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Development of a Liquidified Petroleum Gas Leakage Detector, Level Indicator and Automatic Shutdown System

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Abstract: Fire outbreak prevalence is a disastrous occurrence across the globe, its causes vary but, a major portion of these outbreaks result from gas explosions, mostly caused by gas leakages in residential, commercial premises and gas powered transportation systems. A very effective preventive measure to avoid the menace associated with it is to install a gas leakage detector at vulnerable locations. Difficulty in detecting /managing gas level often posed inconveniences as it sometimes gets exhausted unexpectedly, when the user cannot possibly get access to buy more. This study presents a system capable of indicating gas levels by continuously measuring the weight of the cylinder, detecting gas leakage and alert the user through alarm and status display while automatically shutting down the supply valve as a major safety measure. This was implemented with the Resistive force sensor, MQ6 gas sensor and Arduino mega. This device can be used in residential premises and commercial establishments like hotels, retail shops, gas plants amongst others, while ensuring better safety of all the stakeholders thereby improving profit.
Keywords: Liquefied Petroleum Gas (LPG), leakage, fire explosion, level detector and automatic shutdown.

1. Introduction

Liquefied Petroleum Gas (LPG) consists of mixture of propane and butane which are both highly flammable chemicals. It is an odourless gas due to which Ethanethiol is added as a powerful odorant, so that leakage can be easily detected [11]. But even with the presence of Ethanethiol, fire

outbreaks are still a major occurrence in our world today and when traced to its causes, a major portion of these outbreaks result from gas explosions which are mostly caused by gas leakages in the homes and industries. The purpose of this study is to come up with a device that will not only detect the gas leakages and alert the gas cylinder owners but will also act as a "first aid" mechanism by shutting off the supply point(s) in the cylinder. The study will also involve developing a device which will be capable of indicating gas levels and alerting the user appropriately. The system detects the leakage of the LPG using an MQ-6 LPG sensor. When the system identifies that LPG concentration in the air reaches the specified level then it alerts the consumer by sending SMS to registered mobile phone and alert the people at home by activating the alarm which includes Buzzer simultaneously and also display the same message on a Liquid Crystal Display (LCD) and automatically shut off the gas supply point. The system also measures the weight of cylinder by using a load cell (weight sensor) and alerts the cylinder owner when LPG levels are at 50%, 20% and 0%.

Modern day advancement in science and technology has led to the abandoning of archaic methods of doing things. Before now, gas leakage detection has depended entirely on an individual sensing the smell of gas resulting from the leak. This method of detection has proven to be ineffective as the level of the leakage may have escalated before it is detected; this delay in detection has led to the loss of countless lives and properties. In addition, there are some individuals who do not perceive any odour and as such cannot perceive any leakage.

Also, as is the practice before now, checking of gas levels was almost impossible and people relied on shaking their cylinders and it was even harder for industries running on gas to monitor gas levels due to the size of the cylinders being used. So many inconveniences arise as a result of not being able to detect the level of the gas as it sometimes gets exhausted even when the user cannot possibly get access to buy more.

Background of the Problem

LPG was first produced in 1910 by an American chemist and explosives expert, Dr. Walter O. Snelling and since its production and consumption in homes and industries began, there have been a lot of incidences leading to loss of lives and property [1], [2], some of the most notable catastrophes are:

1. The tragedy of San Juanico: A leakage in one of the pipes connected to the cylinders most probably caused by excessive pressure led to a series of explosions that killed about 500-600 people all at once and severely injured between 5000-7000 others [3].
2. The Feyzin disaster: This event was caused by an LPG spill which started when an operator

was draining water from a pressurized propane tank. The vapour of the propane spread and the heat from an oncoming car led to a massive fire that killed and injured firemen and spectators totalling about 18 in number, it took about 48 hours to bring the situation under control [4], [5].

3. Salamonowicz and Majder-Łopatka [6] on the other hand mentioned various incidences of LPG accidents and various places of occurrences.
4. In the year 2018 alone, scores of lives and properties worth millions of naira were destroyed due to gas explosion in Nigeria. On January 15 2018, there was gas explosion at Magodo in Lagos State; on September 10 of the same year, there was another explosion at Lafia, Nasarrawa State, on the 19th of October of the same year, there was yet another explosion at Rosy Restaurant in Area 11 in Abuja, and each explosion claiming lots of lives and properties [7]–[9]. Just recently, on the 22nd of March this year another explosion occurred at Aguda Surulere [10].

