LPG DETECTION AND PREVENTION USING SVL TECHNOLOGY

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ABSTRACT

Home safety from hazardous gases is often taken for granted which results in unnecessary loss of lives as well as the environment. Liquefied Petroleum Gas, though an essential part of our daily lives also possesses some threats if not used carefully. In this project, an approach has been taken to detect LPG leakage as early as possible using an MQ6 gas sensor and also to stop further leakage with an automatic valve locking mechanism obtained with the help of servomotors connected to a microcontroller. The said microcontroller is also used to cut off the power supply to prevent electrical damage using relays and circuit breakers. In addition, the setup will also send SMS to the required authorities about the incident using a GSM module. Also, if it detects even a tiny amount of fire it will automatically send a message to the concerned authorities with the help of the IR flame detector. An exhaust fan will also be turned on to dissipate the leaked gas to avoid concentration. The above measures will be taken to detect and nullify the leakage of gas as early as possible.

I. INTRODUCTION

This paper is based on experimental analysis and a means to provide proof of concept for providing a solution for LPG gas leakage using smart valve locking technology. Various research journals have been explored for implementing the system and are discussed thoroughly in the following sections.

Impacts and wounds due to of gas in enterprises, vehicles, and houses, a gas spillage framework has been structured by utilizing installed frameworks and associating Internet of things. IOT cannot be utilized in the detection of poisonous and toxic gases to reduce spillage-based accidents [1]. LP Gas leakage detection and a warning system which is designed using Kalmann filter and a specialized neural network to address the issue of inaccurate gas leakage detection. First, Kalman filter is utilized to filter the noise from the gas concentration which is calculated using a sensor. Then, various predictions about the change of gas concentration are made using the back propagation neural network optimized by a special genetic algorithm. Kalman Filter based neural network is used for inaccurate detection. Then an early detection system is designed using concentration as the parameter [2].

Another means can utilize cloud-based IOT software for accurate detection of poisonous and LPG gas leakage which also includes a detection system for fire and temperature monitoring capabilities. The article mentioned the development of an embedded system design with real-time monitoring techniques. Here software technology is used to monitor fire and gas leakage which incorporates an early-stage fire detection system [3]. Another system model used an integrated working principle is proposed to evaluate the ultimate consequences of toxic gas which contains flammable gas leakage and explosion accident. Here a risk-based concept and the more stable grid-based concept are utilized to combine the effectiveness of the processes. The solution is used in a hypothetical accident scenario which concerns an H2S-containing natural gas leakage and explosion accident on an offshore facility [4].

Toxic gas and LPG leaking and explosion detection and visualizing the potential explosive area using Wireless Sensor Networks (WSNs). In this proposed model, a planarization algorithm is used to planarize a WSN, and based on the mentioned network, the accurate boundary area of gas diffusion is found out to delimitate the dangerous area. The algorithm applied for calculating accurate explosive area in case of toxic gas spillage like LPG [5].

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Several research-based journals were studied and analyzed for the mentioned experimental project from a variety of credible sources. Karthik M et al.[1] proposed a system of detection that would properly detect gas spillage and its prevention with the help of IOT to reduce accidents occurring due to spillage and leakage of poisonous gases. Here IoT based detection system was used for the mentioned cause. Guoquan Liu et al.[2] proposed a system where the inaccuracy of gas leakage is first rectified before applying a prevention mechanism. Kalman filter-based neural network was used for addressing the issue of inaccurate detection in many existing systems. Kalman filter is used to filter the noise using isolation from the concentrated amount of gas which is measured by a special sensor and then an early detection mechanism for gas leakage has been designed and modeled.

