Paper No: SC-09 **Smart Computing**

Design of an auto disconnecting regulator and a safety switch to prevent domestic gas leakages

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***Abstract*: There is a growing demand for research in various aspects of smart homes. Automated security systems are an integral part of smart homes. Liquid Petroleum Gas (LPG) is one of the popular fuels used in domestic cooking. Therefore, there is a very high demand for LPG fire security systems. In this study, an automated LPG fire security system for domestic gas leakages has been designed and a prototype model is constructed. The designed system automatically takes preventive measures in case of gas leakage. It includes a newly designed automatically disconnecting regulator from the cylinder which shuts OFF gas supply from commercially available gas cylinders, a control circuit for switching OFF the power supply of nearby area of gas leakage and transceiver unit for sending SMS to the corresponding people. It has been designed to operate automatically when LPG concentration reaches to 200 PPM, a value well below the LPG gas inflammable concentration. LPG concentration is sensed by the MQ-5 gas sensor and fed into the microcontroller. The commercially available gas regulator is modified by attaching a spring and solenoid valve. The spring is compressed when the regulator is ON. Once an LPG leakage of appropriate PPM is detected, a pulse is sent to the solenoid valve such that the attached spring gets rest by removing the regulator from the cylinder. At the same time, a warning message will automatically send to the corresponding users and security personnel through a GSM module attached to the circuit. The circuit is embedded with a rechargeable battery to work even in power outage. Additional gas sensors are installed in electrical switches located near to the gas cylinder and kept in connection with the microcontroller through the Bluetooth module to cut-off electrical power to prevent any spark.**

Keywords: *Bluetooth, Gas sensor, GSM, IoT, Smart home, Solenoid*

I. INTRODUCTION

Smart City and Smart Home are among the emerging concepts in modern society. They appear as the next stage of recent trends in the urbanization of all around the globe [1]. While moving towards the knowledge-based economy, smart cities augment physical and digital infrastructure for urban development. A smart home is an integral part of the smart city and is going to be the promising future of high-quality living standards for the increasing urban population in the world [2]. An automated security system comes on top of many aspects of the smart home. The main objective of such a system is to secure the home from fire and trespass. For this purpose, wireless sensors increasingly embedded in smart home security systems. In this study, a novel gas-fire security system has been designed for domestic usage. A prototype model of the proposed system is constructed and tested successfully.

Liquefied Petroleum Gas (LPG) is a highly inflammable gas made up of the mixture of propane and butane, with butylene, propylene and other hydrocarbons in small quantities. LPG is used as fuel for domestic, automotive and industrial purposes, including several heating applications such as metal cutting, welding, etc. However, it has gained considerable popularity in domestic usage as a fuel for cooking. Therefore, LPG fire security is an essential part of modern homes due to the increased use of LPG in daily life. Ethanethiol is added as a powerful odorant to give its characteristic smell since LPG is odourless so that when there is gas leakage it can be detected through smell. It is very important to detect LPG leakage as early as possible because of its highly flammable nature. If it is left undetected it can lead to a fire outbreak, causing severe injuries, loss of assets and sometimes death.

Several factors can be led to gas leakages, such as the carelessness of the user or the person who refills or service the gas cylinder/burner, faulty hose, and gas cylinder. Gas leakage as a result of a faulty cylinder is very rare because the cylinder can last more than two decades before it expires. LPG fire accidents are most commonly happen early in the morning. Electrical sparks inside the electrical switches are one of the main reasons for domestic gas fire accidents. If an LPG leakage lasts for a considerable period, it will eventually increase LPG concentration in the air. When it exceeds the harmful level, there is a high probability for a gas fire due to a spark caused by the switching ON an electrical switch of the nearby area. This happens as a result of a lack of sensory impairment on a person who awakened from sleep or person who didn't sense the smell of the LPG gas, unknowingly ON the electrical switch [3]-[4]. Therefore, this kind of gas fire accidents is most commonly happens early in the morning [5].

Therefore, the need for an efficient system to detect LPG leakage and preventing fire has topmost importance. LPG detection and security systems are not new and they have been studied by various research groups [6]-[14]. Most of them are capable of detecting LPG leakage and turning ON a warning alarm while sending SMS to the relevant parties. None of them are capable of automatically disconnecting the regulator from the cylinder and switching OFF the electric power in the nearby area. The proposed system in this study addresses those two fundamental limitations ensuring the total prevention of the LPG fire outbreak.

