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A Review on Dynamic Stand-Alone Gas Detection System

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ABSTRACT: Growing industries are need of 21st century, but these growing industries are also responsible for growing pollution. Not only the industries but also need of transportation is also increasing which leads to increase in concentration of carbon dioxide, carbon monoxide, etc. gases. So, detection and concentration monitoring (mapping) of these gases is very important issue. Currently various static systems are located at key locations. But these systems doesn't provide gas source localization and mapping at various different locations. Therefore this dynamic system is designed. This system is designed such as by connecting as payload to drones we can use the same system at various locations. In this system chemo resistive and electrochemical sensors used for detection of carbon monoxide, sulfur dioxide (any sulfurvapors) and carbon dioxide. For controlling of system AVR ATmega 16 controller is used. This system is very beneficial as only single circuit can be used for large area and main purpose of gas localization is satisfied.

KEYWORDS: carbon monoxide (CO); methane (CH_4); LPG; gas detection and gas source localization; permissible exposure limit; lower explosive limit; upper explosive limit.

I. INTRODUCTION

In the past few years, earth's atmosphere is becoming more and more unstable due to growing pollution. Major cause of pollution is industries and increase in number of transportation vehicles. Result of this is depletion of ozone layer and adverse effects on human health. Thus monitoring of these gases is very necessary.Earth's atmosphere contains various gases in specific concentration which keeps earth's atmosphere as per required by human body. Major components of earth's atmosphere in homosphere (80-100 km from surface) are nitrogen, oxygen and water vapours. Amongst these gases some are permanent gases while some are variable.

The causes of pollution may be different such as man-made and natural. Man-made causes includes industrial pollution, pollution from vehicles, pollution from plastic wests, etc., while natural pollution occurs due to forest fire, volcano etc. Measurement of gases is important aspect according to pollution control as well as toxic gas detection and their source localization. In industries or at gas station there is possibility of toxic or flammable gas leakage. Most of the gases are colourless and odourless which makes them difficult to detect by human sensory organs. These gases can cause fatal accidents such as fire, suffocation, etc. Therefore detection and GSL of these gases is very important.

Occupational Safety and Health Administration (OSHA) and National Institute for Occupational Safety and Health (NIOSH) give the maximum permissible exposure limit for different toxic and combustible gases. PEL for toxic gases is given by ppm whereas for combustible gases it is given by Lower Explosive Limit (LEL) and Upper Explosive Limit (UEL). According to OSHA and NIOSH, in the industrial area with 8 hours of work shift maximum PEL for CO_2 is 5000 ppm, for CO it is 35 ppm, for CH_4 there is no specific PEL, for LPG it is 1000ppm. The combustible gases such as LPG and Methane are also represented in terms of LEL and UEL. For LPG, LEL is 1.8% and UEL is 8.4% whereas for methane, LEL is 5% and UEL is 15%. Concentration of these gases beyond given PEL for more than 8 hour work shift can cause adverse effects to human health.

Gas detection is the recommended system and it is required by the law for people's safety. It is needed for pollution control by concentration measurement as well as for detection of combustible and toxic gases which are difficult to detect by human. The system is required for safety of life and property which must provide early warning of

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hazardous condition with safety measure such as notification, ventilation, water sprinkler, etc. by GSL and gas detection mapping.

II. RELATED WORK

As gas detection is very important issue various methods can be used from manual inspection using trained dogs to advanced satellite using multiple spectral imaging. Optical and non-optical detection are two major categories for gas detection technique. Optical gas detection methods are again classified as active and passive optical techniques. As the name suggests optical source such as laser is used in the active gas detection and no source is used in passive gas detection. Passive gas detection system will reduce the cost required for the source but the detectors used must require higher sensitivity for proper detection of gases which also increases the cost of the system.

Thermal imaging [12][24] and multi-wavelength imaging [1][2][19] are the two major types of passive optical systems used for monitoring natural gas leaks from pipelines. Thermal imaging detects natural gas leaks from pipelines due to the temperature difference between the natural gas and the immediate surroundings. This method can be used from moving vehicles, helicopters or portable systems and is able to cover several miles or hundreds of miles of pipeline per day. Usually, high sensitivity thermal imagers are required to pick up the small temperature differential between the leaking natural gas and the surroundings which are expensive. Also, thermal imaging will not be effective if the temperature of the natural gas is same as that of the surroundings.