This study is aimed at developing a system to detect when there is a gas leakage, which will trigger a failsafe that will result in the shutting off of the gas supply and will also involve creating a device to check the LPG levels and inform the cylinder owner via text message. The aim of this study is to design and develop a microcontroller based LPG level indicator and leakage prevention system for home and industrial use which would be used to monitor LPG leakage to avoid major fire accidents and also facilitate safety precautions where security has been an important issue.

2. Related Works

Some authors have worked on the area of LPG leakage detector [11]–[14], very few on LPG level indicator [15]–[17] and some others on monitoring and automatic shutdown system [18]–[24].

For instance, Naayagi et al; Hema et al; Wickramasinghe & Abhayasinghe and Kholgade et al [11]–[13], [20] proposed a cost efficient gas leakage detection system for domestics and industrial uses. The system uses MQ-4 and MQ6 gas sensor to form a sensor node. The system comprises a network coordinator containing a GPRS/GSM Module. The range of wireless transmission is extended using the relay nodes, which support communication between the sensor node and network coordinator. Whenever a hazardous gas is detected in the atmosphere, the network coordinator alarms an operator by the GSM/GPRS or Ethernet network and/or controls a gas emission source by wireless actuator. The sensor node monitors the combustible gas concentration in the environment. It is set up for several ranges of gas concentration and sound alarm when necessary.

Shyamaladevi et al; Kasar et al and Jolhe et al [15]–[17] worked on automatic LPG refill booking and

detection system. This consists of a system that not only has gas detection abilities but is also able to inform gas cylinder owners about the levels of their cylinders and also help them book their cylinders at refill points upon exhaustion of the LPG in them. The mode of operation of the device is that, MQ6 gas sensor is placed in the vicinity of the gas cylinder. In the advent of leakage, the resistance of the sensor decreases increasing its conductivity. Corresponding pulse is fed to microcontroller and simultaneously switches on the buzzer and exhaust fan. Microcontroller sends a message "EMERGENCY ALERT: LPG gas leakage found in your home" to required cell numbers via GSM module and the same will be displayed on LCD. In automatic Gas booking system, LCD continuously monitors the weight of the gas in cylinder and displays it on seven segment display. When the weight of the gas is less than or equal to 2 Kg, a logic high pulse is fed to a port pin of microcontroller. As this pin goes high, microcontroller will send a booking message to LPG distributor of format, "AA01-RAJA-05-B". At the same time, the message will be displayed on LCD as "Cylinder Booking". A major advantage of this study is that it helps to solve a problem whereby you can have your cylinder refilled without necessarily going to meet the local distributor but then, the system does not have an alarm which will inform the residents at home in case of a leakage and still does not have an effective means of combating leakage.

Ramya and Palaniappan; Rawat; Kholgade et al; Naresh et al and Apeh et al [18]–[22] presented the Embedded system for treacherous gas detection and alerting while turning off the supply valve as a major safety measure. This study is an improvement on the existing safety model installed in industries and this system can also be used in homes and offices. The main objective of the study is the design of a microcontroller based toxic gas detecting and alerting system. The dangerous gases like LPG and propane were sensed and displayed each and every second in the LCD display. If these gases exceed the normal level, then an alarm is generated immediately and also an alert message (SMS) is sent to the authorized person through GSM. The advantage of this automated detection and alerting system over the manual method is that it offers quick response time and accurate detection of an emergency and in turn leading faster diffusion of the critical situation. Tamil and Aimi [25] also introduced online monitoring via internet of things (IOT) in addition to the LPG detection system presented.

Ogbette et al [26] carried out an investigation on continuous gas explosions in Nigeria shortly after the September 10, 2018 Nasarawa explosion. Their findings revealed that most explosions occurred due to lack of gas leakage detector at homes, factories and gas stations as

well as lack of maintenance of all these systems. He then recommends installation and proper maintenance of gas leakage detector systems at homes, industries and gas stations. Therefore, this study is carried out on three major aspect of the LPG system which includes the leakage detector, level indicator as well as automatic shutdown of the supply as soon as any leakage is detected.

