Design and Implementation of a GSM based Fuel Leakage Monitoring System on Trucks in Transit

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ABSTRACT

Many people in Uganda have been victims of fuel tank explosions from leaking fuel through getting injured, destroying their property and more so, losing their lives. This is a result of accidents and fuel leakages that go undetected causing fire explosions leaving big numbers of people dead.

The victims include those mostly at the refinery, during transportation including those who ignorantly rush to fetch fuel or those that happen to be at the scene at the time of the accident and also those working at the fuel storage site thereby claiming their lives unknowingly including;

31 people perished on Saturday 29th June 2013 at 10pm near Hoima Road round about along the northern by-pass in Kampala when a Toyota Ipsum bumped into a Fuel tanker.

In 2007, (26th August2007), 27 people died in a mini bus when it collided with a fuel truck on Masaka Jinja Highway. (KFM, 2014).

On December 3rd 2000, 90 people died when a fuel truck caught fire in Bukeesa, Iganga district.

These and many more have occurred in Uganda and if there is no immediate solution, the numbers will rise.

Therefore, there is need to come up with a circuit design that will automatically detect the presence of leaked fuels which will reduce on the fuel losses incurred by the owners and also reduce on the number of people who would get involved/injured in such explosions.

1. INTRODUCTION

The world generally depends on liquid fuel for its energy needs. Its uses are enormous ranging from industrial to domestic purposes and finally electricity generation.

Without liquid fuels, the world energy sector will be insufficient, this would affect economic developments. Since the source of liquid fuels is finite, there should be need to preserve the little that currently exists, this means, emphasis should be put to activities that lead to fuel loss.

With an estimate, each country surely has fuel reserve stations and several distant fuelling stations. This means, fuel has to be transported to different fuelling stations and during transit; these trucks encounter several problems ranging from accidents to theft of the liquid fuel.

With the theft of this fuel, or even in the event of an accident, the companies lose a lot of revenue. Putting revenue losses apart, fuel leakages can also lead to numerous of deaths of people (who gather at the accident scenes) in the event of a fire after the accident.

To avoid such accidents, fuel leakages should be detected before they cause a substantial loss of revenue and/or people. However, there has been an inefficient way of detecting fuel leakages in fuel storage tanks and also fuel tanks in transit. This has been done through smelling of these gases because when fuel gets in contact with air, it evaporates turning into a gas. It is this gas that is smelt to detect the presence of leaked fuel.

This has however, proved inefficient as it takes a lot of time to smell the presence of these gases and if such situations are not handled careful, explosions may result leading to death of people.

This paper presents an electronic mechanism of controlling this problem. The proposed circuit design helps to reduce on the probable dangers caused by these fire outbreaks after fuel leakages. The outbreaks may be a result of the fuel leaked through the welded joints of the tank. Also, after stealing fuel, the driver may unintentionally drive the truck while leaking the fuel and in the due process, an accident could be caused where the driver is left un-blamed. The outbreaks may also be at the remote fuelling stations in the fuel storage tanks as a result of leakages through the welded joints of the storage tank.

This design therefore consists of one or more sensors that can reliably monitor, detect, and send alerts upon occurrence of any fuel leakages. The alerts could be sent to the Police, the driver and the company responsible for the fuel in transit.

With the alert sent to the police, the police will always reach in time in-case the accident has occurred and before the tank explodes to keep away the innocent and greedy civilians from accessing the scene. This will in turn reduce on the number of people who could be affected and also secure their property around. Additionally, with the alert sent to the driver, he will be in position to stop the truck to take the necessary precautionary measure and thus avoid consequences of a further serious fire accident.

2. METHODOLOGY

The design and implementation was mainly partitioned into two core activities that include;

- Hard ware system design and implementation
- Software system design and implementation

2.1 HARDWARE SYSTEM DESIGN AND IMPLIMENTATION

The hardware system was built on a microcontroller based system that interfaced with two MQ-6 gas sensors for measuring LPG gas concentration in the air. The hardware system also had a keypad for changing the phone numbers stored in the system, GSM module for sending the alert messages, GPS module for acquiring the location coordinates, and a Liquid Crystal Display (LCD) for indication of the system status and any alarms that may occur within the hardware system.

2.1.1 System Design

The system layout diagram in figure 1 was developed to depict system functional design. After development of the system layout, design preceded with a system circuit design; selecting and interconnecting the various components based on the system layout. The circuit was designed using Proteus Isis Schematic Capture editor as shown in figure 2. The circuit consists of potentiometers that are used to represent the MQ-6 gas sensors, two virtual terminals that represent the GSM and GPS module, a keypad for input of commands to the system.

