Development of wireless sensor network system for LPG gas leakage detection system

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Abstract— Leakage of a gas in any sector may cause many health issues and hence in the work places it is to be cautioned against such disaster happenings by implementing a safety system that can make an early alert to the users. This paper describes the development of wireless sensor network for LPG gas leakage detection. The proposed design includes: an Arduino Nano microcontroller, gas sensor and a XBee. The sensor node will detect a minute concentration of the gas according to the voltage output of a sensor and also collects the gas leakage data thereby locating the specific area of the sensor node. XBee sends the data from gas sensor to the monitoring system that is displayed on LabVIEW GUI. A GSM module was as a communication tool between the microcontroller unit and mobile phone unit. The system could be installed at any remote place and could be controlled by any mobile phone supporting the SMS service. The reliability and productivity of the system are the key concerns and influence the design and development choices for the system in terms of the hardware and software designs.

Index Terms— Arduino, Gas leakage detection, GSM shield,Gas leakage monitoring,RSSI, LabVIEW, XBee.

1 INTRODUCTION

Natural gases such as liquefied petroleum gas (LPG) are widely used in industries. It is certainly possible that the gases may leak and the system needs to be real time monitored. This paper presents design and development of a wireless gas leakage monitoring system by using the Arduino and XBee.

The system is configured in star type topology with devices and sensors in it and then controls all the devices through a gateway node with XBee network, and takes safety measures to protect against serious risk. The proposed system uses XBee as a wireless device, sensors and Arduino controller that not only increases the system performance and but provides safety measures also.

In actual, the work was carried out using Arduino nano board, MQ-2/MQ-6 gas sensor, XBee and a GSM module. The sensor has excellent sensitivity combined with a quick response time at low cost. Under gas leaked condition message to the authorized person or family member using Arduino GSM shield is sent automatically.

Traditionally, gas leakage detection is monitored by a wired sensor network, wherein power requirements and maintenance cost are significantly high "[1]".To overcome the limitations of traditional system wireless sensor network is the best choice. The high power requirement of wired sensor network can be made simpler using WSN technology that uses different protocol standards for short range wireless communication like Bluetooth, WI-Fi and Zigbee. Nowadays, Zigbee is widely used in gas leakage monitoring applications for real time monitoring of the threat area.

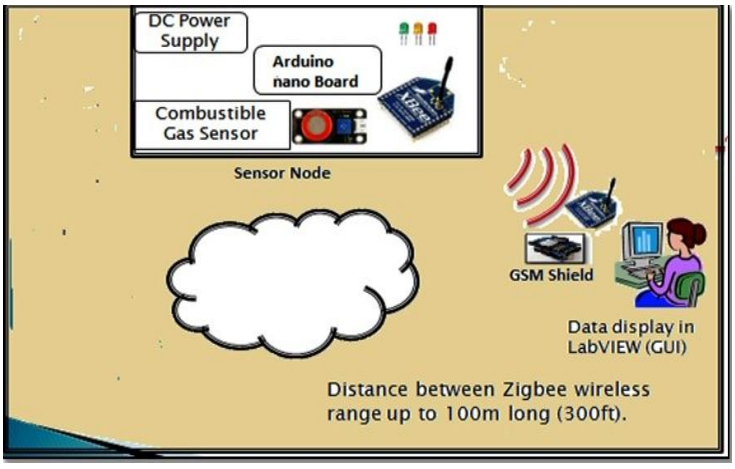
The monitoring of the proposed design is done through LabVIEW "[2]", [3]". Also, GUI created using LabVIEW tool is more interactive, facile and effective compared to the reported methods.

2 SYSTEM ARCHITECTURE AND DESCRPTION

Many gas detecting systems are available which can detect different levels of gas concentrations effectively. In this paper we present a wireless sensor network for gas leak detection based on a small-scale and low cost device those achieve Processing, storing, sensing and communicating. The basic block diagram of the proposed system is shown in figure 1.

Fig. 1. Block diagram of a wireless gas sensing s system

2.1 Wireless sensor node



The fundamental architecture of the WSN sensor node consists

of a sensor unit, an analog signal conditioning unit, a computation unit and a wireless communication unit. The WSN nodes were designed using these architectural tools.

Figure 2 shows a node prototype which is an Arduino board that serves as a sensor node.

