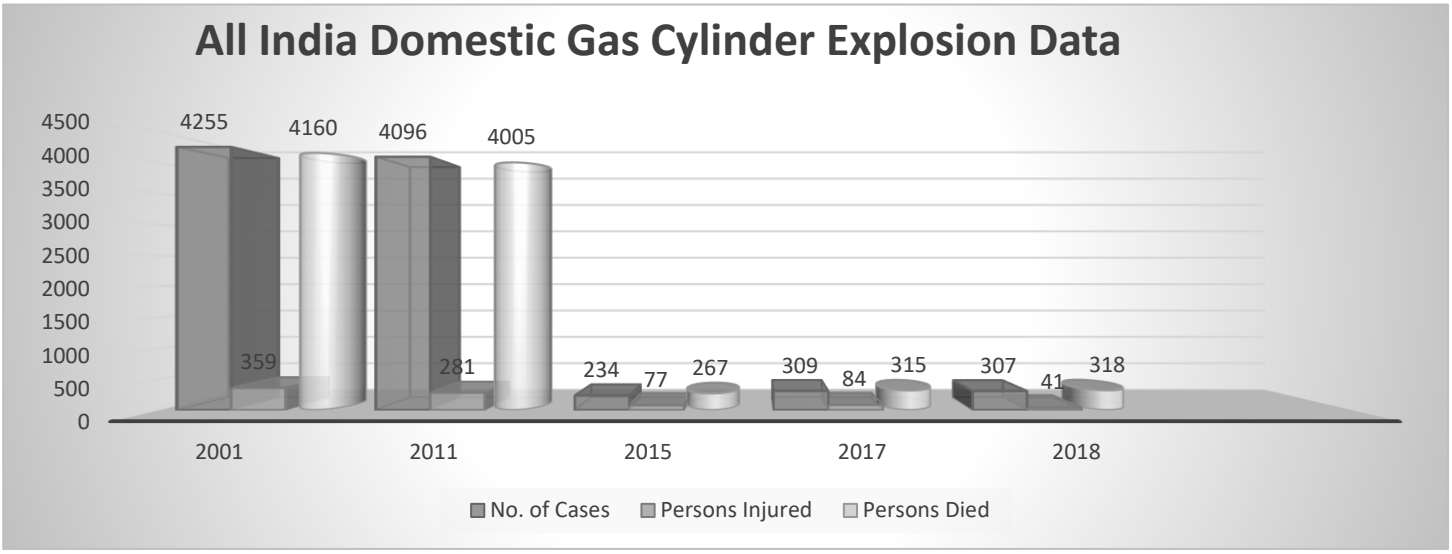

Fig. 1 Graphical Representation on Domestic Gas Cylinder Accidental Explosion according to the Data Available from NCRB Survey [3]

in the absence of a house owner. Thus, this work can give complete hope to diminish any kind of LPG leakage accident in our daily life without human intervention not only detecting and alarming the leakage using LED, Buzzer, 16x2 LCD display, and GSM module but also controlling the leakage of the system by using BLDC motor operated fan and control valve connected to the regulator for achieving the total safety of household.

2. SCHEME OF THE PROPOSED SYSTEM

This is an instrumentation system as shown in Figure 2 which consists of one highly precise gas sensor i.e., SGAS711 along with a microcontroller refurnished with explicit computer programming for delivering the alertness through its peripherals connected in the form of physical analog outputs as a real-time response. Although SGAS711 is a highly precise gas sensor, due to the current pandemic situation, we have to work with MQ-6 instead of SGAS711 for LPG leakage monitoring purposes. The proposed device is working in two phases viz. A. monitoring phase and B. Controlling phase.

2.1 Monitoring Phase

In this phase, the presence of the LPG gas, or isobutane, propane etc. is monitored by the said sensor via LED, buzzer and LCD Module. The LED turns from GREEN to RED as well as the buzzer starts the alarm only when the presence of the surrounding LPG gas crosses the safety limit [4-7] [20].