Mobasshir M et al…[3] proposed a design comprising of cloud and IOT based embedded system using digitized methods for monitoring humidity, temperature and an early-stage efficient fire detection method. The system developed used an embedded system with HTTP protocol-based real-time monitoring through smartphones and PC along with a fire detection mechanism. Mithun Mukherjee et al[4] proposed a design to detecting toxic and poisonous gases with the help of wireless sensor networks. An explosive area is calculated to determine and delimitate the dangerous area and then an algorithm was developed for the detection of such poisonous gases. Dongdong Yang et al.[5] proposed a method where a risk-based concept and the more stable grid type concept are utilized to combine the effectiveness of the processes. The solution is used in a hypothetical accident scenario which concerns an H2S-containing natural gas leakage and explosion accident on an offshore facility [4].

II. PROPOSED METHODOLOGY

The method proposed by us is aimed at increasing the security factor when it comes to unfortunate incidents of gas leakage like LPG and methane. Especially LPG since it is widely used in a household where a leakage incident can result in immense loss. Our experiment with the project will be useful in the situation where the owner of a resident is not present on the premises to take necessary action regarding the gas. More than one action or mechanism will be taking place as well in the entire process that includes the detection and prevention stages. The system includes gas sensors, a microcontroller (Arduino UNO), servomotors, battery as well as direct DC power, GSM modules, fire sensors, and liquid crystal display for monitoring and analyzing important parameters.

The methodology will be implemented in such a way that upon detection of the leakage an automatic valve locking mechanism will get deployed immediately to turn off the knobs of the cylinder followed by shutting off the power supply of the vicinity. At the same time, an SMS signal will be sent to the owner of the resident which will contain information of the entire incident starting from the leakage detection to prevention as an additional alerting technique. It is worth mentioning that an additional 12V battery is included which ensures that the components will still be working even after the direct power source is deliberately cut off for preventing electrical damage.
III. SYSTEM MODELLING

Figure 1: Block diagram of the system

IV. OPERATION AND WORKING

Several steps or processes come into play while executing the steps necessary for the development and implementing the project as intended. The very first step to detect the LPG based on the volume of gases that will be leaked initially. An arbitrary number (for example 300 or 400) can be set up as the threshold point for the sensor to go off. This will be programmed with the help of the Arduino code into the system. When the gas starts leaking the MQ6 gas sensor starts detecting the gas as an input and the threshold counter will start from Zero, once it reaches the set threshold point, the detector will go off along with the alarm buzzer and will continue to do so until it is stopped manually. At the same, the programmed microcontroller comes into action by sending control signals to the servomotors to automatically rotate the valve of the cylinder i.e. turning off the cylinder valve to an off position. This will result in immediate termination of further leakage by executing the said rotation. It is noteworthy that the servomotors should be placed accurately relative to the valve of the cylinder so that upon receiving the signals the servomotors don’t miss out on striking the valve with appropriate force.

The next action that takes place immediately alongside the rotation of the valve is turning off the electricity supply in the vicinity. In the demonstration, a stable lamp with a test circuit has been used for replicating the action. This will be achieved using the Arduino Uno and a two-way relay module which are often used in controlling electrical conduction. The relay module will turn off the electrical supply of the room upon receiving the required control signal. In real life scenario, the relay module will be replaced with another device with a higher capacity.

The microcontroller used will also be useful in sending another control signal to the GSM module which sends a warning message to the owner of the resident about the mentioned leakage incident to their cellphone within seconds of detection.

In addition to the above-mentioned steps or action, an exhaust fan is also attached to the system to dissipate the gas through an opening so that it will not be concentrated in a confined space. A higher concentration of propane and butane leads to asphyxiation. This action will help in the prevention of fainting or passing out of the individual upon arrival to the location of the incident.

An additional 12 V battery is used as an additional power source to keep the system running after the Arduino and relay cuts off the direct DC power supply. Under normal circumstances, ideal results are expected as intended.
5.1 Hardware Components

The list of hardware components used in this experimental and conceptual project is briefly discussed in the following paragraphs.

Arduino Uno: Arduino Uno is a microcontroller board belonging to the ATmega38 family used for a wide range of applications from basic machine controlling to IOT based devices. The board has many smaller sections which completes the interface, 14 digital input-output pins, 6 analogue pins, and two pins for transmission and reception namely Tx and Rx pin.