In multi-wavelength or hyper spectral imaging, there are two modes of operation absorption mode and emission mode either can be used for gas detection. In emission mode, the gas temperatures have to be much higher than the surrounding air in order to detect gas concentration. Multiwavelength emission measurements have been typically used in the past to obtain single point concentrations in hot combustion products [19]. Multi-wavelength absorption imaging utilizes the absorption of background radiation at multiple wavelengths to directly image the gas concentration, even in the absence of temperature gradients between the gas and the surrounding air. Although the technique can be installed successfully from ground or vehicle or aircraft, high sensitive and expensive imagers are required for accuracy. The similar hyper spectral imaging system was designed where cost effective multispectral scanner was designed for natural gas detection. The system reliably detected small leaks at 30- 50 feet height but source localization was little challenging which required moving vehicle mounted scanner [25].

Active monitoring of natural gas leaks from pipelines has been achieved with Lidar systems, [18][7], diode laser absorption [8], Millimeter Wave Radar systems [4], backscatter imaging [11], broad band absorption [20], and evanescent sensing. Lidar systems typically use a pulsed laser as the illuminating source. The absorption of the energy of the laser along a long path length is monitored using a detector. According to the Lidar gas detection system pulse of laser radiation of wavelength λ_0 is transmitted by Lidar trans-receiver, laser waves are scattered according to Raman scattering principle. Due to special properties of the gases the wavelength of transmitted signal gets shifted to λ_i and according to the deviation of wavelength gas is detected.

Diode laser absorption uses the same technology but here diode lasers are used instead of the more expensive pulsed lasers. If only a single wavelength is used, the system can be prone to false alarms since the laser can be absorbed equally well by dust particles.

Broad band absorption systems utilize low cost lamps as the source for reducing the cost of the active system. Also, monitoring is achieved at multiple wavelengths to prevent false alarms. For evanescent sensing, an optical fiber is buried along with the pipe. When natural gas leaks causes local changes in pressure or concentration leads to a change in the transmission characteristics of the optical fiber. This change in the transmission characteristics is monitored using lasers and optical detectors.

Millimeter wave radar systems obtain a radar signature above the natural gas pipelines. Since methane is much lighter than air, the density difference provides a signature that can be used as an indicator of a potential leak. Backscatter imaging utilizes a carbon-dioxide laser to illuminate the area above the pipeline. The natural gas scatters the laser light very strongly. This scattered signature is imaged using an infrared imager or an infrared detector in conjunction with a scanner.

The primary non-optical methods include acoustic monitoring [6][10]; gas sampling [21], soil monitoring [22], flow monitoring [23][3], and software based dynamic modeling [5][13]. Acoustic monitoring techniques typically detect changes in the background noise pattern using acoustic emission sensors. The advantages of the system include detection of the location of the leaks as well as non-interference with the operation of the pipelines. However, a large number of acoustic sensors are required to monitor a large area. The technology is also unable to detect small leaks that

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do not produce acoustic emissions at levels substantially higher than the background noise. Attempts to detect small leaks can result in many false alarms.

In gas sampling method, flame ionization detector housed in a hand held or vehicle mounted probe is used to detect methane or ethane. The primary advantage of gas sampling methods is that they are very sensitive to very small concentrations of gases. Therefore, even very tiny leaks can be detected using gas sampling methods. The technique is also immune to false alarms. The disadvantages of the technology are that detection is very slow and limited to the local area from which the gas is drawn into the probe for analysis. Therefore the cost of monitoring long pipelines using gas sampling methods is very high.

In soil monitoring methods, the pipeline is first inoculated with a small amount of tracer chemical. This tracer chemical will seep out of the pipe in the event of a leak. This is detected by dragging an instrument along the surface above the pipeline. The advantages of the method include very low false alarms, and high sensitivity. However, the method is very expensive for monitoring since trace chemicals have to be continuously added to the natural gas. In addition, it cannot be used for detecting leaks from pipelines that are exposed.

In flow monitoring devices detection of gas leakage is done using measurement of the rate of change of pressure or the mass flow at different sections of the pipeline. If the rate of change of pressure or the mass flow at two locations in the pipe differs significantly, it could indicate a leakage. The major advantages of the system include the low cost of the system as well as non-interference with the operation of the pipeline. The two disadvantages of the system include the inability to pinpoint the leak location, and the high rate of false alarms.

In software based dynamic modeling, various flow parameters at different locations along the pipeline are measured. These flow parameters are then included in a model to determine the presence of natural gas leaks in the pipeline. The major advantages of the system include its ability to monitor continuously, and non-interference with pipeline operations. However, dynamic modeling methods have a high rate of false alarms and are expensive for monitoring large network of pipes.