II. Design & Implementation

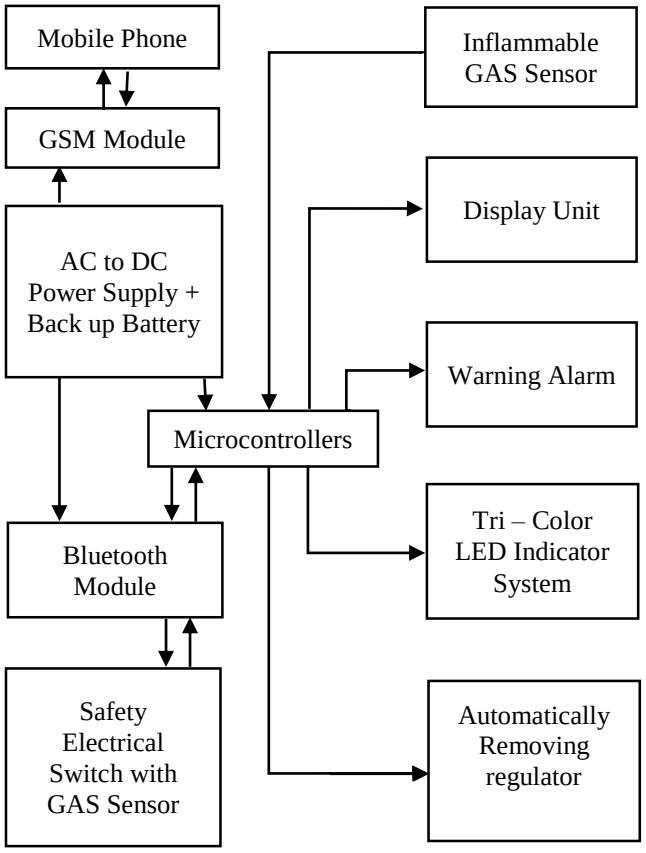

Fig. 1. Flow diagram of the proposed design

The designed LPG fire security system contains several major parts as shown in Fig. 1. The microcontroller acts as the main controller of the system. In addition to that, it consists of a Gas sensor which monitors the LPG concentration in real-time, automatically disconnecting LPG regulator, AC-DC Power Supply with back up battery, Safety electrical switch, Bluetooth module to keep connection between Microcontroller and safety electrical switch, Display Unit, GSM module for SMS alert system, Warning alarm, and Tri-color LED indicator system. Some of the features of the designed system are not available in any of the published literature or commercially available products. Specifically, the automatically disconnecting regulator, Safety electrical switch, and Try-color LED indicator are unique to this design.

The LPG concentration in the air is monitored using the MQ-5 gas sensor which is extensively used in previous studies [6]-[14]. This sensor can detect LPG concentration in air and provides the output as an analogue signal. The automatically disconnecting LPG regulator has designed by modifying a commercially available regulator. It contains a solenoid valve and spring system for automatically disconnecting technique. A GSM module and Bluetooth module are used to communicate with mobile phone and safety electrical switch respectively. In addition to the AC-DC power supply, a backup battery is embedded to ensure protection even in a power failure.

All these circuits and modules are connected with the microcontroller. LPG concentration in air is continuously monitored in real-time and sensor output is fed into the Microcontroller. The microcontroller then calculates LPG concentration as PPM value and compares it with reference. Reference is chosen as 200 PPM, a value below the possible minimum LPG concentration in the air to have an LPG fire. If the LPG concentration is greater than the reference value (200 PPM), the LPG regulator is designed to be disconnected automatically from the gas cylinder. At the same time, the microcontroller sends a warning message to corresponding users and security personnel through the GSM module. Additional gas sensors and electrical power control circuits are installed in electrical switches located near to the gas cylinder by making them safety electrical switches. Those switches are capable of cut-off electrical power which will prevent any electric spark in case of gas leakage. The microcontroller and all the safety electrical switches are connected via Bluetooth technology.

A. Sensing unit

The accuracy of the gas leakage detection depends on the sensitivity of the sensor. For this reason, the MQ-5 gas sensor was chosen since its capability of detecting LPG and natural gases, while avoiding the detection of alcohol, cooking fumes, and cigarette smoke. In order to make the system to be very sensitive, a reference point of 200 PPM was chosen. At a value greater than 1000 PPM concentration, the environment is considered as dangerous.

