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Innovative Smart Gas Accident Detection and Prevention System for Nigeria

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ABSTRACT

Gas accidents have killed thousands of people and rendered several million homeless in Nigeria within the last decade. Majority of Nigerian citizens and residents use LPG gas stored in highly compressed cylinders for cooking at homes and for industrial usage. This is because the alternatives which are kerosene stoves and electric cookers are not effective because AGO (kerosene) is highly unavailable and electricity supply in the country that supposed to be used to power electric cookers is unreliable and epileptic. The high rate of home, industrial and road accidents associated with gas leakages calls for an urgent attention. In this work, we proposed a prototype of a Smart Gas Accident Detection and Prevention System (SGADPS) that could be embedded into the LPG cylinder regulator as a safety measure. This was achieved in five major modules: alarming, alerting, evacuation, displaying and shutting down when necessary. A high speed AVR Micro-controller (ATmega 168), MQ-6 LPG gas sensor and other components were used. C language and AT commands were used for the programming and via an Arduino IDE (Integrated Development Environment), the chip was loaded. The proposed system satisfied all the objectives for Gas accident detection and prevention tool.

KEYWORDS: *SGADPS, Gas accident, Nigeria, LPG, AVR Micro-controller*

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INTRODUCTION

Gas accident is one of the devastating accidents that can occur because its occurrence can always escalate to an unimaginable range, causing high mortality and damage or complete loss of properties. This is because liquefied Petroleum Gas (LPG) is highly combustible, flammable and inflammable. In a quest to preventing accident in our homes, and other places, an innovative micro-controller based approach was proposed in this paper to detect LPG leakages and take appropriate actions. Liquefied Petroleum Gas (LPG) also called propane or butane is a flammable mixture of hydrocarbon gases used as fuel in heating appliances, cooking equipment at homes and in automobiles or vehicles. It is equally used in *refrigeration*. LPG is a popular cooking fuel. It is an odorless gas, but an odorant known as *Ethyl Mercaptan (C_2H_6S)*; a colorless liquid is added to it to enable leakage detection [1]. Greater percentage of gas accidents are traced to leakages due to mainly human negligence and carelessness. Despite the challenges of using LPG, many people use it for cooking both in developed and developing countries for a good number of reasons, energy efficiency, responsive heat, even heat distribution, environmental friendliness, and cost effectiveness. Even here in Nigeria, it is very popular and highly used at homes, industrial plants, and restaurants. It is popular in Nigeria because it is not electricity dependent, it keeps the cooking materials neat, unlike the kerosene stoves, it is easy to store and transport; for instance, a 4.5kg is almost equivalent to half a ton of wood. But despite these advantages, a single gas accident through leakage can wipe off the benefits from the history. This is the major motivation of this research paper, to find a way to detect leakage on time and forestall unmitigated accident and loss of precious human lives and properties.

Gas accident can be described as an unplanned gas event resulting in injury, damage, loss of life or properties. It is an unexpected event, most times resulting in an explosion, involving gas leakage leading to damage and loss of lives and properties.

Several gas accidents have been recorded recently in Nigeria mostly in the populated and commercial city of Lagos. Between 2016 and 2021, several gas accidents have occurred in places like Abule-Egba, Ijegun, Ile-Epo, Oke-Odo, Baruwa, and Abule Ado, all in Lagos. In Baruwa, a densely populated suburb of Lagos, an LPG tanker was in the process of discharging its content at a time the station's generating set was running. The spark and the explosion which followed threw the discharging tanker across the road. Aside the loss of no fewer than five lives, 25 buildings, 16 shops, a private school building, a hotel and several vehicles/tricycles were razed [2].

On Tuesday November 16, 2021, a gas explosion occurred at Ladipo Spare Part Market, at No. 33/35 Ojekunle Street Ladipo Spare Part Market, Lagos claiming five lives [3]. Another gas accident occurred on June 17, 2021, in Lagos at Mobalaji Bank Anthony Way, Ikeja claiming eight lives [4]Similarly in Lagos,Nigeria, another explosion caused by leaking gas cylinder on Monday killed four persons and left several others with severe burns in Badagry area of Lagos [5]. Figure 1 depicts the type of LPG gas dispensing plant normally found in Nigeria.