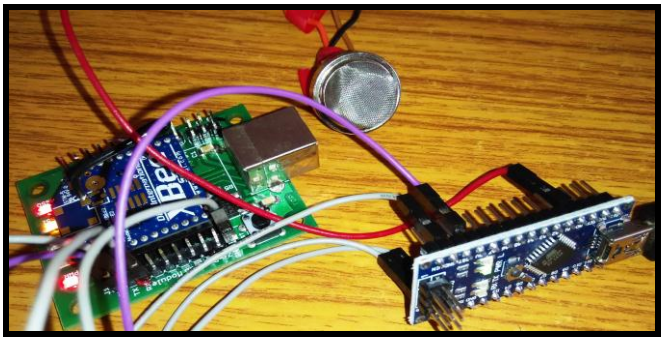


Fig.2 wireless sensor node

2.2 MQ-2 gas sensor

The sensitive material used in MQ-2 gas sensor is tin oxide (SnO2), which has lower conductivity in a clean air medium. When the target LPG leak is detected, the sensor's conductivity rises and increases proportionately as the extent of gas leakage increases. The detection range of MQ-2 gas sensor is 300-5000 ppm"[4]" and has fast response time and is a low powered device (5V). This sensor has different resistance value in different concentration.

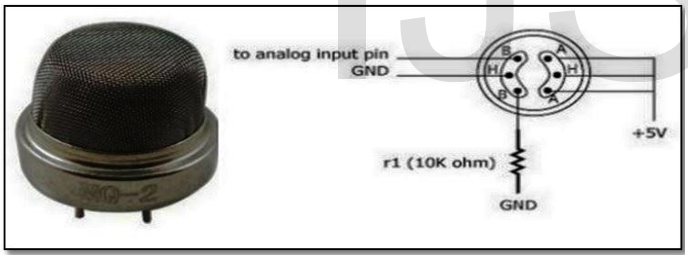


Fig.3.MQ-2gas sensor

2.3 Gas sensor calibration

The Calibration of MQ-2 gas sensor was done in a gas chamber using a standard medical syringe. The gas concentration in ppm was varied and corresponding output voltages were noted. This is shown in fig 5.

Fig.4. Sensor calibration unit

The voltage ranges for LPG gas concentration corresponding to various levels were measured and these are given in the following Table 1.

Gas concentration in ppm	voltage range in volts
≤400PPM	**≤1.5V (normal level)**
400PPM – 800PPM (lower exposure limit)	**≥1.5V TO _ ≤4.2V (low level)**
≥800PPM (upper exposure limit)	**≥4.2V (explosive level)**

TABLE 1. THRESHOLD LEVEL OF GAS SENSOR

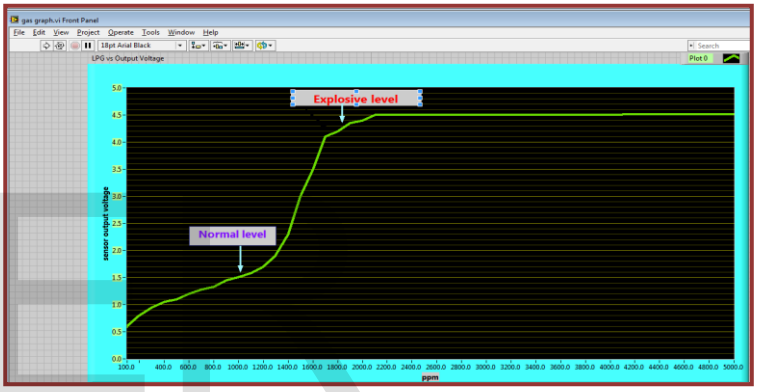


Fig.5.Graph on sensor output voltage Vs ppm

The fig. 5. Implies that if the gas concentration is increased above the normal threshold level (400ppm), the system activates and gives alert to the user.

2.4 Microcontroller unit

An Arduino UNO was used as a microcontroller for gateway node and an Arduino nano as a microcontroller for sensor nodes. These devices are considered as an open source electronic platform based on flexible hardware and software. Windows, Macintosh and Linux operating system supported the Arduino software based on C programming language and can be expanded through C++ libraries" [5]".

One of the microcontroller board used was an Arduino UNO based on the ATMEL microcontroller (ATmega328). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button [11]. It contains everything needed to support the microcon-

troller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. Arduino nano is small, complete and breadboard-friendly board based on ATMEGA 328 and works with Mini-B USB cable instead of standard one. It has 14 digital input or output pins (of which 6 can be used as PWM outputs), 6 analog inputs and a power jack, an ICSP header, and a reset button [5-6] having number of facilities for communication with the computer.