2.2 Controlling Phase

In the controlling phase, the system takes immediate action through the microcontroller by switching off the valve connected to the regulator which closes the flow of LPG from the cylinder. In addition, the BLDC motor-based exhaust fan is also made ON automatically to reduce the density of the leaking gas near the cylinder instantly [20].

In case the intensity of the leakage gets out of control i.e., for a high amount of leakage or explosion, the system will directly send

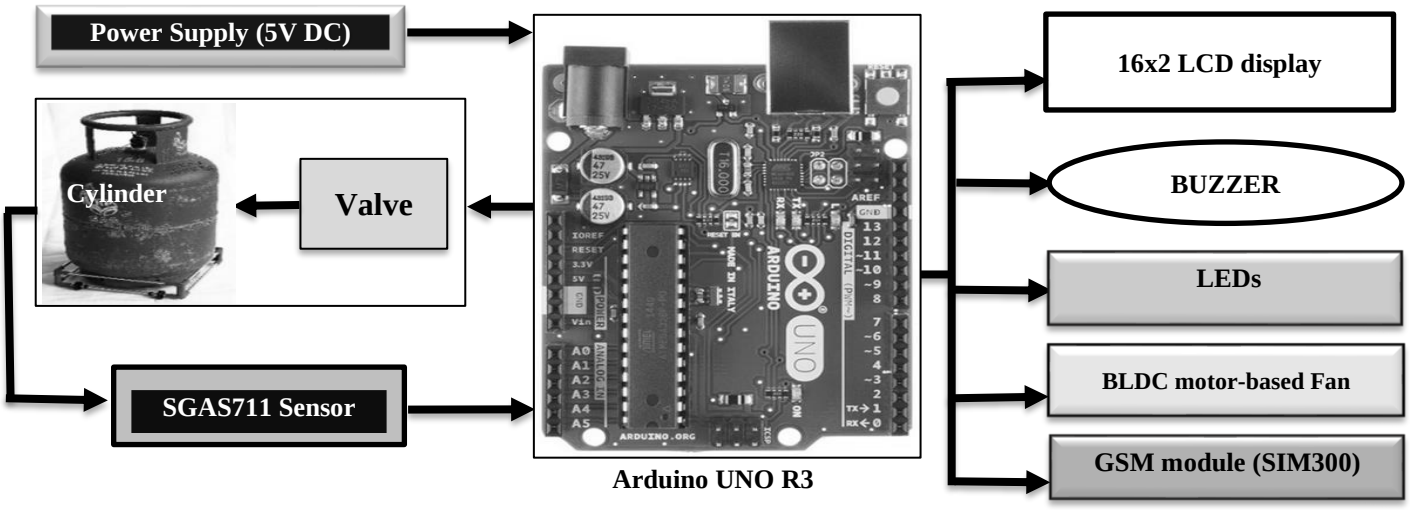

Fig. 2 Block Diagram of the Proposed System

a signal to the fire brigade of the local area as well as the house owner (even when he/she is away from home) by sending a notification for emergency backup through GSM module. Therefore, based on the features, a compact system has been developed that can automatically handle the casualties that occur due to LPG gas leakage (that may cause an accident) by flawless management of the whole situation**.**

3. ALGORITHM USED

The flow diagram of this system as shown in Figure 3 describes the algorithm of our device step by step. At first, the gas is sensed through Arduino and the reading is compared with the highest value (here we take it 10,000ppm) showing the value on the LCD Module. Hence, if the reading is going beyond this value, then it turns on the Buzzer and makes the LED RED as well as starts to show the leakage status on the LCD module. Moreover, it will send notifications through the GSM Module for local emergency backup. In the next step, the reference value is set at 2000ppm and if it exceeds, then again, the same alarms will ON as well as the previous condition and one more precaution is taken care of by switching off the regulatory valve of the cylinder to stop the leakage immediately. If this condition is not satisfying, then the system will check the minimum threshold value (here we take 500ppm) and the LED glows GREEN as the value is under the aforesaid level. Otherwise, it turns on LED RED, the alarm buzzer, displays on the LCD module and starts the BLDC motor-operated fan to make the gas leakage concentration less. Instead of one sensor we can use three sensors to make the system more reliable and accurate. We can easily transform this embedded-based system into an IoT-based system from household devices to