Chemical sensor based method (chemo resistive, electrochemical sensors) are most suited method as it can be implemented on drones very easily as payload weight is relatively less and sensitivity is good which gives proper gas detection with source localization. Mcgonigle provided an early demonstration using a small remotely piloted helicopter flying into gas plumes from an active volcano to measure the chemical concentrations of CO2 and SO2 as a part of geophysical research [16]. Neumann demonstrated the first rotary wing micro-UAV-based GDM and GSL. The experiments were conducted in small outdoor environment. The challenges in the system were reported to be gas distribution changes due to drone rotors [17].Malaver illustrated the efforts in greenhouse gas monitoring through the use of a fixed wing, solar-powered UAV system with an integrated MOX sensor to measure CO2 and CH4 [14]. Johnson presented chemical vapor detection sensor with two types of micro-UAV i.e. fixed wing and rotary wing. The tests were performed in an enclosed environment but the work did not progress to the real time system [9].

As far as optical gas detection techniques are concerned both active and passive techniques are expensive with complicated process for GSL. For non-optical techniques, in acoustic monitoring small gas leakages are difficult to detect. In gas sampling method sensing process is slow and restricted for small area. In soil monitoring method only underground detection is possible. In flow monitoring GSL is not achieved. Software based techniques are expensive for gas detection.

Chemical sensor based techniques can be more reliable techniques for gas detection and GSL in real time. These systems are not so expensive and also light in wright with low power consumption. So that payload can be easily attached to a drone for gas detection in large areas.

III. PROPOSED ALGORITHM

The proposed system consists of chemo-resistive and electrochemical sensors which will detect different gases such as CO_2, SO_2, and CO. These sensors detect the concentration of the gases, if the gas concentration is above PEL the gas concentration is recorded with the location and it will take the sample readings in surrounding area and record them. These recorded readings are compared and gas leakage source is detected according to highest recorded gas concentration. The readings are recorded in the SD card and location is determined using GPS system. After processing readings gas source is located and the location is send to base station or monitoring station or the emergency services in the area of gas leak to avoid catastrophe. Here LCD display is also attached which will display the current gas concentration reading. Whole sensing, monitoring and controlling is done by microcontroller. The whole system mainly focuses on two things i.e. detection of gas concentration and gas source localization.
Hardware requirement of this system consists of following components:

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1. AVR ATMega16 Microcontroller
2. MQ7 sensor
3. GPS module
4. GSM module
5. Display unit
6. Power supply

System block diagram is shown below in fig 3.1.