The LPG concentration in PPM is given as;

$$PPM = 10^{\left(\frac{loglog\frac{R_S}{R_O}-2.1}{-0.47}+2.3\right)}$$

where

- R_s = sensor resistance at various concentrations of LPG gas,
- R_o = sensor resistance in the clean air.

B. The main controlling unit

The objective of the main controlling circuit is to concatenate the several associated modules with a microcontroller. Mobile phones, Bluetooth module, Display unit, Tri-color LED (RGB) indicator system, Gas sensor output signal for disconnecting the regulator must be communicated with the microcontroller, to automate the system. The entire system is controlled by ATmega328P Microcontroller.

The SIM800L GSM module is chosen since it is capable of configuring the telephone numbers of the users. When a gas leakage is detected, it sends an SMS alert to the user as

well as to the security personal. The LCD visualizes the present PPM value of LPG, GSM Signal strength and charge level of the backup battery.

The HC-05 Bluetooth module is used to keep communication with safety electrical switches to send a signal to power ON or OFF. When the LPG concentration exceeds the harmful level, the microcontroller automatically sends a power-down signal to all nearby safety electrical switches to prevent gas fires due to the sparks in case of the electrical switches are being operated. There is a status LED added to the main controlling circuit to indicate whether the Bluetooth is connected or not with switches. If the Bluetooth is connected, the status LED blinks once per two seconds. If it is not connected status LED always blinks until it connects to the safety electrical switches. When the main controlling circuit is powered up, it automatically connects with safety electrical switches in the nearby area without any user interaction. A snapshot of the prototype's main controlling unit is shown in Fig. 2.

The Tri-color LED (RGB) array is used as an indicator system, Red colour for dangerous LPG gas leakages, Green colour when there is no dangerous gas leakage and Orange colour for the cases that gas sensor detects a certain level of gas leakage which is at a non-dangerous level.

Fig. 2. The prototype of the main controlling unit

One of the major reasons for domestic gas fire accidents is operating electrical appliances in the area of gas leakage. If an LPG leakage existed for a considerable period of time, it will eventually increase LPG concentration in the air. When it exceeds the harmful level of gas concentration, there is a high probability for gas fire due to spark caused by operating the switches of appliances in the nearby area. To prevent this fire, safety electrical switch is designed by embedding additional gas sensors and electrical power controlling circuits into the switch and keep it in contact with the main controlling circuit through the Bluetooth module. This feature is not available in any commercially available gas detectors as well as any published literature [6]-[14].

The circuit diagram of the designed safety electrical switch is shown in Fig. 3. The designed safety electrical switch consists of Atmega328P microcontroller, HC-05 Master Bluetooth module, 230 V to 5 V power supply, buzzer alarm, a Triac based 230 V power control circuit and additional MQ-5 gas sensor. HC-05 Master Bluetooth module is used for communication between the main controlling unit and safety electrical switch. The main task of the Bluetooth module is to receive the signals that are sent from the main controlling unit and then send data to the microcontroller to process. The main feature of this safety electrical switch is that it will automatically be connected with the main controlling unit without any user interaction. In addition, there is a status LED attached to the safety electrical switch to indicate whether the Bluetooth module is connected or not with the main controlling unit.