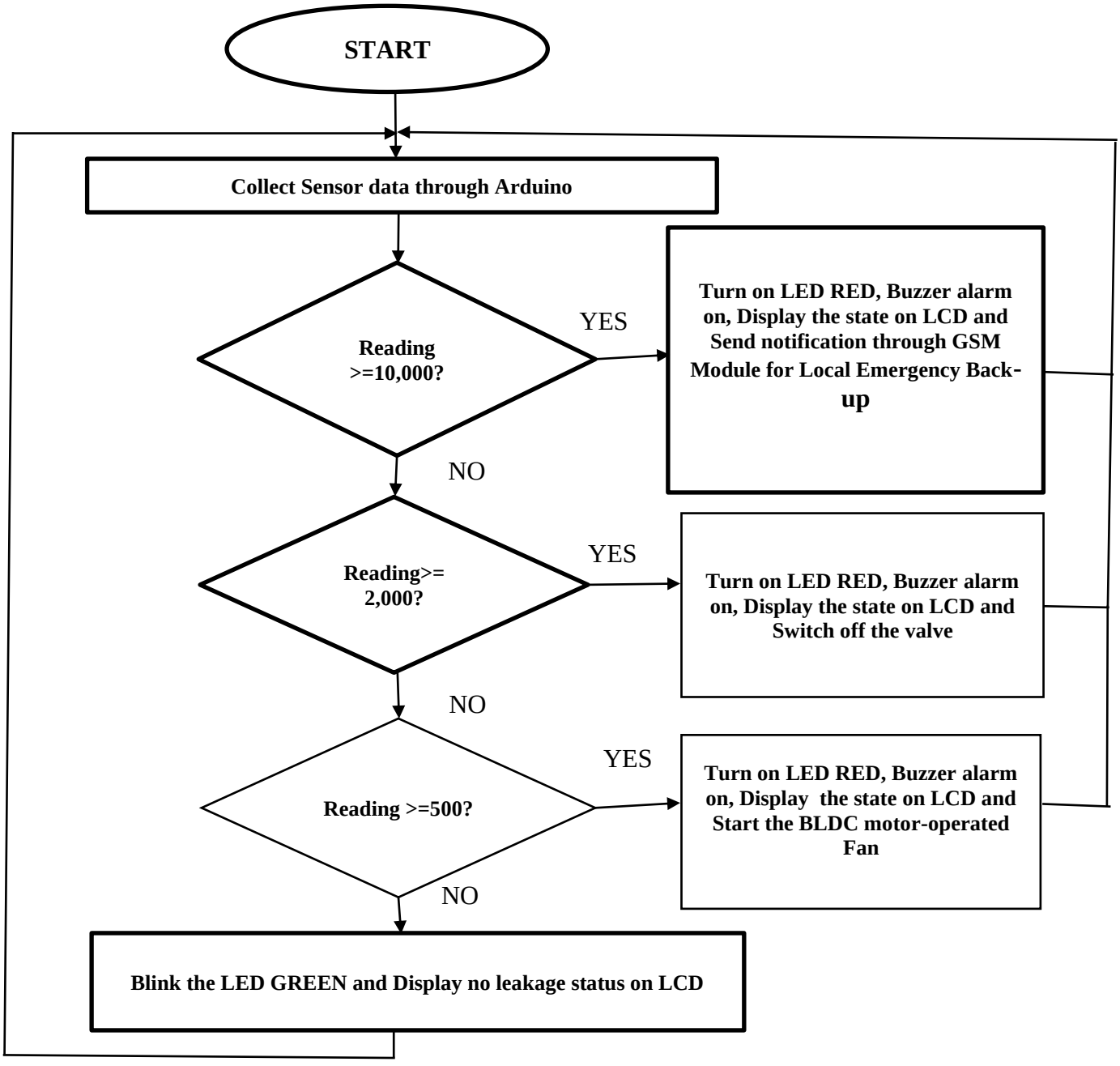

Fig. 3 Flow Chart of Control Action of the Proposed System

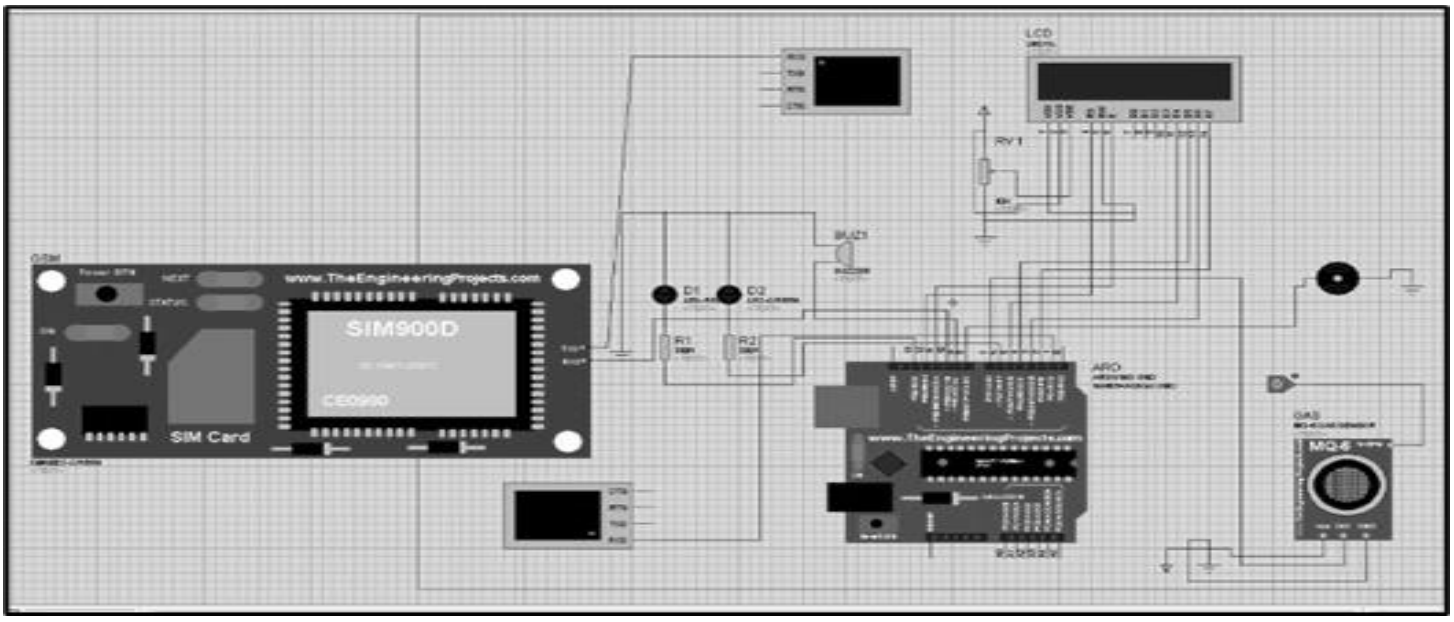

Fig. 4 Basic circuit diagram of the system using Proteus Design Suite Software

industrial-specific devices as well as commercial purposes for safety assurance.

4. EXPERIMENTAL SET-UP

To experiment, we have done both software simulations by using the Proteus Design Suite software tool as shown in Figure 4 as well as hardware simulation in Figure 5. Hardware set-up is designed with different components i.e., MQ-6 gas sensor, Arduino UNO R3 board, LEDs, Buzzer,16x2 LCD display module and SIM300 GSM module to detect the LPG leakage concentration undoubtedly. Due to the pandemic scenario, our resources are limited for experimental purposes. So, Proteus Design Suite Software helps us visualize the nature of signal outputs properly by using the different library components.