Relay Module: The relay module used in this experimental project can be easily controlled by microcontrollers like Arduino UNO, Raspberry Pie, etc. A relay module works on the principle of electromagnetic attraction. If the circuitry of the relay senses any fault current, it energizes the field which produces the temporary magnetic field in its vicinity.

MQ6 Gas sensor: The MQ6 is a highly sensitive gas sensor used for the detection of various poisonous as well as non-poisonous gases. Most commonly it is used for the detection of LPG, LNG, and iso-butane gas in household and commercial places alike. It can also be used for the detection of alcohol, cooking fumes, and cigarette smoke.

Liquid Crystal Display: A 16x2 liquid crystal display is used for displaying vital information regarding the detection mechanism. A standard 16x2 display is an electronically operated display module that has a wide range of applications and usage. It can display 16 characters per line and there are a total of two lines.

Servomotors: Servomotors are electronic devices and rotary and linear actuators that rotate and push parts of a machine with a high degree of precision. They are mostly and primarily used in angular or linear positions and for certain velocity and acceleration. Small servomotors such as the MG996 can also be interfaced with microcontrollers like Arduino UNO for various applications and usage.

Fire sensor: The fire sensor that can be paired with an Arduino is the IR flame sensor used for detecting flames by implementing LDR properties from a set distance. This particular model is based on YG1006 NPN phototransistor. By interfacing a flame sensor with Arduino it will be useful in detecting fire and also activate a buzzer for an emergency involving fire.

12V Battery: A 12V battery is used in this conceptual project as a source of additional power supply. The premise is to cut off the power supply upon detection of leakage of LPG gas. So there needs to be an alternate source in case of ceased power supply, this is where the 12V battery will come in the battery.

Capacitors: A capacitor is a passive two-terminal electronic device used primarily for storing energy electrostatically. Different forms of capacitors exist but most of them use at least two or more conductors called plates which are separated by a dielectric also called an insulator.

Diodes: Diodes are passive semiconductor devices that allow current to flow in one direction. Mainly used for controlling the direction of flow of current. If the voltage across a diode is positive then the ideal diode looks like a closed circuit and thus is considered to be on and forward biased. If the voltage across the diode is negative then it looks like an open circuit and then it is said to be reversed biased.

Buzzer: Buzzers are used as alerting device by giving off a high-frequency whistling sound when triggered. They are audio signalling device which may be mechanical or piezoelectric. They are mainly used as alarm devices, timers, etc. In this experimental project, piezoelectric buzzers are used for alerting.

Transformers: A transformer is an electrical device and a transducer that is used for the transfer of electrical power by varying the voltage output. There are two types of transformers—step up and step down transformers. If lower voltage needs to be amplified to a higher level a step-up transformer is used. On the other hand, if high voltage needs to be toned down to lower values then a step-down transformer is used.

Tabulations
<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microcontroller</td>
<td>ATmega38</td>
</tr>
<tr>
<td>Max Clock Speed</td>
<td>16-17Mhz</td>
</tr>
<tr>
<td>Ideal Operating Voltage</td>
<td>5Volt</td>
</tr>
<tr>
<td>Normal Supply Voltage</td>
<td>7-12V</td>
</tr>
<tr>
<td>SRAM available</td>
<td>2Kb</td>
</tr>
<tr>
<td>EEPROM</td>
<td>1024Mb</td>
</tr>
<tr>
<td>Flash Memory</td>
<td>32x1024Mb</td>
</tr>
</tbody>
</table>

Table 1: Arduino Specifications Table

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Voltage</td>
<td>5V</td>
</tr>
<tr>
<td>Gases used</td>
<td>LPG or Butane</td>
</tr>
<tr>
<td>Analog Output Voltage</td>
<td>5V</td>
</tr>
<tr>
<td>Preheat</td>
<td>20 seconds</td>
</tr>
</tbody>
</table>

Table 2: MQ6 Gas sensor specification table

5.2 Components Circuitry

Figure 2: Gas Sensing Circuit
Figure 3: IR Fire Sensor Circuit
VI. FLOWCHART IMPLEMENTATION

Figure 4: Flowchart of the system
VII. STATISTICAL ANALYSIS

A statistical report from a couple of years prior indicates the large number of deaths caused by the accidental fire of which LPG leakage is a part. This experimental project is aimed at reducing the yearly death toll as much as possible with the aid of appropriate resources.