3. Methodology

The complete block diagram and the flow chart for this study is shown in Figure (1) and (2) respectively. The system consists of the Arduino mega, a gas sensor, force sensing resistor, GSM module and the power supply. The main component in this system is the Arduino mega which was used for easy access and connectivity; it provides flexibility to write the code effectively and also makes debugging process much faster. The second main component used is the Force Sensing Resistor, it changes resistance in a predictable manner when force is applied to its surface. The sensing film consists of both electrically conducting and non-conducting particles suspended in matrix. When force is applied to the surface of the sensing film, it causes particles to touch the conducting electrodes thereby changing the resistance of the film but because of the small size of the "granules" in the polymer, they achieve a much more uniform resistance change with pressure. Another major component used is the gas sensor which converts one form of signal to another form. The gas sensor used here is MQ6 which detect when there is a gas leakage and the amount of the gas concentration by giving out a voltage output depending on the gas leakage concentration

The GSM module operates at 800MHz or 1800MHz frequency band, it alerts the user by sending a Short Message Service (SMS) about gas leakage and also the level of the gas at intervals of 25%. When the gas sensor detects leakage in the environment, it triggers the buzzer to go ON. It displays on the LCD that a leakage has been detected and simultaneously turns off the gas supply valve as a major safety measure while sounding the alarm and sending an SMS to alert the user of the leakage. This system is able to automatically turn off the valve through the use of a servo motor when the user put a call through to the system in the case he/she remembers that the cylinder was not switched off while leaving the house.

A 12V battery is being used to power the system but the needed voltage is 5V so a voltage regulator LM7805 is used to regulate the voltage to produce an output of 5V used as power supply for microcontrollers such as Arduino mega.