Note: *For purposes of this design, 4 gas sensors were used per truck; they are put around the welded joints of the truck as this is the likely point where fuel leakages could start.*

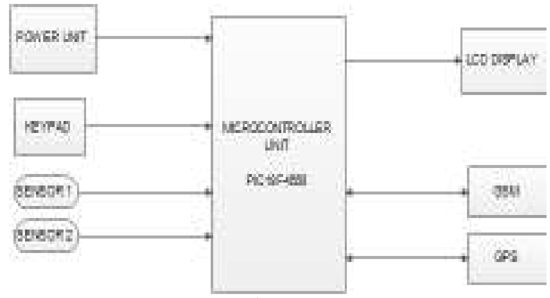

Figure 1- System Layout

The microcontroller was programmed to take analog readings from the sensors, convert the analog readings to ppm values, which later processes/analyses the values to determine if there is a fuel leakage or not.

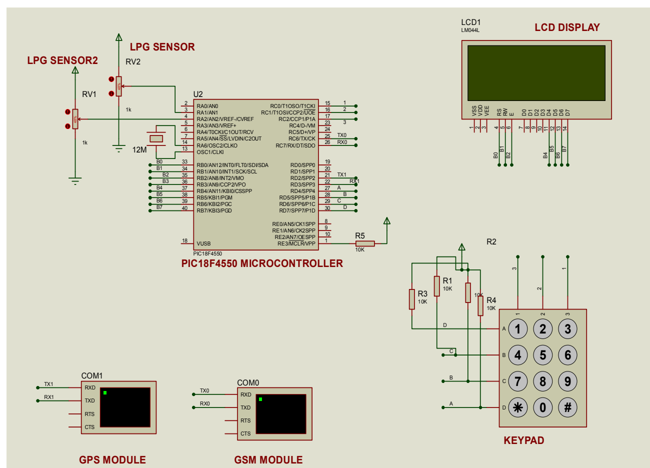

Figure 2 - Hardware circuit Design

With the circuit designed, selection of the desired components was the next phase.

2.1.2 Component Selection

a) Microcontroller; the PIC18F4550 microcontroller was chosen because of its features and specifications that are in the datasheet, and was to be programmed using the PICKIT3 (Microchip, 2014).

b) MQ-6 Gas sensors: These gas sensors are specifically sensitive to LPG gas and give an analog voltage reading at the output pin (DFRobot, 2014) (Emartee, 2014).

c) LCD display; the LCD display selected was a 20x4 monochromatic parallel LCD based on the HITACHI driver for easy interfacing with the microcontroller.

d) GSM module; this was a SIM900 based GSM module (SIM, 2014).

e) GPS Module; A UBlox GPS Receiver module (u-blox, 2014) was selected

f) Keypad. This was a 4x4 keypad that had all the number digits, i.e. zero to nine.

g) Perf Board. This is the circuit board that allows components to be soldered on to it, so that they are firm.

2.1.3 Component integration

The components were inter-connected with the aid of additional accessories to form the system unit, as shown in figure 3, based on the schematic design after careful analysis. The MQ-6 gas sensors were connected to the analogue inputs of the PIC18F4550. The GSM module Serial port was connected to the microcontroller's serial port for communication. The GPS module was connected to a software serial port of the microcontroller for communication; the KEYPAD was connected to a PORTD of the PIC18F4550 microcontroller.

2.1.4 Hardware Configuration and testing

The microcontroller was programmed to take periodic readings from the MQ-6 gas sensors, and process the readings to determine if there was a gas present due to fuel leakage.

If the gas due to fuel leakage was present the MCU would go ahead and notify (by SMS means) the authorities (i.e. appropriate stakeholders configured in the system) of the fuel leakage appending the GPS coordinates of the location for the truck or storage tank having the leakage.

The microcontroller was programmed as well to listen to keypad inputs and process them whenever a user needed to change the telephone numbers (to be notified by SMS) stored in the memory of the system.

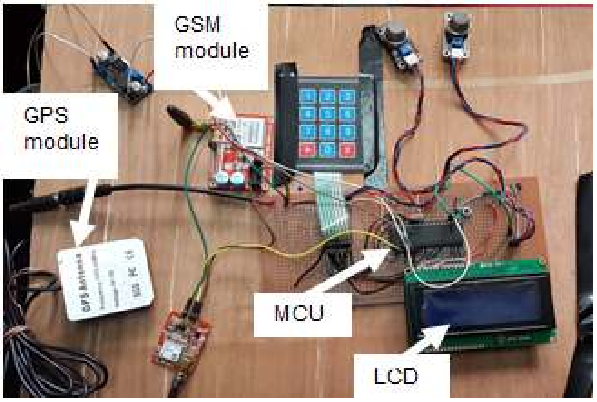

Figure 3- Developed System unit

2.2 System Software Features

The features of the designed prototype include the following;

a) LPG Gas concentration measurement
b) SMS based alerting of fuel leakage with GPS location coordinates.