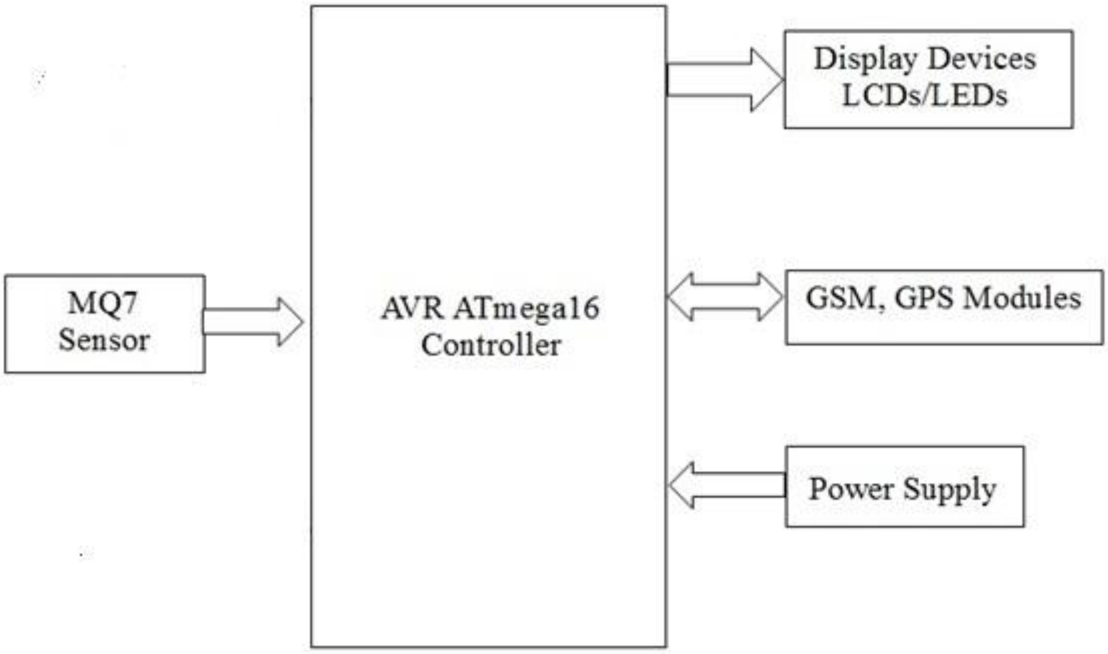

Fig 3.1 Block Diagram of Proposed System

A) AVR ATMega16 Microcontroller

In the proposed system microcontroller is programmed to read the sensor output and compare it with the max PEL which is predefined by OSHA and NIOSH. If the sensor value is greater than PEL then sensor value is recorded with location and monitoring station is informed that gas is detected with concentration value and location. Also after taking reading in the nearby areas controller compares all the readings in that area and gives location with highest concentration which can be referred to gas leak source.

Here we are using arduino board with given AVR ATmega16 microcontroller. Auduino boards are very popular nowadays due to their promising features. Major advantages of the arduino include inexpensive hardware board, cross platform means arduino software can run on windows operating system, Macintosh OSX and linux. Arduino programming environment is easy for beginners. Arduino software is published as open source tool available for extension by experienced programmers. Programming language can be expanded through C++ libraries. Also user can leap from Arduino to AVR-C programming language. AVR-C code can be directly added into arduinoprograms.Technical specifications of this controller are given below:

• High-performance, Low-power AVR® 8-bit Microcontroller
• Advanced RISC Architecture
  – 131 Powerful Instructions – Most Single-clock Cycle Execution
  – 32 x 8 General Purpose Working Registers
  – Fully Static Operation
  – Up to 16 MIPS Throughput at 16 MHz
  – On-chip 2-cycle Multiplier
• High Endurance Non-volatile Memory segments

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– 16K Bytes of In-System Self-programmable Flash program memory
– 512 Bytes EEPROM
– 1K Byte Internal SRAM
– Write/Erase Cycles: 10,000 Flash/100,000 EEPROM
– Data retention: 20 years at 85°C/100 years at 25°C
– Optional Boot Code Section with Independent Lock Bits
– Programming Lock for Software Security

• JTAG (IEEE std. 1149.1 Compliant) Interface
  – Boundary-scan Capabilities According to the JTAG Standard
  – Extensive On-chip Debug Support
  – Programming of Flash, EEPROM, Fuses, and Lock Bits through the JTAG Interface
• Peripheral Features
  – Two 8-bit Timer/Counters with Separate Pre-scalers and Compare Modes
  – One 16-bit Timer/Counter with Separate Pre-scaler, Compare Mode, and Capture Mode
  – Real Time Counter with Separate Oscillator
  – Four PWM Channels
  – 8-channel, 10-bit ADC
  – Byte-oriented Two-wire Serial Interface
  – Programmable Serial USART
  – Master/Slave SPI Serial Interface
  – Programmable Watchdog Timer with Separate On-chip Oscillator
  – On-chip Analog Comparator
• Special Microcontroller Features
  – Power-on Reset and Programmable Brown-out Detection
  – Internal Calibrated RC Oscillator
  – External and Internal Interrupt Sources
  – Six Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, Standby and Extended Standby
• I/O and Packages
  – 32 Programmable I/O Lines
  – 40-pin PDIP, 44-lead TQFP, and 44-pad QFN/MLF
• Operating Voltages
  – 2.7 - 5.5V for ATmega16L
  – 4.5 - 5.5V for ATmega16
• Speed Grades
  – 0 - 8 MHz for ATmega16L
  – 0 - 16 MHz for ATmega16
• Power Consumption @ 1 MHz, 3V, and 25°C for ATmega16L
  – Active: 1.1 mA
  – Idle Mode: 0.35 mA
  – Power-down Mode: < 1 µA

IV. CONCLUSION

In this paper a dynamic stand-alone gas detection system is proposed. This system is used to detect combustible and toxic gases in order to avoid any type of catastrophe. Amongst various gas detection systems, sensor (chemo resistive) based system is used as the sensor based technique is reliable, comparatively low cost, low power consumption and easy portability. Here sensor detects the gas concentration and notifies if danger is present with gas leak source localization. Locations and respective gas concentrations are notified and recorded.

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