Figure 1 A typical LPG dispensing plant in Nigeria

In August 2017, 4 persons were killed, and many injured at Obosi, Idemili North Local Govt., Anambra State following a cooking gas explosion at Trinity gas Limited station. [6]. These tragic events undoubtedly call for an immediate action such as a prevention system.

There are several other cases of gas accidents not mentioned in this paper in Nigeria and other parts of the world but generally the rate of this tragic incident is alarming. This calls for attention as it is unhealthy to continue to lose lives and properties at this rate. This ugly situation has no single support for sustainability development since it is only marked by a step forward and five of such steps backward. This motivated us to do this work. In this work, we propose a proactive measure to prevent such accidents in our environment. Specifically, we propose a smart gas accident prevention system that could be integrated into the regulator system of a gas cylinder that automatically turns on whenever the regulator is turned on. The system is smart enough to take appropriate actions as soon as leakage is detected without any human intervention. This preventive system is ideal for the Nigerian LPG users due to some reasons discussed later in this work.

Using LPG for cooking in our homes is usually faced with some challenges viz: risk of explosion or leakage, which in most cases escalates to fire outbreaks. Paying for the fuel price, which does not apply to conventional fuels (firewood or charcoal) in rural areas and the finite nature of the resource, is equally a challenge. Figure 2 shows the typical LPG compressed gas cylinders used at homes and factories in Nigeria.

Figure 2 Compressed 12.5 KG LGP Gas Cylinders normally used in Nigeria for cooking

A Micro-controller is an electronic chip that came for the rescue of small applications development and control. Micro-controllers, unlike the conventional microprocessors, have in-built memory and provisions for connection of peripheral devices. They are the self-contained versions of the computer system with affordable costs but with limited memory capacity since there is no room for external storage like the microprocessors. They are characterized by their bits, memory architecture and instruction set. A typical microprocessor includes a processor, memory, and Input/Output peripherals on a single chip. There are basically three families of micro-controllers viz: 8051, PIC (programmable intelligent computer) and AVR (Alf-Egil Bogen and Vegard Wollan's RISC) Processors. The AVR family was used for this work. Using micro-controllers for designing embedded systems is advantageous in many ways including enhanced operational speed, reduced error sources, reduced energy consumption, reduced cost and then room for modifications and improvements.

Literature Review

Due to the devastating effects that gas leakage accidents leave behind with humanity, a great many researchers have worked and still working in that area to prevent such ugly incidents from occurring. Researchers would not relent on this effort until 100% safety is assured. An automatic gas accident prevention system was implemented using Atmega328p and MQ-5 gas sensor. The system could detect gas leakage, alert the user through alarm and SMS, evacuate the area, display message, and equally shut down the system. But was not integrated into the regulator system of the gas cylinder, which is the ideal model for Nigerian users. [7].

LPC2148 micro-controller was programmed to detect gas leakage and alert the user via SMS, activate an audio-visual alarm and display message on LCD. It also evacuates the affected area and shuts down the valve. [8]. A gas leakage detection system was also implemented using ATmega 16 Micro-controller with functionalities like alarming, sending SMS and evacuating the affected area [9]. This work also did not include any form of integration with the regulator, which means it did not bother much about the Nigerian users. Another system with gas and fire detector was simulated using PIC16F877A micro-controller, MQ-2 gas sensor and LM35 temperature sensor. On detection, it sprinkles Water on the affected area to reduce the effect of fire, alarms and alerts the user via SMS [10]. It also did not consider the Nigerian problem. A similar system was built using PIC16F628A micro-controller. The system could detect gas leakage and activate an exhaust fan which evacuates the area, triggers an alarm, enables the solenoid valve, and as well send SMS [11].

Gas leakage and fire outbreak detection system was designed using AVR micro-controller. The system monitors the environment and feeds real time sensor data over the cloud using ZigBee network.[12]. The system equally had zero consideration for LPG Nigerian users.