2.4 Zigbee transceiver

ZigBee is a set of specifications created specifically for control and sensor networks. Built on IEEE 802.15.4, the standard for low data rate wireless personal area networks (WPANs). It is a low latency, low data rate, low cost, and low energy consumption device. IEEE standard 802.15.4, which defines the physical layer (PHY) and media access control (MAC) for low-rate WPANs, restricts the data rate to 250 kbps in the global 2.4-GHz Industrial, Scientific, Medical (ISM) band, while also specifies low power consumption and cost. The Zigbee is a program using X-CTU software.

2.5 Arduino GSM shield

The Arduino GSM shield allows an Arduino board to connect to the internet, make/receive voice calls and send/receive SMS messages. The shield uses a radio modem M10 by Quectel and it is possible to communicate with the board using AT commands. The shield establishes for software serial communication with the M10. Pin 2 is connected to the M10's TX pin and pin 3 to its RX pin. The modem's PWRKEY pin is connected to Arduino pin 7.

The M10 is a Quad-band GSM/GPRS modem that works at frequencies typically, at GSM 850MHz, GSM 900MHz, DCS 1800MHz and PCS 1900MHz. It supports TCP/UDP and HTTP protocols through a GPRS connection. GPRS data downlink and uplink transfer maximum speed is 85.6 kbps. The modem can pull up to 2A of current at peak usage, which can occur during data transmission. This current is provided through the capacitor on the board's surface.

3 SOFTWARE APPROACH

3.1 Flowchart

The sensor node sends the output data from gas sensor to the gateway node with the help of XBee transceiver. The LabVIEW tool is provided for interfacing the hardware and software parts. Then based on the threshold value set, the sensor will keep on sensing the gas concentration, which is monitored it on LabVIEW as shown in Fig. 6. Fig.6 is a flowchart for a wireless gas leakage monitoring system.

Fig 6. Flowchart for wireless gas leakage monitoring system.

3.2 Arduino Programming for MQ-2

In this wireless gas leak detection system, the sensor is connected to an analog port of the Arduino nano board (sensor nodes)" [7]", which measures various gas concentration at ppm level and sends them to the Arduino UNO board (Gateway Node).The status of sensor nodes where the leakage exists is shown in serial monitor window in a gateway node as below (fig.7)

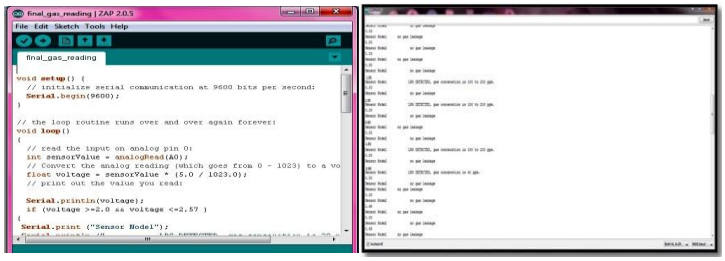


Fig. 7.Arduino programming for MQ-2

4 RESULT AND ANALYSIS

The present system was placed inside a room where a gas cylinder was placed and leak detection was noted. The gas leakage response can be obtained and send to the mobile users saved in Arduino GSM shield and also displayed on the monitoring system.

4.1 RSSI test of XBee module:

The signal strength indication of XBee series 2 was tested using USB to UART convertor connected to it and tested on condition such that they are between the indoor of the room. Ta-

ble 2 shows the actual value obtained from the X-CTU software on testing the signal strength indicator for XBee module.

TABLE 2. READING OF RSSI AND INDOOR DISTANCE FOR XBEE MODULE

Distance meters	RSSI dBm
0	-40
4	-67
5	-79
8	-81
9.77	-84

The fig.8 shows a plot of RSSI values in dBm versus distance in meters. The longest detect range for XBee is up to 9.77m, and captured RSSI value is -84 dBm. As the distance is increased, signal strength of XBee is decreased.Fig.9 indicates RSSI indication of XBee module in X-CTU.