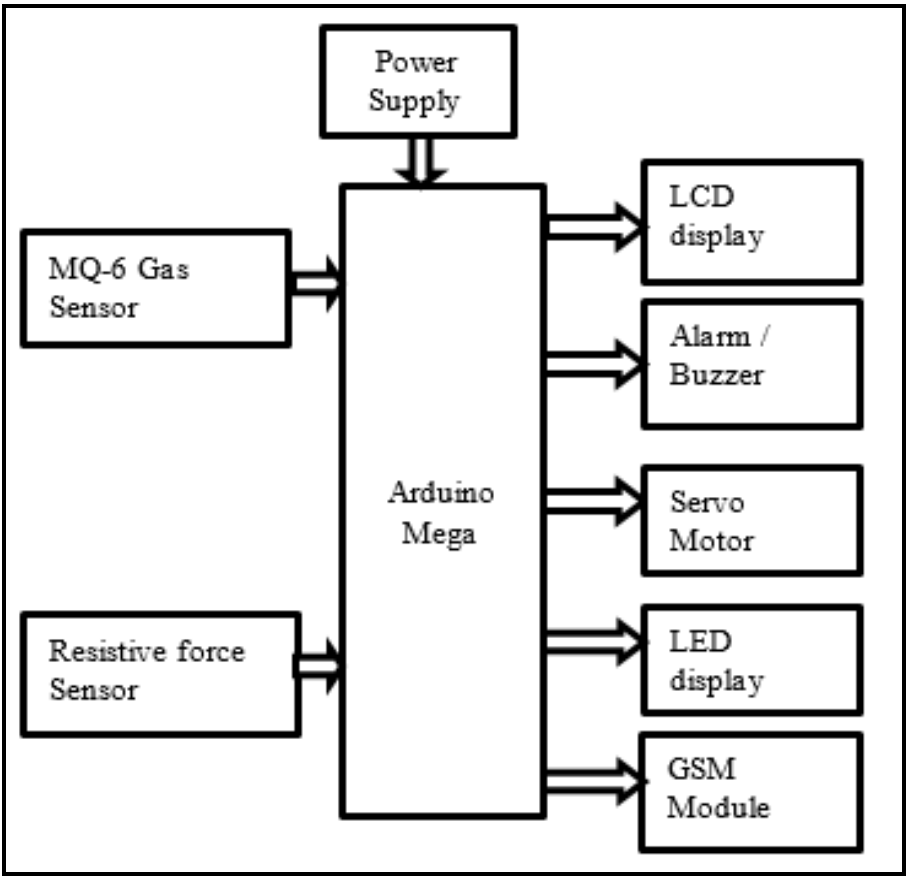

Figure 1: Block diagram of the system

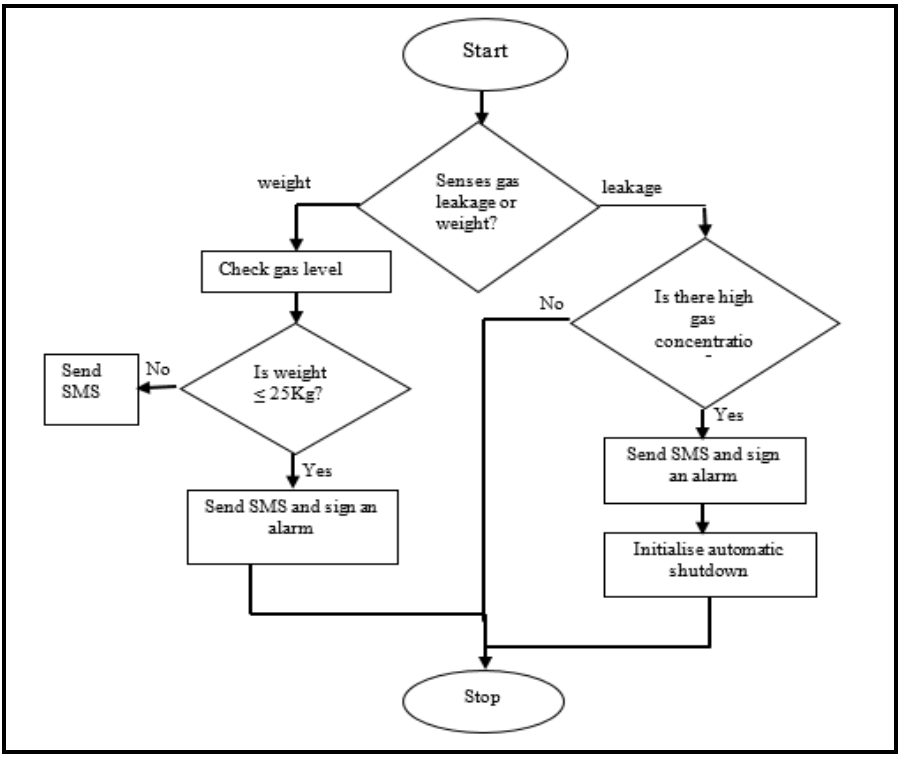

Figure 2: Flowchart of the system

1. Results and Discussion

When the system is powered on, the Power LED (Green LED) comes on while the red LED (which indicate the gas leakage) and the alarm are off. As soon as the MQ6 sensor detects gas leakage through the use of butane gas lighter, it passes signal to the Arduino which sends an output to the red LED to come ON while the alarm comes up and the servo motor rotate anticlockwise to lock the valve of the cylinder.

Figure 3: LCD display at power up

Figure 4: LCD display when a leakage is detected

Table 1: LPG cylinder leakage detection time testing

Attempts	**Time taken for the sensor to sense leakage (seconds)**	**Time taken for GSM Module to send SMS to Cylinder Owner (seconds)**	**Time taken for GSM Module to receive SMS from Cylinder Owner (seconds)**
1	7.21	13.59	20.84
2	8.50	15.23	22.45
3	4.10	12.94	19.34
4	6.70	14.54	21.74
5	9.2	11.34	18.98