According to a recent survey, on average India reports 58-59 deaths daily due to fire and gas leakage-related causes. Although the number of people using sound and safe technologies available might not be looked upon as very high, this still counts as an unnecessary loss of human lives. Finding a precautionary measure to reduce death as much as possible should be undertaken by more and more of us in the present moment. This demonstrated project aims at providing an early gas detection mechanism along with a smart LPG valve locking protocol to curb the issue of gas leakage.

Figure 5: Deaths due to accidental death in India

VIII. THEORETICAL ANALYSIS OF TECHNOLOGIES USED

Arduino utilizes the renowned Harvard architecture where program code and the program are stored in different memory units. It consists of two types of memory – program memory and data memory. The ATmega38 has 32kb of flash storage for storing all the code that will be written in its IDE. It operates at a clock speed of 16mhz. The main advantage of Arduino is that all the programs based on it can be directly loaded into the device without needing any hardware programming modifications.

Some of the positive aspects of using Arduino are:-

1. It is not very expensive
2. It comes with an open-source hardware feature
3. It is compatible with all available OS like Windows, Mac, Linux, etc.
4. The code is relatively easy to use compared to its competitors

The MQ6 gas sensor used has its way of detecting leaking LPG or butane gas. If the gas has to be measured in ppm, then the analog pin has to be used by combining it with a microcontroller. When it comes to accurately measuring the concentration in terms of ppm is the ideal choice that is obtained using a module.
R<sub>c</sub> is the value of resistance of fresh air while R<sub>s</sub> is the resistance of the LPG gas. With the help of this, resistance value of the gas sensor can be found out.

\[ R_s = \left( \frac{V_c}{V_R} - 1 \right) x R_L \]

The analog voltage of the MQ6 sensor can be converted into the corresponding concentration value with the help of the formula below:

\[ PPM = \left( \frac{V_{cc}}{V_o} - 1 \right) \times \left( \frac{R_l}{R_s} \times 10^{-c} \right)^{1/m} \]

Where V<sub>cc</sub>= Supply voltage, V<sub>o</sub>= Output Voltage, R<sub>l</sub>= Load resistance, R<sub>s</sub> = Sensor resistance.

The internal working of the single-channel relay module used in this journal paper is discussed as follows. The principle behind a relay is electromagnetic attraction. There are two circuits. Initially, the first circuit is turned off and thus no current flows through until a sensor or similar device turns it on. When a small current flows through the initial circuit it triggers the electromagnet and generates a magnetic field all around the circuit. A single channel relay usually has three terminals Common contact, normally closed and normally open along with three control pins.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter name</th>
<th>Technical condition</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>V&lt;sub&gt;c&lt;/sub&gt;</td>
<td>Voltage for circuit</td>
<td>5V±0.1</td>
<td>AC / DC</td>
</tr>
<tr>
<td>V&lt;sub&gt;H&lt;/sub&gt;</td>
<td>Voltage for Heating</td>
<td>5V±0.1</td>
<td>AC / DC</td>
</tr>
<tr>
<td>P&lt;sub&gt;L&lt;/sub&gt;</td>
<td>Load</td>
<td>~20KΩ</td>
<td></td>
</tr>
<tr>
<td>R&lt;sub&gt;H&lt;/sub&gt;</td>
<td>Resistance of Heating</td>
<td>~33Ω±5%</td>
<td>Room Temp.</td>
</tr>
<tr>
<td>P&lt;sub&gt;H&lt;/sub&gt;</td>
<td>Heating consumption</td>
<td>&lt; 750mw</td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Specifications of MQ6

The above tabulation shows the working parameters of MQ6 sensor.