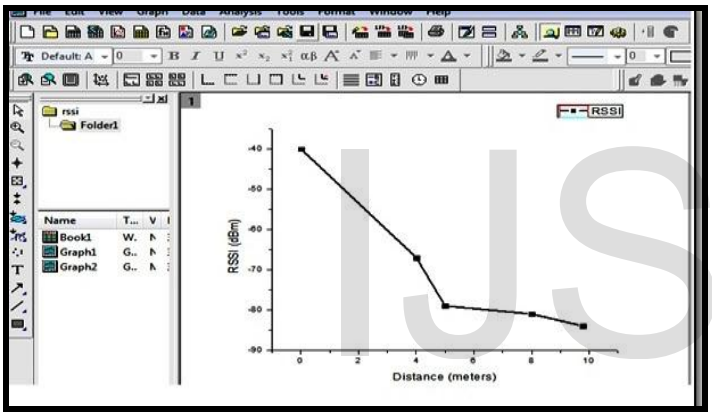


Fig. 8. A plot of RSSI (dBm) vs Distance (meters)

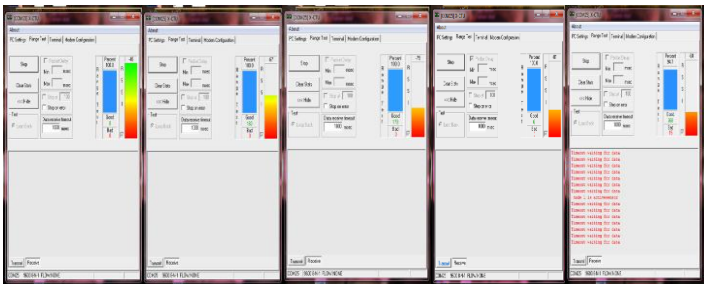


Fig. 9. RSSI indicator of XBee module in X-CTU

4.2 Monitoring the system using GSM shield

In order to perform the correct operation of the proposed system, we selected a fixed phone number in our system and applied different operations (monitoring). The user is from the different locations than the gas leakage place "[8]". Fig.10 shows the pictures taken from user mobile phone after the fixed phone number in GSM shield sends SMS when gas leakage happens.

The mobile phones do not require to have any special applications or hardware to be used in this system, and any mobile phone supporting the SMS service could be used in the system. At normal situation, just one mobile phone number depended to send/receive command-messages in the system (i.e. homeowner's phone number). But, to add additional numbers, it can be done very easily by changing the related source code.

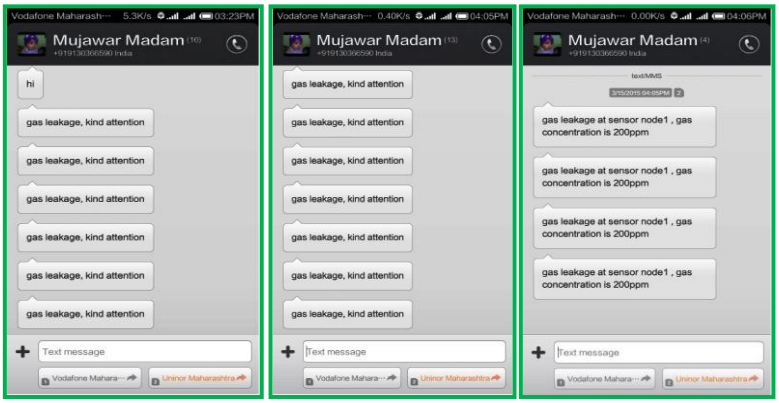


Fig.10.SMS indication on user mobile phone

4.3 Monitoring the system using LabVIEW tool

The LabVIEW graphical user interface (GUI) was used to monitor the leakage level of gas concentration. It offers unrivaled integration with thousands of hardware devices and provides hundreds of built-in libraries for 14 advanced analysis and data visualization – all for creating virtual instrumentation [6]. The LPG detection using LabVIEW is demonstrated using star rating. Figure 11, 12 and 13 indicate three levels of gas leakage, i.e normal, low and explosive level. If the gas concentration is less than 400 ppm and sensor output voltage is less than or equal to 1.5V, then LabVIEW front panel will display one star which indicates normal level of gas leakage.

If the gas concentration is in the 400 to 800 ppm range and sensor output voltage is between 1.5V to 4.2V, then LabVIEW front panel will display three stars which indicate low level of gas leakage. If the gas concentration is greater than 800 ppm and sensor output voltage is also greater than 4.2V, then LabVIEW front panel will display five stars, which indicates explosive level of gas leakage. Based on the GUI, there are voltmeter and gas tank provided, to ease user's to observe the level of gas leak. Fig. 11, Fig.12, Fig.13 shows the gas leakage monitoring system in normal level, low level and explosive level respectively.