2.3 System process flow

This was developed to aid in system programming as shown in the flow chart in figure 4.

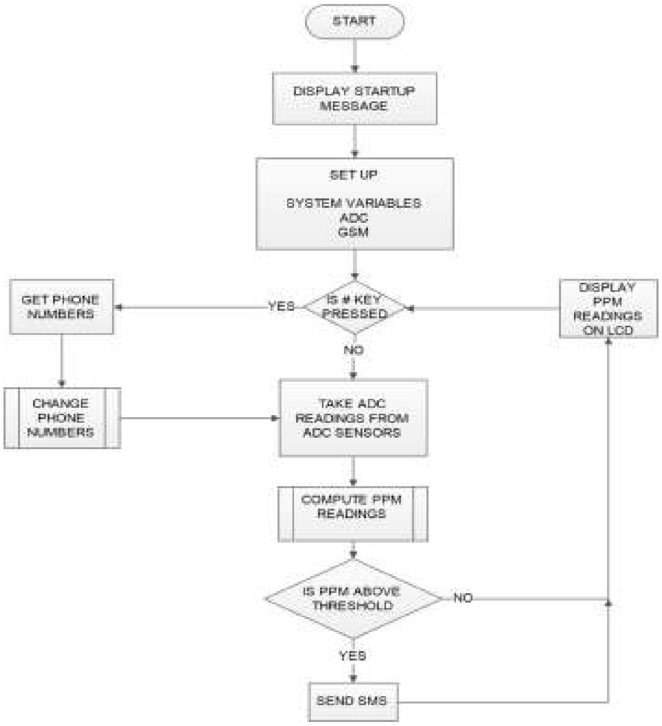

Figure 4-Process flow during start and monitoring of the LPG gas concentration levels

2.4 Testing and Tuning

The procedure of testing begins with powering up the system, and taking sensor readings. The fuel leakage was simulated by using fuel in a bottle and since it is highly flammable, the sensor was exposed to high concentrations of fuel.

The time response of the sensor was noted and using the different sensor readings, the threshold value was determined as 'ppm' as an appropriate level that fuel is leaking.

3. RESULTS

These results were obtained by running the system, testing it after it starts up, placing fuel next to the sensors to gauge the system speed of response, and sending of the notification SMSs to pre-configured telephone numbers.

3.1 Start-up

During this period of initial action, the sensors' readings were abnormally high without an LPG gas present. This was overcome by configuring a start delay message to allow the sensors to stabilize. The figure 5 below shows the start-up message shown as the system waits to stabilize after its start-up (i.e. powering).

Figure 5- Startup Message Display by system and sensors stabilize

3.2 Nominal Readings and Stable System

After the start-up, the system stabilizes and gives nominal system values of around 60ppm to 100 ppm as shown in the figure 6 below.

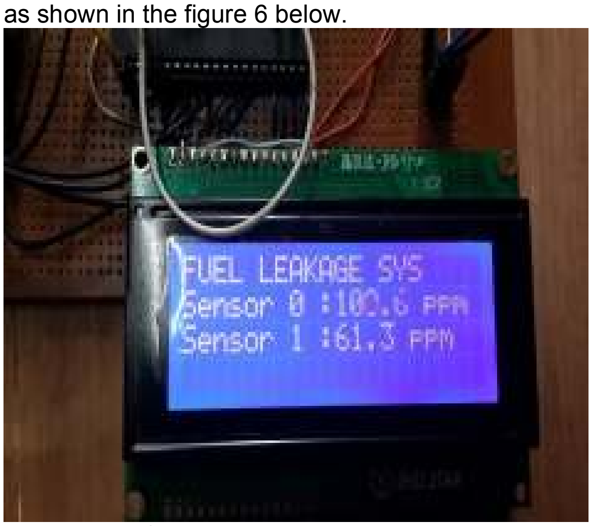

Figure 6 - System stable giving nominal readings

Once stability is achieved, the system was ready to detect the simulated fuel leakages. The fuel was then exposed (i.e. brought near) to the sensors to detect the gases emanating from the simulated fuel leakage.

Figure 7 below show what happens when a message has been initiated by the system and is to be sent to the relevant stakeholders.

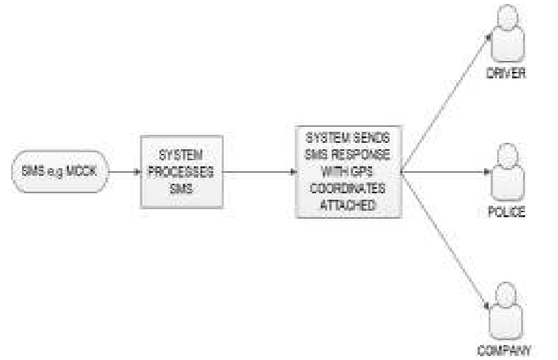

Figure 7 - Flow of message through the system (User-Initiated)

The figure 8 below shows the message received on the mobile phone when the system detects a fuel leakage.