C. Safety electrical switch

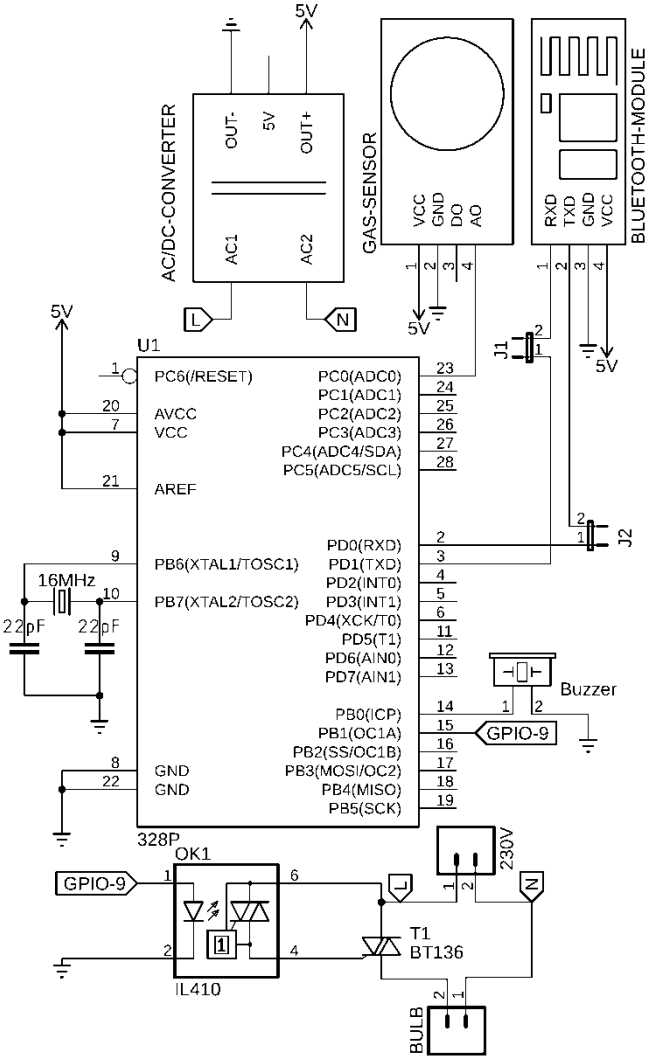

Fig. 3. Circuit diagram of safety electrical switch

All arithmetic and logic functions are handled by the Microcontroller. The HC-05 Bluetooth module, buzzer alarm, and MQ-05 Gas sensor are directly connected with the Microcontroller. Also, the 230V power control circuit is connected with the microcontroller through an optocoupler. Here the optocoupler acts as a switch that can be controlled using a microcontroller. MQ-05 Gas sensor always checks the LPG concentration whether it is harmful or not. When the LPG concentration is greater than 200 PPM, safety electrical switches automatically disconnect their 230 V power instantly. At the same time, the buzzer alarm will automatically be turned ON and a warning message will be sent to relevant parties. When the risky condition has become

normalized, such that LPG concentration becomes less than 200 PPM, the 230 V power for the Safety electrical switches will be restored after five minutes from the critical condition. Also, when the Bluetooth module receives the warning signals from the main controlling unit, the safety electrical switches will run through the same steps. Another main advantage of the proposed system is the size of the safety electrical switch, where it can be fixed to a commercially available standard sunk box as shown in Fig. 4.

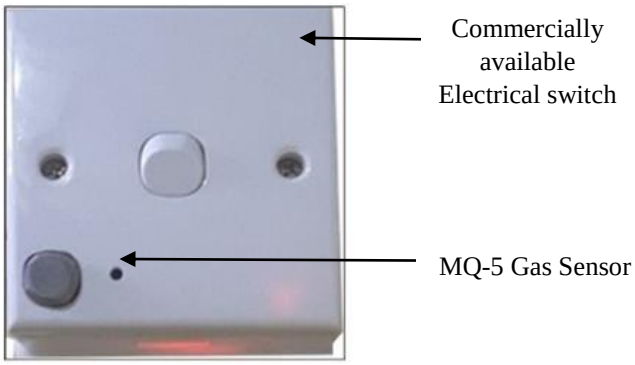

Fig. 4. The prototype of safety electrical switch attached to a standard sunk box

D. Automatically disconnecting regulator

The Gas regulator is the most useful item which connects the gas pipe of the appliance and the gas cylinder. There are many commercially available regulators that all have quality certificates such as ISO, SLS, etc. Usually, gas regulators have a long life without any failures. But the gas pipe of the appliance may damage in long time usage. Therefore, there may be invisible, smaller holes in the gas pipe. Eventually, there could be a high probability to leak LPG through small holes in the gas pipe. In addition to that, there can be a risk of gas to be leaked from any weak places of the appliance, and due to some inappropriate user actions.