The fire sensor used in this paper is based on the infrared flame sensor for early detection of fire (if any). It acts as an infrared thermometer. The infrared thermometer works by focusing light that is approaching from the object in the form of infrared and funnelling that light into a special sensor which is also known as thermopile. It is a form of non-contact temperature measurement and monitoring. One law that highlights the principles of noncontact temperature measurement is Planck’s radiation law.

![Figure 6: Variance in spectral radiance](image)

The above plot is significant to Planck’s law of blackbody radiation which is essential in the analysis of infrared thermometer technology.
The GSM module used in this demonstration uses basic mobile communication technology, however, despite being a GSM, it also supports 4G SIM cards for operation. The model used here is the SIM800L which is a miniature version of the standard GSM module that comes with an antenna of its own. The maximum power consumed by this available module is around 2 Amperes during the transmission burst. The following datasheet summarizes what we may expect.

<table>
<thead>
<tr>
<th>Modes</th>
<th>Frequency</th>
<th>Current consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Down</td>
<td></td>
<td>60µA</td>
</tr>
<tr>
<td>Sleep mode</td>
<td></td>
<td>~1 mA</td>
</tr>
<tr>
<td>Standby mode</td>
<td></td>
<td>18mA</td>
</tr>
<tr>
<td>Call mode</td>
<td>GSM850/EGSM900</td>
<td>199mA/216mA</td>
</tr>
<tr>
<td></td>
<td>DCS1800</td>
<td>146mA</td>
</tr>
<tr>
<td>Transmission burst</td>
<td></td>
<td>1 A</td>
</tr>
</tbody>
</table>

Table 4: Current Consumptions

Capacitors are used to store energy electrostatically for devices and circuits alike. It stores electric charges when we apply an amount voltage to a circuit. Since charge accumulation in the conductor causes potential differences across the capacitor. This measure of charge accumulating capabilities of a capacitor in a unit called is called capacitance. In other words, capacitance is the charge that gets stored in a capacitor for developing a 1-volt potential difference across it. Thus it is clear that there is a direct relationship between the charge and voltage of a capacitor.

Capacitance is measured in farads and the relationship between charge stored and voltage is given by:

\[ C = \frac{Q}{V} \] or \[ Q = VC \]

Where \( Q \) is the amount of charge stored in unit of coulombs, \( V \) is the potential difference in the capacitor and \( C \) is the capacitance of the Capacitor.

The parallel plate capacitor is the most basic form of capacitor. It can be created by using two metalized foil plates at a certain distance parallel to each other. The general equation for the parallel-plate capacitor is always given by

\[ C = \frac{\varepsilon_0}{A} \left( \frac{1}{d} \right) \]

Where \( \varepsilon_0 \) is the dielectric constant of free space, \( d \) = distance between the parallel plates, \( A \) = area of plate overlap.

Other hardware components included in the demonstration are resistors & diodes. Resistors are passive electrical device or component that creates resistance in the flow of current in a conductor and is proportional to the induced potential difference established between two ends of the conductor. This opposition of flow of current is called resistance. The presence of resistance helps us control the flow of current in a conductor. The relation between resistance, current, and voltage is demonstrated by Ohm’s law.

Ohm’s law states that the current flowing through a conductor is directly proportional to the potential difference established in it.

\[ V = IR \]

Where \( R \) = resistance constant, \( V \) = Potential difference, \( I \) = current flowing through the conductor.

Diodes are a two-terminal passive electrical device that allows the flow of current in only one direction in a circuit. In a way, it acts as a valve for electronic circuits. When the polarity of the battery is such that the current is allowed to flow through the diode, the diode is said to be forward-biased. Conversely, when the battery is
backward and the diode opposes current, the diode is said to be reversed biased. A diode acts like a switch, closed when forward-biased but open when reverse-biased.