Figure 8 - Message Received structure on Phone

Table 1: Summary of Results.

DESCRIPTION	VALUE
Start-up Time	10s
Sensor Response time to Fuel changes	1s
System Response time after detecting Fuel Leakage	10s
Threshold ppm Sensor Value	230ppm
Time Interval between sending messages to the different stakeholders	8s

3.3 ANALYSIS

System response is analysed on the desired operation and the following are the responses obtained by considering the particular equipment used in the system design.

3.3.1 System Start-up Sensor Response

According to the datasheet information, the sensors required some time to warm up initially and stabilize before they could be used; this time is referred to as the start-up time of the sensors.

When the sensors are powered down, and powered up later after some time, the sensor resistance drops sharply making the sensor give high output voltages (spikes) at the analog pin, irrespective of whether a gas (from the fuel leakage) is present or not. These voltages later reach a stable level which is dependent on the ambient atmosphere, and this according to the datasheet, was referred to as "initial Action"

This time before the sensor reaches a stable value (Initial Action) is dependent on the time the sensors been stored (without powering), storage environment, and the sensor variety, which are put into consideration when programming the system such that the "Initial action" period is catered for and the system does not give false alarms when the system starts-up since the sensor is still warming up during that time.

The figure 9 below shows the sensor resistance when initially powered up, it shows the start-up time for different times of the sensor being de-energized, with the longest time corresponding to when the sensor has been off for a long time.

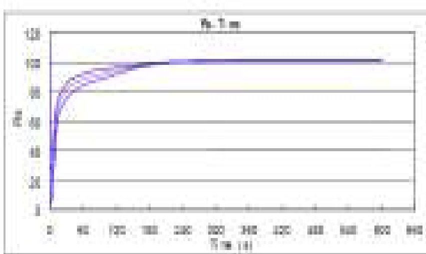

Figure 9 - Initial Sensor Response when powered up

3.3.2 Sensor Response

The MQ sensors were not so responsive, and adjustments needed to be done to get them to be sensitive enough to the fuel leakage. This was done based on the datasheet information obtained about the sensors.

Sensor resistance will drop very quickly when exposed to the gas produced due to the fuel leakage, and when removed from this gas its resistance will recover to its original value after a short time. The speed of response and reversibility vary according to the model of sensor and the amount of gas involved.

For the MQ-6 Sensors, the speed of response was within 1s. In order to avoid false positives when the sensor detects high fuel leakage presence, it periodically checks the sensor readings every 10s. If after 10s the sensor readings are still high, then fuel is most definitely leaking.

3.3.3 System Response

Sensor sensitivity was 1s, which allowed the system take readings after a period, and wait for some time before alerting by SMS that fuel is leaking and immediately sent SMS upon detection of high fuel leakage levels.

To cater for stray false positives that would occur such as fuel blow over the sensor by air, a time lag was introduced to the detection, such that it would delay for a given time period while taking readings to determine whether actually there is constant high readings of fuel leakage before sending the notification (alert) message.

4. CONCLUSION

With all the gas sensors accurately placed and with a reliable GSM network provider, communication to the concerned personnel can easily be relayed if there is any fuel leakage with the correct GPS location coordinates, and depending on the reported leakage, the necessary precautionary steps can be taken.

In comparison to the smelling method that is being used by most people to realise fuel leakages, this system offers a much improved and automated solution before there is a substantial negative effect on the lives of people the revenues of companies whose fuel is in transit.

5. AREAS OF IMPROVEMENT

- To use an Arduino Board (Arduino, 2014). Arduino is an open source platform, and the compilers are free, it has a lot of support with a lot of libraries that are readily available. The Arduino is a better microcontroller as compared to the PIC microcontroller.
- Using XBee wireless transceivers for redundancy incase the GSM network goes down. XBee works in the 2.4 GHz spectrum, this transceiver works in a 40km radius, so it can always send a message to the relevant stakeholders in that radius range.
- Developing a web portal for proactive monitoring of the truck, this will as well show if the driver has taken a different transit route from the prescribed one.
- Using GPRS for communication with the web portal.

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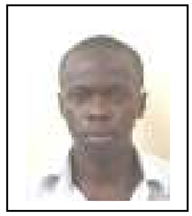

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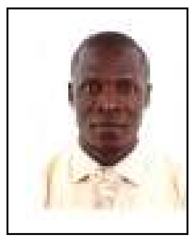

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