From the reviewed literature, a lot of researchers have tried to proffer solutions to the negative effect of gas leakage in their immediate environment. These solutions are workable any way, but they were not suitable and considered for Nigerian environment. In Nigeria, the kitchens, and other places where we cook are not up to standard coupled with other factors that may not warrant the efficient use of the designed prototypes and systems. We, therefore, propose a smart gas accident prevention prototype with functionalities like SMS notification, alarming, shutting down, evacuation and displaying messages. This smart prevention system is to be embedded into the gas cylinder regulator instead of the present wall mount. The system is of high speed and cost effective since the ATmega 168 AVR micro-controller is used, which has a direct interface with the analog signal from the sensor unlike other micro-controllers like ATmel and others that require external devices (eg ADC). Currently an integrated system exists but the only output is a buzzer, which is not enough. Our proposed

embedded prototype is ideal for Nigerian LPG users because they would find it difficult to install and maintain a separate system.

The aim of this paper is to promote self-regulatory safety practices across the LPG value chain, with the view to reducing occurrences of avoidable LPG accidents in Nigeria.

Methodology

The methodology used in this work is summarized in the block diagram shown in Figure 3. The methodology includes both hardware and software designs.

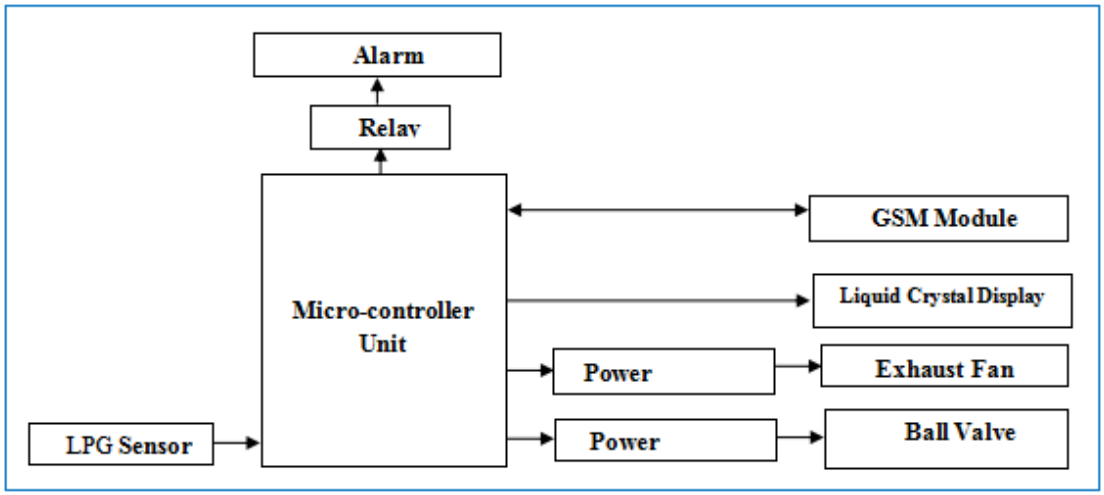

Figure 3 Block Diagram of the System

A. Design of Hardware System

The hardware design consists of the Micro-controller unit, the Sensing unit, the Alarm unit, the Communication unit (GSM Unit), the Display unit (Liquid Crystal Display), Evacuation unit and the Shutdown unit. These units are linked to the micro-controller, which is the brain of the entire system. The micro-controller receives an analog input from the Gas sensor (MQ-6 sensor) and converts it to a digital signal via the ADC. Based on such input, a control is now given to any of those modules/units to take an appropriate action.

B. Arduino ATmega 168 Micro-controller

ATmega 168 is an 8-bit AVR micro controller that comes with 32-pin interface and is mainly based on RISC (Reduced Instruction Set Computer) instruction set based on Harvard architecture and CMOS (Complementary Metallic Oxide Semiconductor) technology. The Program memory is 16K, based on Flash, and incorporates read-write capabilities.