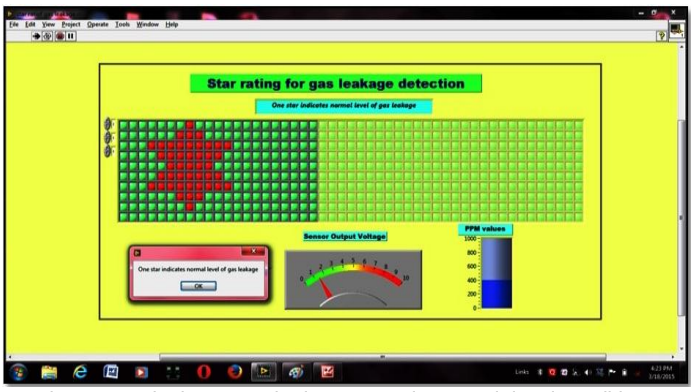


Fig. 11.Gas leakage monitoring system in normal level condition

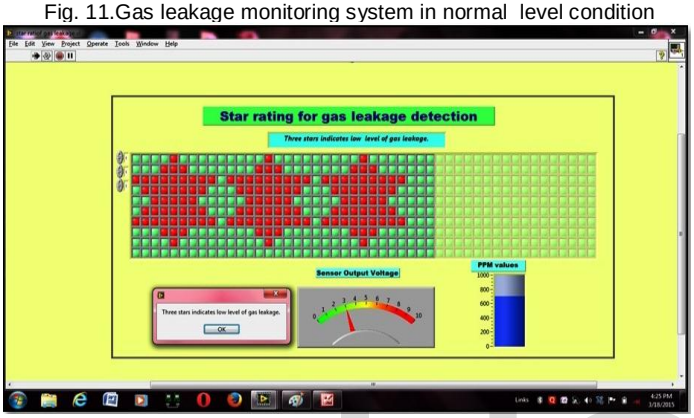


Fig. 12.Gas leakage monitoring system in low level condition

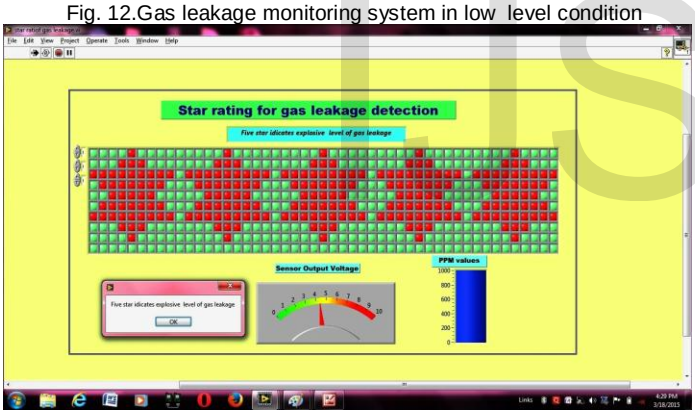


Fig. 13.Gas leakage monitoring system in explosive level condition

The programming of these is done by using block diagram in LabVIEW software.Fig. shows programming of GUI using LabVIEW software.

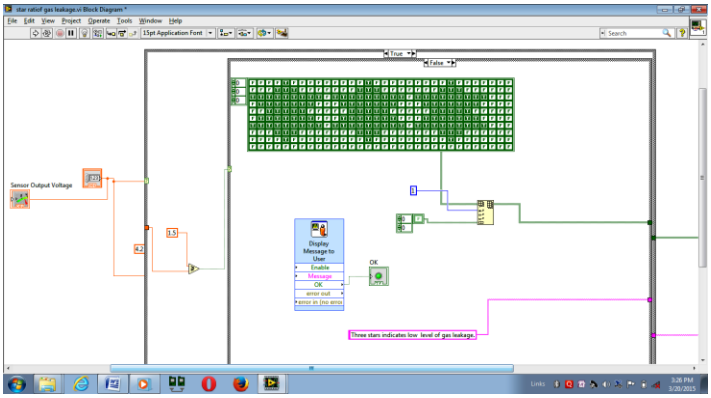


Fig. 14. shows programming of GUI using LabVIEW software.

4 Conclusion

The proposed system describes a new visual LabVIEW approach in the area of gas leakage detection at a low gas concentration. The leakage is detected with the help of MQ-2 gas sensor. As a conclusion, reading of the output voltage from the gas sensor shows the value of concentration and level of explosiveness in LabVIEW using five star rating. The designed system monitors the gas leakage detection via Arduino microcontroller depending on the GSM network. The most important is that the mobile phone does not requires any special application or hardware to be used in this system, and any mobile phone supporting the SMS service could be used in the system. The system also gives an advantage to the user to easily get the information about the gas leakage area by monitoring the system using PC/Laptop via Zigbee wireless.

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