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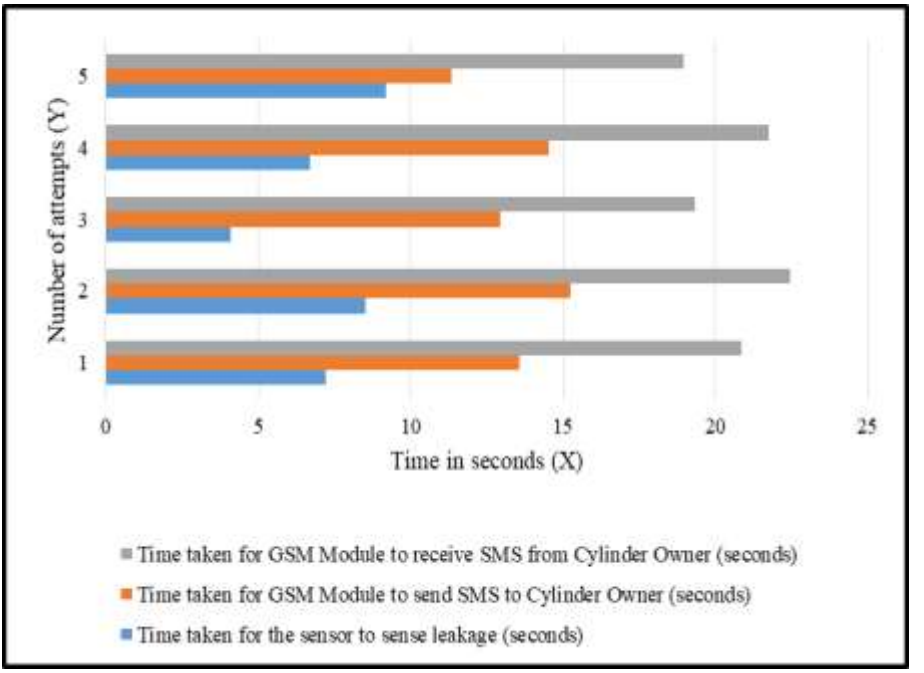

Figure 5: Graph of Time taken to detect gas leakage, send and receive SMS

Table 2: Voltage and Resistance values of the gas sensor at each attempt of gas leakage

Attempts	Voltage of Gas Sensor (V)	Resistance of Gas Sensor (Ω)
1	0.47	2.04
2	0.59	3.47
3	0.64	4.92
4	0.69	6.27
5	0.72	8.00

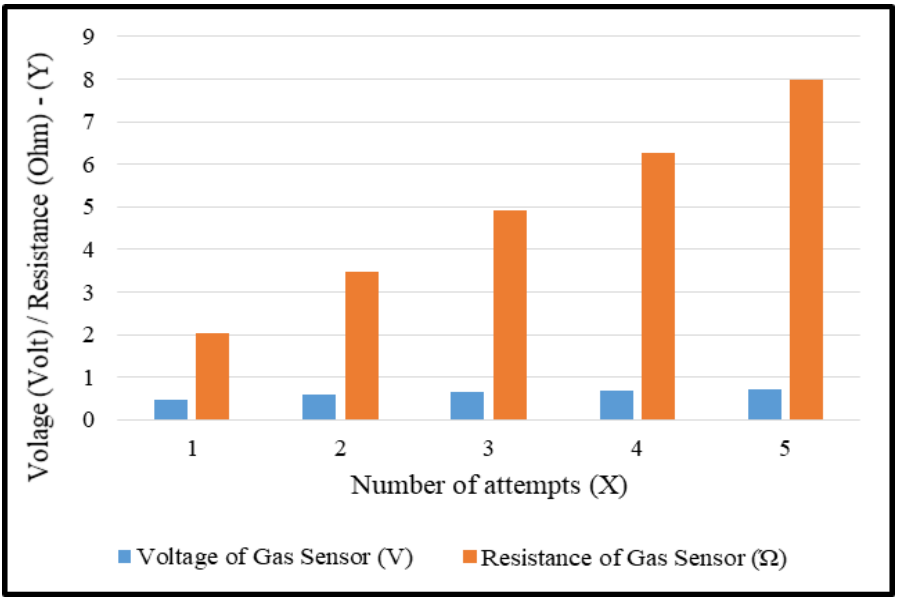

Figure 6: Graph of Voltage and Resistance values of the gas sensor at each attempt of gas leakage

Table 3: Voltage and Resistance value of the servo motor at each attempt of gas leakage

Attempts	**Voltage of Servo (V)**	**Resistance of Servo (Ω)**
1	4.7	0.6
2	4.5	0.4
3	4.6	0.5
4	4.5	0.7
5	4.4	0.6