The general diode equation is given by

\[ I_D = I_S (e^V_d / 0.026 - 1) \]

Where \( I_D \) is the current of the diode in amps, \( I_S \) = Saturation current in amps, \( e \) = Euler’s number, \( V_d \) = Diode voltage.

The servomotor used in this paper is a 36g servomotor intended for automatically turning off the valve of the LPG, that is, to rotate the valve of the cylinder to an off position to prevent further leakage. To elaborate further there are two types of servomotors to classify broadly – DC servomotors and AC servomotors. The working principle of a DC motor is the same as any other electromagnetic motors however the design, construction, and modes of working are different. The DC motors can be further classified into Series motor, split series motor, shunt control motor, and permanent magnet shunt motor.

AC servos work under the principle of PWM (Pulse Width Modulation). In pulse width modulation the width of the pulse is varied following the discrete modulating signal. A simple illustration of pulse width modulation is shown in the picture below.

The transformer used is a step-down transformer that is used to bring down the voltage to a suitable level which will be safe for the Arduino microcontroller. The transformer used is a voltage transformer and is used to vary voltage output from one value to another depending on the requirements. These work under Faraday’s law of electromagnetic induction by transforming one electrical value to other.

Faraday’s law states that the instantaneous EMF induced in a circuit is directly proportional to the time rate of change of the magnetic flux through the circuit. It is depicted by the equation

\[ \mathcal{E} = -N\Phi_B / dt \]

A buzzer is used as an alerting device after the detection of the LPG leakage which is a piezoelectric type alarm. It works on a similar principle as that of a basic piezoelectric transducer is piezoelectricity when mechanical pressure is applied, a proportional electric voltage is created which is ideally amplified using a charge amplifier and used for calibration of applied stress on the used material.

The formula for charge generated longitudinally

\[ Qe = F * D \]

Where \( F \) = force, \( D \) = piezoelectric coefficient for the quartz crystal.

**IX. OBSERVATION AND RESULT**

The system was implemented and tested successfully by establishing a small amount of LPG gas and fire. The gas sensor was set to a threshold analogue value of 400 and the fire sensor was set to the digital value of 0. Under normal circumstances, the gas sensor was giving the reading between 0-8 but when a gas of small-scale was established in the environment surrounding the gas sensor the value of the gas sensor increased and it crossed the threshold value of 400 and the signal was sent to the Arduino, then the Arduino performed multiple actions simultaneously. Starting with closing the knob of the LPG regulator using the MG996 Servomotor and cutting off the power supply of the house by using the relay module. The Arduino then sent an SMS to the concerned regarding the gas leakage through the GSM module and set the buzzer off to alert the nearby persons. Further, an exhaust fan was also turned on to remove the excess gas from the house. And in case of a fire, the value of the fire sensor changed from 0 to 1 in the LCD display and all the similar actions were performed by the Arduino.
Figure 7: Pictorial representation of the setup.

Figure 8: Raw assembly of the system
Figure 9: Threshold indicator for Gas leakage.

Figure 10: The exhaust after detection is automatically turned on for dissipating the gas.

X. CONCLUSION

This system allows an efficient, fast, and economical way to detect gas leakage and fire and consequently taking necessary precautions to avoid any further damage to life and property by utilizing the methodologies explained above. Furthermore, it will also alert the concerned individuals regarding the incident through SMS. The integration of detecting LPG gas and fire at the same time would be very effective in stopping a hazard. The LPG whose leakage is very harmful to human health and the fire outburst which can have devastating effects on human life and property can be saved at a very minimal cost and efficiency.
XI. FUTURE SCOPES

This monitoring and prevention system can be further enhanced by adding a mechanism to open the windows to remove the unwanted gas quickly and more effectively. In addition to that, a smart water sprinkling system can also be added to extinguish the fire (if any).

In the future, more advanced fire and gas sensors can be used to detect the leakage more effectively and quickly resulting in superior efficiency than the proposed setup. This system can also be developed to detect different types of gas leakage and fire in industries as well as in commercial places.

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