5. RESULTS AND DISCUSSION

From the basic experimental setup of the proposed system, we can detect the LPG gas leakage when the safety level is exceeded. Among these three reference values (as described in the algorithm), when the leakage concentration level rises higher than the minimum threshold value (here 500ppm), the system alerts users by turning on LED RED, alarming buzzer, displaying the gas leakage status "Gas is detected" on 16x2 LCD module as shown in Figure 6. Otherwise, the system indicates the GREEN signal by displaying gas leakage status "No Gas detection" on LCD module

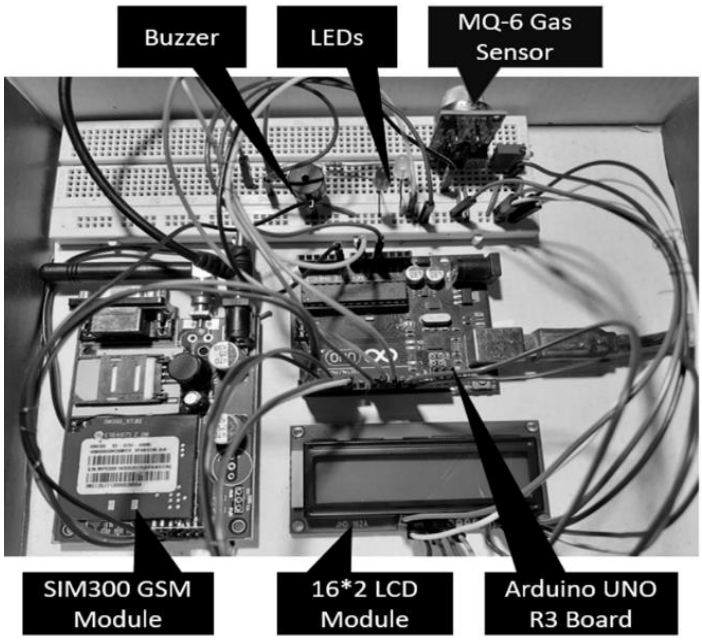

Fig. 5 Experimental set-ups of Proposed System

Fig. 6 Output result of gas leakage detection

as shown in Figure 7. The different operations will be performed

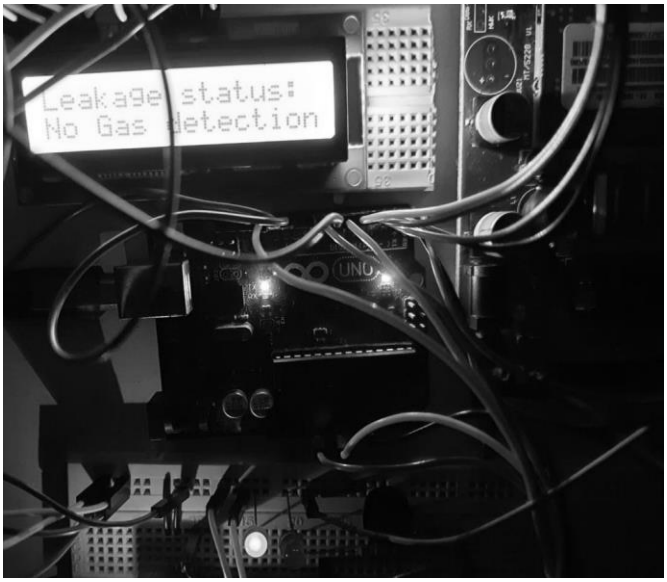

Fig. 7 Output result of no gas leakage detection

in different LPG concentration levels from 200ppm to10,000ppm based on the MQ-6 gas sensor technical data. So, here the maximum limit of the level of LPG gas leakage is 10,000ppm. A specified datasheet is provided by the manufacturer for detailed information about each sensor. MQ-6 graph datasheet describes the gas concentration(ppm) in Figure 8, along the X-axis, the ratio of sensor resistance at various concentrations of gases (Rs), and Sensor resistance at 1000 ppm of LPG in the clean air (R0) along the Y-axis [29]. SGAS711 graph datasheet also describes the sensitivity characteristics as shown in Figure 9 [30].