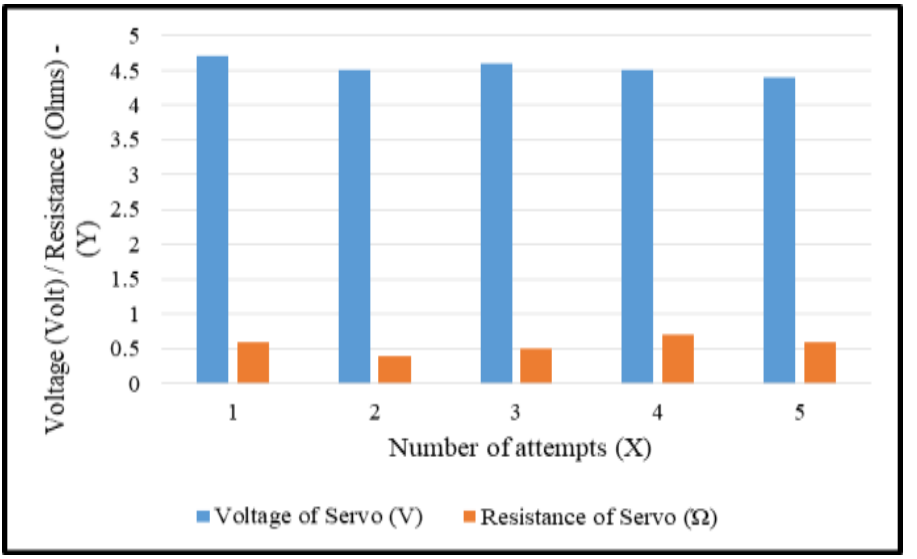

Figure 7: Graph of Voltage and Resistance values of servo motor at each attempt of gas leakage

Table 4: Current of Servo and Current of Gas Sensor values at each attempt of gas leakage

Attempts	**Current of Servo (mA)**	**Current of Gas Sensor (mA)**
1	67	70
2	68	68
3	70	57
4	71	65
5	69	71

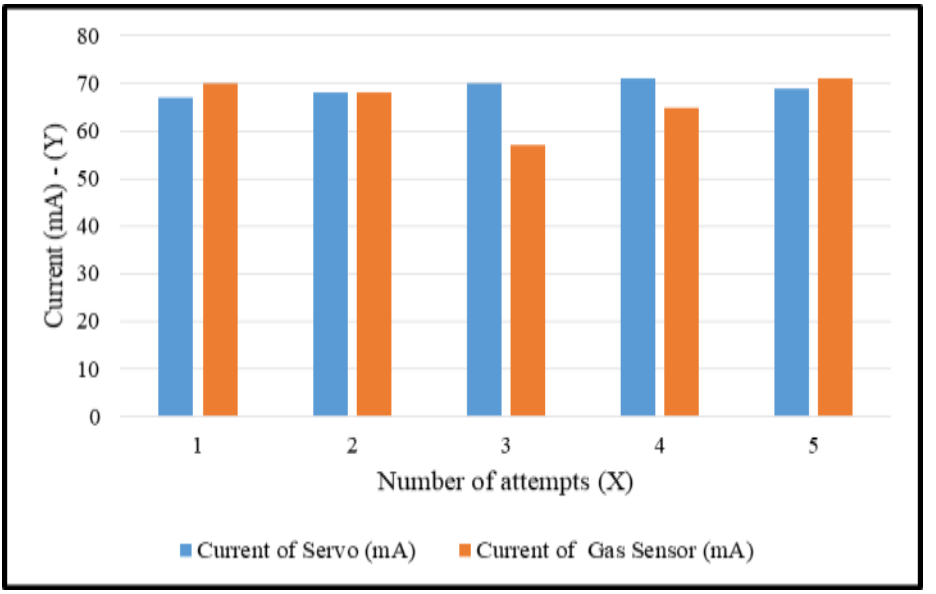

Figure 8: Graph of Current of Servo and Current of Gas Sensor values at each attempt of gas leakage