It has RAM (1K) and 512 Bytes EPROM with a retention capacity of around 20 years. It has 10-bit ADC (Analog to Digital Converter) module for sensor interfacing and has up to 8 channels for providing analog to digital conversion to several pins. It is one of the few micro-controllers that has all the three communication protocols (Serial Peripheral Interface (SPI), 12C and Universal Synchronous/Asynchronous Receiver/Transmitter (USART)) for communicating with external devices. A 28-pin ATmega 168 Plastic Dual in Line Package (PDIP) was used in this work. AVR executes most instructions in one cycle, unlike PIC (programmable Intelligent Computer) that requires several clock cycles per instruction; this makes AVR faster than their counterparts. Figure 4 shows the ATmega168 Micro-controller chip

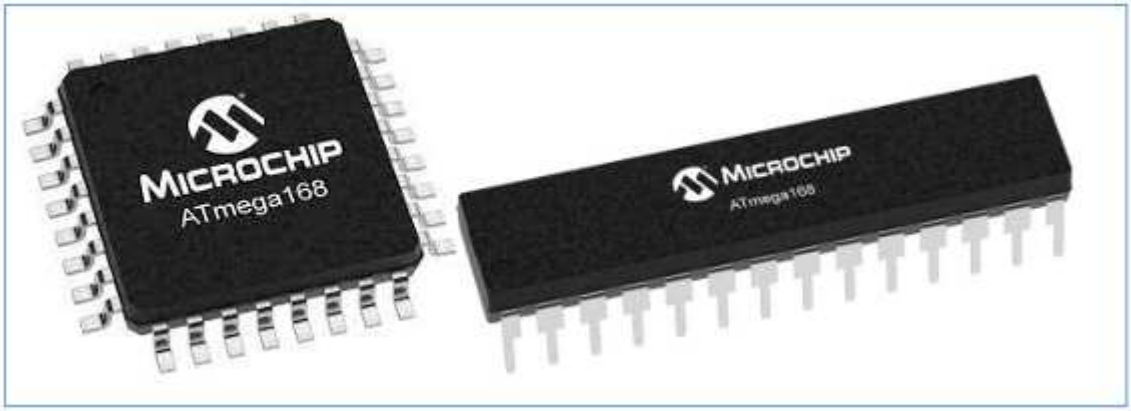

Figure 4 ATmega168 8-bit Arduino compatible micro controller chip

C. The Gas Sensor Module

This module stands as the nose of the entire system. An MQ-6 gas sensor was used to detect any form of LPG leakage around the area.MQ-6 gas sensor can detect gas concentration from 200 to 10000ppm. It has high sensitivity and fast response time (<10s). Its output is an analog resistance which interfaces to the micro-controller's ADC and is converted to a digital signal and then triggers an action depending on the gas concentration detected. When the concentration of the LPG in the air around the area reaches the defined threshold, the output voltage of the sensor increases and then the system can take action. Analog output of the sensor was used. Figure 5 depicts a typical commercially available MQ-6 LPG Gas sensor.

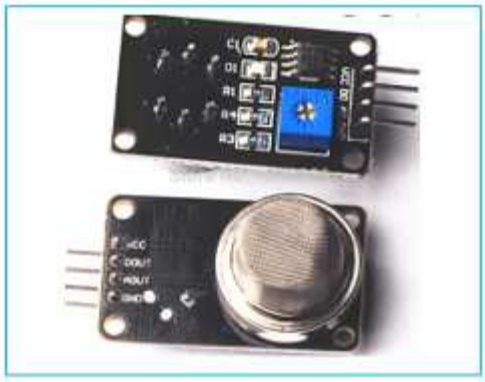

Figure 5 MQ-6 LPG Gas Sensor

D. The GSM Module

This is the communication module of the system. It is used to establish communication between the micro-controller and the mobile user. The communication between the GSM module and the micro-controller is bidirectional or two ways. SIM800 GSM module was interfaced to the micro-controller through the USB port and issued AT commands in the Arduino IDE, making it send SMS to the stored cell number when triggered. Figure 6 shows the commercially available SIM800 GSM module.

Figure 6 SIM800 GSM Module

E. The Alarm Module

This module when triggered, generates an alarm to alert the people around the affected area. The signal from the micro-controller (5V) is amplified by a relay to generate an alarm (220V) that is loud enough to alert the people within the area.

F. LCD (Liquid Crystal Display) Module

This module in Figure 7 displays the status of the system using LCD Display as well as the SMS information.