Here, the auto disconnecting gas regulator was developed to avoid gas fire accidents. This mechanism consists of 12 V solenoid lock and commercially available common gas regulator. The 12 V solenoid lock is used for preventing the electrical sparks. As shown in Fig. 5, the specially moulded case has been fixed on the outside of the LPG regulator using epoxy resin. Also, a small spring and liver technique is attached to the regulator valve. The 12 V solenoid lock is used for triggering the liver. If the solenoid lock powered up, the attached spring gets rest by removing the regulator from the cylinder. The operating signal of the solenoid lock is given by the main controlling unit when the harmful level of the LPG concentration in air is detected.

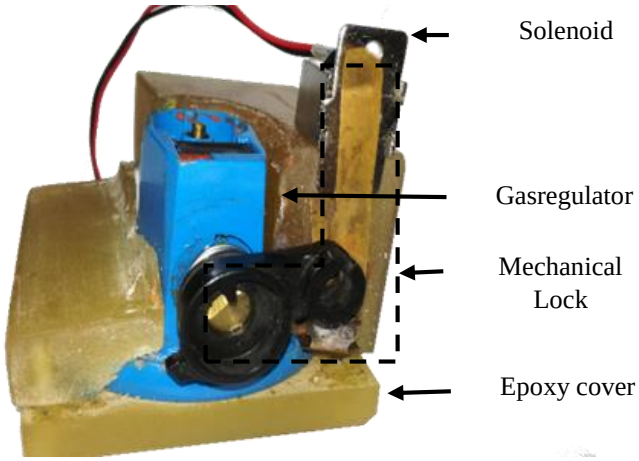

Fig. 5. The prototype of automatically removing the regulator

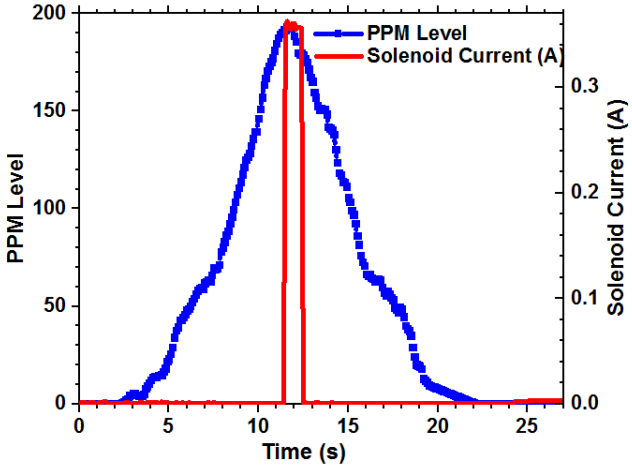

Fig. 6. PPM level and Solenoid Plus at Gas Leakage

III. RESULTS

The solenoid current pulse in a case for gas leakage with a calculated PPM level is shown in Fig.6 to validate the proper operation of the designed system. This clearly identifies the powering up of solenoid at the 200PPM level, which validates the proper operation of the designed system.

TABLE 1. COMPARISON OF COMMERCIALLY AVAILABLE SYSTEMS WITH THE PROPOSED SYSTEM

Feature	Commercially available system	Designed system
Emergency shut off and automatically disconnecting the regulator from the cylinder	**No**	Yes
Instantly cuts off the power supply of the nearby area	**No**	Yes
Send SMS alert to corresponding people	Yes	Yes
Back up battery for work even in power failures	Yes	Yes

IV. CONCLUSION

LPG leakage and fire security system has been developed to reduce the harm to human and domestic assets. The main task of this system is, when a gas leakage occurs, the leak is detected quickly and disconnect the gas regulator from the gas cylinder, disconnect the power supply to all electrical switches in the nearby area, and send warning alert to the relevant important parties. This system can be powered from the mains as well as from a rechargeable battery such that the reliability of operation of the system is guaranteed all the time.

The designed system is incorporated with several attractive new features making it unique as compared to the existing gas detector and security systems. Bluetooth technology is used as a communication medium between the main controlling circuit and the safety electrical switches in the vicinity. The main controlling unit and safety electrical switches connected with each other automatically when the system is powered up. As soon as gas leakage occurs, the Gas fire security system drastically reduces the gas fire risk by separating the gas pipe with the regulator from the cylinder. In addition, even for possible gas leakages from the cylinder itself and if it exceeds the permissible level, the power supply of nearby area switched OFF and the relevant users will immediately be alerted with an SMS. This security system can be installed both in domestic and industrial places. Integrating the designed system with the IoT platform is envisioned in a futuristic smart home.

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