6. CONCLUSION

In this paper, the development of a smart sensing-based gas detector with an alert and automatic gas leakage control system has been planned and discussed elaborately in an efficient manner. Now the time comes to talk about the versatility of the system, it

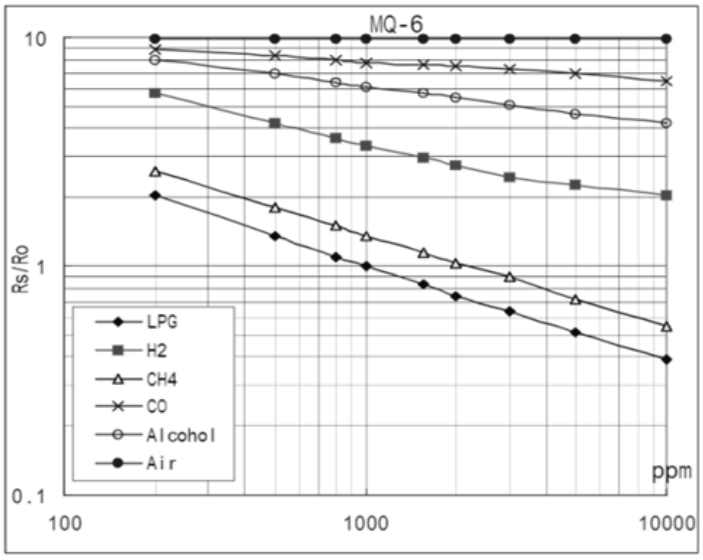

Fig. 8 Sensitivity characteristics of MQ-6 for several gases [29]

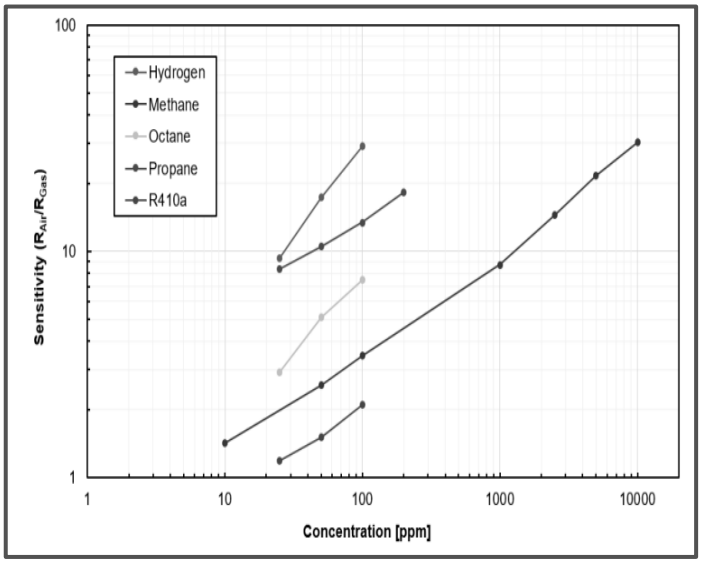

Fig. 9 SGAS711 Sensor Response to a Variety of Flammable Gases [30]

can assure the safety of any human users in a very extended way, especially for the old aged, blind, and physically challenged people who are unable to respond hastily to such sudden accident occurred by the LPG cylinder explosion in both household and industrial purposes. Therefore, the usefulness of this designed system will play a highly important role in safety assurances in indoor applications, industrial complexes, automobiles, and commercial places. The system will smartly detect gas leakage and warn people before hazardous fire accidents as well as control the leakage spontaneously for advance safety and security purposes. The novelty of this system lies in its ability to autonomously detect and manage gas leaks without relying on internet access. Moving forward, the widespread adoption of our innovative system has the potential to significantly enhance safety standards in internet-deprived regions, ultimately contributing to safer and more secure living environments for communities worldwide.

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