Figure 7 12X6 LCD Display

G. The Evacuation Module

This module uses a 12V DC exhaust fan to evacuate the LPG from the affected area once it is detected. A power transistor is used to amplify the micro-controller's voltage to 12V and then switches the 12V to the target load which is the fan.

H. The Shutting Down Module

This module shuts down the system by turning off the cylinder knob whenever leakage is detected. The ball valve uses a power transistor to amplify the 5V micro-controller signal to 12V, which powers the ball valve and then switches the 12V to the target load.

Implementation and Results

A. The Existing System

Presently, gas leakage detection devices are merely used in some executive places like the top star hotels and very few homes in Nigeria. These devices come as wall mount devices as shown in figure 2, which a customer buys at extra cost and installs in his/her place at will. Such a good technology may not be embraced by many Nigerians. This still leaves us at the unsafe state of being exposed to the risk of gas leakage accident. The existing systems, which include the wall mount and the regulator mount with just a single function, will not work perfectly for Nigerian LPG users. This could be due to the following reasons: the cost of purchasing and installing a new separate device after purchasing and installing the cooking unit. This is at times because of the high level of poverty inherent in some LPG users. It could also be attributed to the wrong attitude and low mentality of some users, making them reactive rather than proactive in their actions. Another major reason could be attributed to the substandard nature of many kitchens or buildings of some users in Nigeria, as they do not support the installation of the gas detectors. Some of the cooking places do not have smooth walls for the mounting of the device while some do not have wall at all. Maintenance of such external system could also be ignored when it develops fault, but when it is integrated into the regulator system, there won't be any option than to fix it. A regulator with an in-built buzzer already exists but can only give a beep sound. Figure 8 shows the existing system.

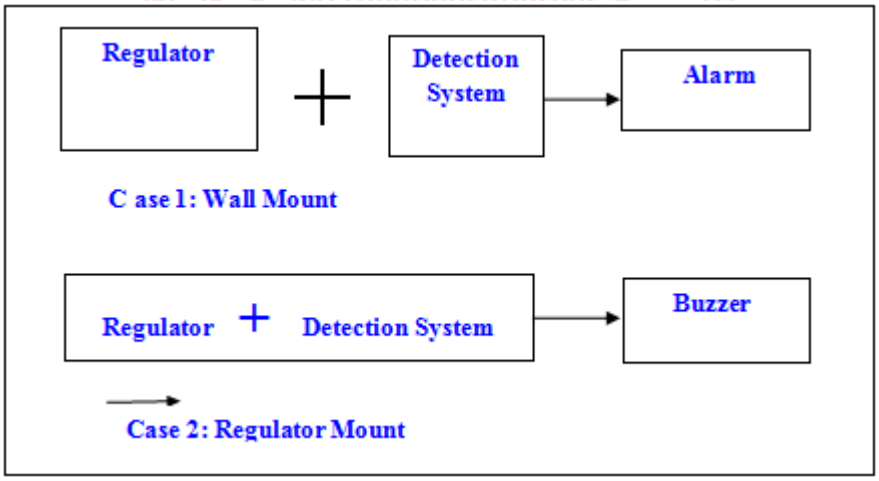

Figure 8: The Existing System

B. The Proposed System

Figure 9 shows the two varieties of the existing system: wall mount and regulator mount. These systems do not solve the Nigerian problem and that is why we propose the new system, the smart prevention system. Figure 10 depicts the interfacing between Arduino UNO interfacing with ATmega 168 micro-controller.