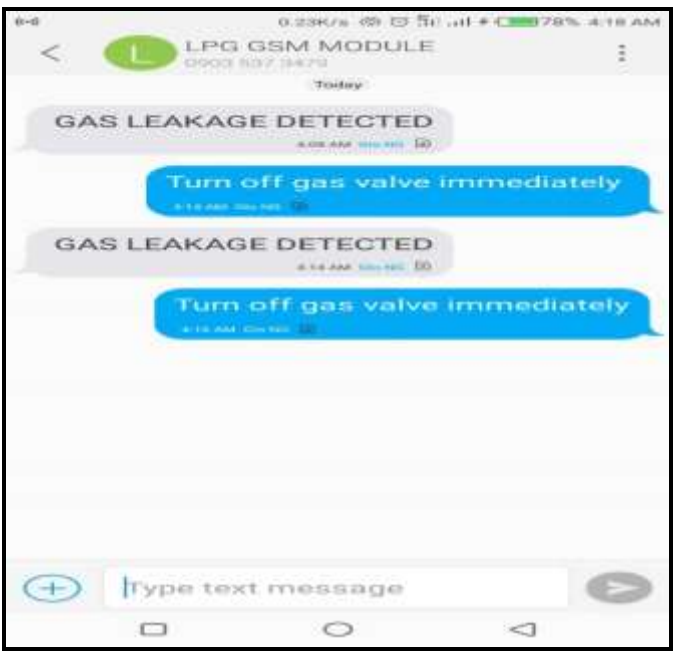

Figure 9: SMS informing users about a gas leakage and messages delivered to the GSM Module informing it shutoff the valve.

Figure 10: Default gas level

Figure 11: Gas level at 23.0 kg

Figure 12: SMS alert on gas level sent to the user

In this system, the force sensing resistor and the MQ 6 gas sensor are the input devices while the GSM modem, the buzzer and the Liquid Crystal Display are the output devices. Figure (3) shows the LCD display at power up, this shows a green light indicating that no leakage is detected. As soon as a gas leakage is introduced to the system via butane gas lighter, the LCD displayed that gas leakage was detected showing a red light as shown in Figure (4). Table (1) shows the time it takes the LPG cylinder owner to get notified by an SMS from the GSM Module and also, the time it takes for the GSM Module to receive an SMS remotely from the owner, this is depicted graphically in Figure (5). The number of attempt of testing

of the gas leakage is placed on the Y-axis while the time taken for the sensor to sense the gas leakage and for the module to send an SMS message is placed on the X-axis. In addition, the voltage and resistance values of the gas sensor at each attempt are indicated in Table (2) and shown in Figure (6). Subsequently, the voltage and resistance value of the servo motor at each attempt are indicated in Table (3) and shown in Figure (7). The X-axis indicates the number of attempt of testing of the gas leakage while the voltage (Volt) as well as the resistance (Ohms) measurement is placed on the Y-axis in Figure (6) and (7). In addition, the current of the servo motor as well as the gas sensor were also monitored at each attempt and the result is reported in Table (4) and shown in Figure (8). The X-axis indicates the number of attempt of testing of the gas leakage while the current (milli-Amperes) is placed on the Y-axis. Figure (9) shows the SMS message sent to the user to inform him/her of a gas leakage and messages delivered to the GSM Module informing it to shutoff the valve. The empty cylinder has been calibrated on the Arduino IDE to reflect 0.00 kg on the LCD as the default gas level as indicated in Figure (10), when it is being placed on the sensor because the weight of the cylinder might be mistaken for gas itself. It was also calibrated such that maximum capacity achieved is 50 kg. However, the corresponding value of the weight of the cylinder is displayed when it is placed on it as shown in Figure (11) which indicated a 23Kg weight of the cylinder. Figure (12) shows the SMS message sent to the user mobile to indicate the gas level.

5. Conclusion

This study achieved its main aim by designing and implementing a cooking gas detector capable of indicating gas level, detecting gas leakage and automatically shutting down the cylinder valve as a major safety measure, giving an audiovisual warning when there is a gas leakage. The system uses an Arduino mega microcontroller and a MQ-6 gas sensor. The detector shows a green LED to show that there is no gas leakage. When there is a gas leakage the detector flashes a red LED and sound an alarm. The detector used a LCD to show that the corresponding display. The system is a low cost and time efficient.

5.1 Recommendation

The inclusion of fire detector is recommended for future work so as to improve the performance of this gas detector system. Such that the system can monitor if there is fire outbreak and inform the owner / user in order to notify the necessary body / agency for the appropriate management action.

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