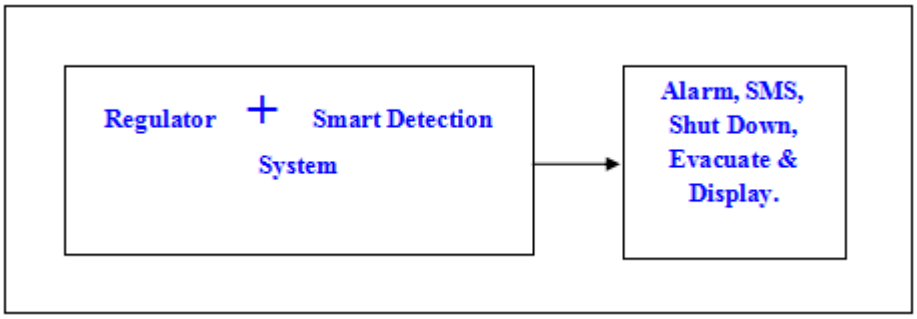

Figure 9 The proposed Gas Leakage prototype for Nigeria

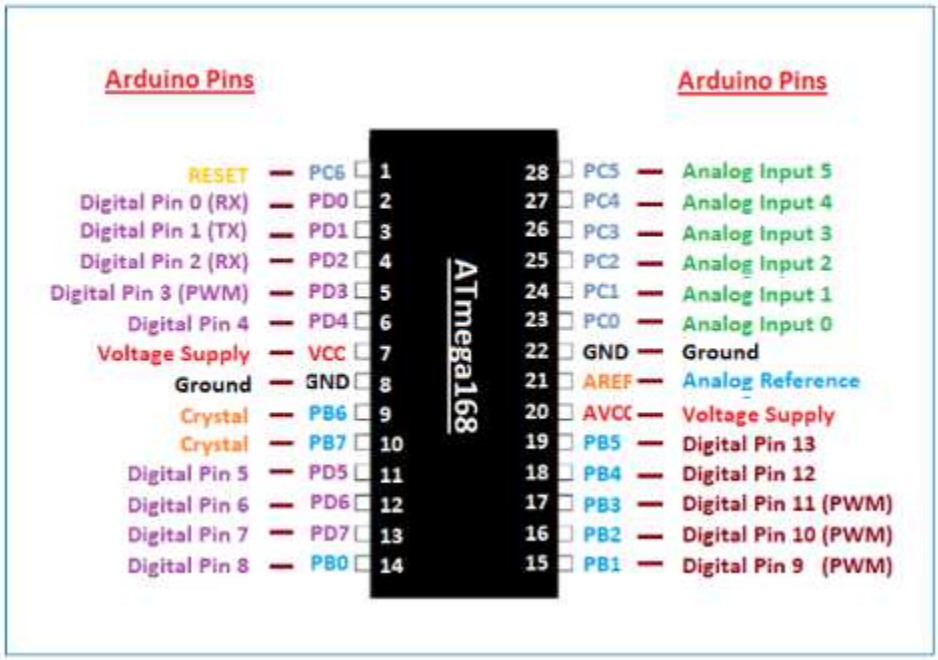

Figure 10 Arduino UNO interfacing with ATmega168 micro-controller

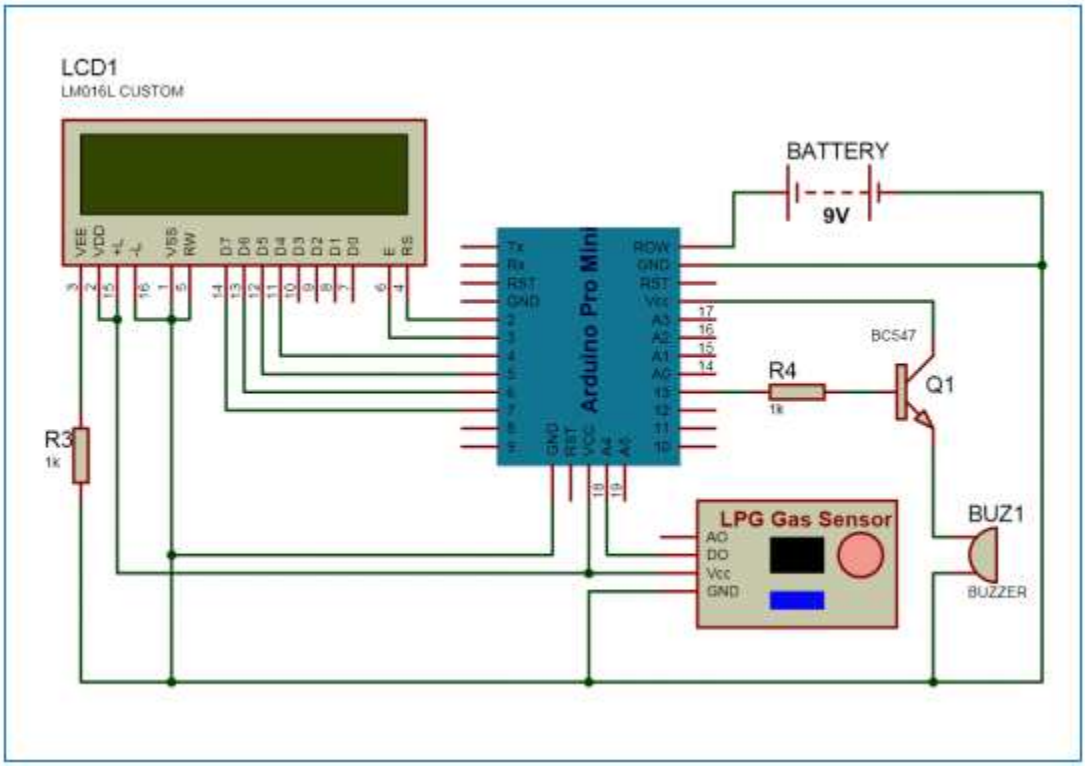

Figure 11 Circuit diagram of the proposed system

From Figure 11, LPG gas sensor module's DO pin is directly connected to pin 18 (A4) of Arduino and VCC and GND are connected to VCC and GND of Arduino. LPG gas sensor module is made up of a MQ-6 sensor which detects LPG gas. This MQ-6 sensor has a heater inside which needs some heater supply to heat up and it may take up to 15 minute to get ready for detecting LPG gas. And a comparator circuit is used for converting Analog output of MQ-6 in digital. A 16x2 LCD is connected to Arduino in 4-bit mode. Control pin RS, RW and EN are directly connected to Arduino pin 2, GND and 3. And data pin D0-D7 are connected to 4, 5, 6, 7 of Arduino. A buzzer is connected with Arduino pin number 13 through a NPN BC547 transistor having a 1 k resistor at its base.

Figure 12 shows the flow chart of the proposed prototype. Once the regulator of a gas cylinder is powered, the sensor is activated, and it keeps monitoring the air concentration of the area. Once the threshold is reached, it triggers the actions as shown in the flowchart; alarming, sending SMS, shutting down and evacuating the area. When actions are fully taken, it starts the process again once the regulator is turned ON.

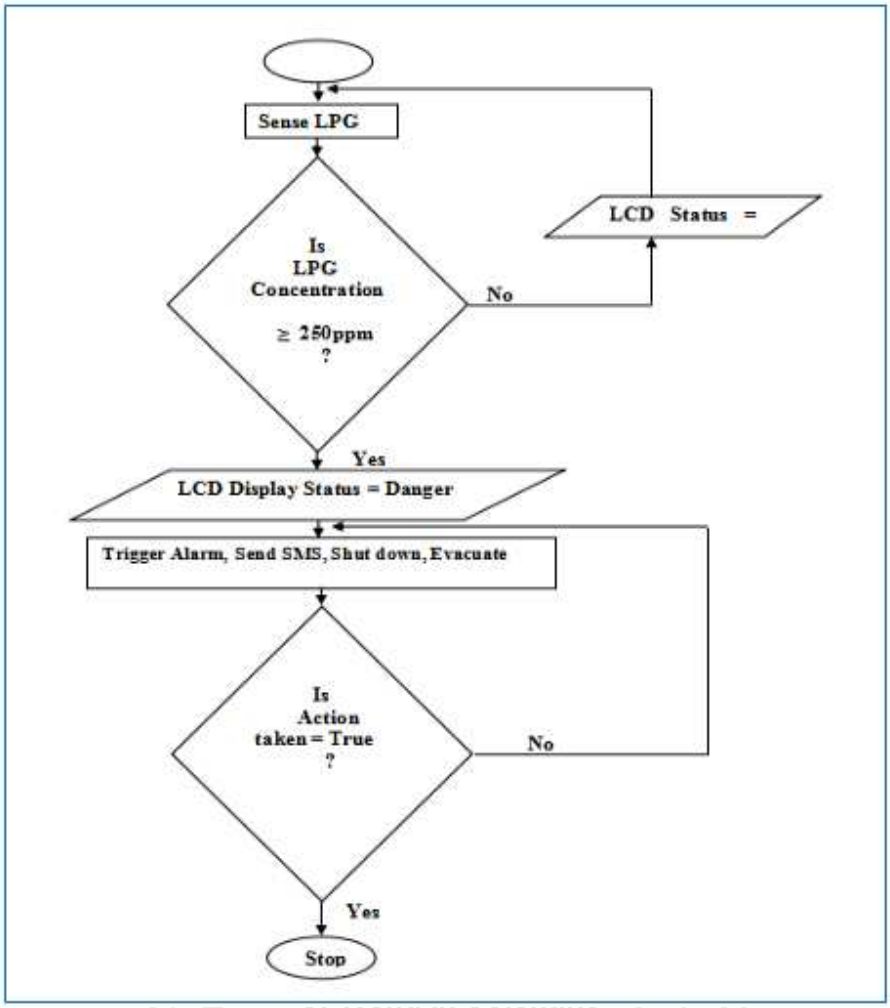

Figure 12 Flowchart of the proposed system

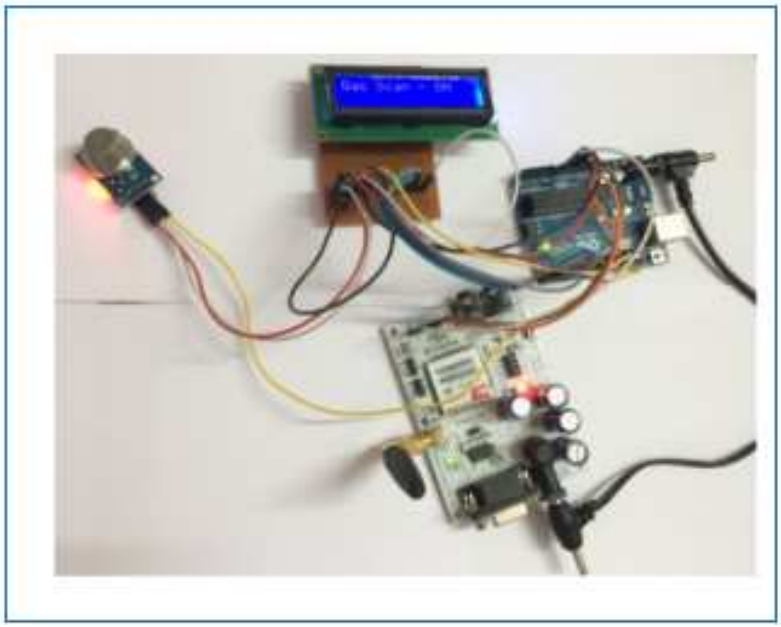

Figure 13 The Proposed Gas Leakage detection system

Figure 13 shows the packaged prototype of the proposed system. In this prototype a gas accident prevention system can be embedded into the gas cylinder regulator. The smart gas accident prevention system is designed to be compulsory for every user unlike the existing system, which is optional. Here, the system automatically turns ON and remains active all the time. The proposed system is advantageous to LPG users, especially Nigerian users for the following reasons: (1.) there is safety when using it despite the substandard nature of their cooking environments, (2.) there is no extra cost of installation and maintenance, all class of people including low mentality and poor attitude users are now carried along with their safety ensured.

Conclusion

Gas leakage can cause unmitigated accident which can result to unwarranted loss of precious human lives and properties. In this paper, a means to detect gas leakage as it occurs in order protect human lives, properties and environment form gas accident has been proposed. A prototype of an integrated safety system in LPG Gas cylinder regulators was proposed and developed. This system is ideally suitable in Nigerian especially where majority of residents are now resorting to the use of LPG to cook because of unavailability and high cost of AGO (Kerosene) and erratic/unreliable electricity supply by the various Electricity Distribution Companies (DISCOs); it helps LPG users in Nigeria both at homes and factories as it guarantees their safety. This prototype has full support for compulsory installation by all users since it is embedded into the regulator system. It can be used by users at home and industry. This is because safety of the users and the environment is paramount for sustainable development.

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