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Underground pipe gas leakage detection robot

Ch. Prasanna Lakshmi, E. Rishita, Y Sneha Reddy, Syeda Sana Ftima, P Akshitha
[1]Assistant Professor, Department Of Eee, Bhoj Reddy Engineering College For Women, India.
[2,3]B. Tech Students, Department Of Eee, Bhoj Reddy Engineering College For Women, India.

ABSTRACT

This project aims to develop an underground travelling robotic system for detecting gas leakages and transmitting real-time location data to the cloud using the Internet of Things (loT). Ensuring safety in underground environments requires automated systems that efficiently detect and respond to hazards. The proposed robot moves along pipelines, monitors gas levels, and provides instant alerts.

The system consists of ESP32 microcontroller, two 12V DC gear motors controlled via an L293D H-Bridge, and an MQ-2 smoke sensor. Upon detecting a gas leakage, the robot stops and sends GPS coordinates to a cloud server using an NE06 GPS module, An ESP32 camera enables live video streaming, accessible via a web-based interface for remote monitoring and control.

Hardware components include a 16x2 LCD for status display and a 12V DC battery for power. The system is programmed using Arduino IDE, with circuit simulations performed in Proteus. loT connectivity enables real-time data transmission and centralized monitoring, improving response efficiency.

This project is beneficial for industries dealing with gas pipelines, fire safety, and hazardous environment monitoring, ask it enhances safety and reduces manual inspection efforts.

Applications include fire-fighting robots, industrial automation, and pipeline inspections. Future enhancements may incorporate sensors for toxic gas detection and environmental monitoring.

1-INTRODUCTION

The transportation of natural gas through underground pipelines is a critical component of modern energy infrastructure. These pipelines often span hundreds or even thousands of kilometers, traversing urban, rural, and industrial areas. While pipelines offer a safe and efficient method of gas distribution, they are not immune to potential hazards. One of the most significant threats to the integrity and safety of a gas pipeline network is leakage. Gas leaks, if undetected or poorly managed, can result in serious consequences, including explosions, environmental contamination, health hazards, and substantial financial losses.

Leak detection and location systems play a vital role in ensuring the safety and operational efficiency of gas pipelines. Traditional inspection techniques such as manual surveys and scheduled maintenance are no longer sufficient, especially in large-scale and high-pressure systems. The growing need for real-time monitoring, faster response times, and improved accuracy has driven the development of intelligent leak detection technologies. These advanced systems can not only detect the presence of a leak but also pinpoint its exact location and communicate this information to a central control room for immediate action.

Modern leak detection systems employ a combination of sensing technologies, including acoustic sensors, gas concentration detectors, pressure and flow monitors, and fiber optic sensing. Acoustic sensors can pick up the high-frequency noise produced by gas escaping from a pipeline. Fiber optic cables, when laid alongside pipelines, can detect changes in temperature or strain indicative of a leak. Gas sensors are designed to sense elevated levels of methane or other hydrocarbons in the surrounding environment. Meanwhile, flow and pressure sensors provide continuous data to identify discrepancies that suggest leakage.

Equally important is the communication infrastructure that supports data transmission from the field to the control room. Remote Terminal Units (RTUs) or sensor nodes are strategically placed along the pipeline to collect and transmit real-time data. These units use communication technologies such as GSM, LTE, LoRa, or satellite to relay information to a Supervisory Control and Data Acquisition (SCADA) system in the control room. SCADA systems analyze the incoming data, visualize pipeline conditions, generate alerts, and guide operators in making quick and informed decisions.

The integration of these technologies enables rapid identification of leaks, accurate location determination, and efficient coordination of emergency response teams. Early leak detection not only minimizes potential risks but also helps maintain the reliability and sustainability of gas supply systems. As environmental and safety regulations become more stringent, the implementation of intelligent leak detection and location systems becomes a necessity rather than luxury.

2- LITERATURE SURVEY

Wireless gas leak detection improves employee protection, environs, and production by A., L. Leakage of gas is a major issue in the industrial sector, residential buildings, and gas-powered vehicles, one of the preventive methods to stop accidents associated with gas leakage is to install gas leakage detection devices. The focus of this work is to propose a device that can detect gas leakage and alert the owners to avert problems due to gas leakages. The system is based on a microcontroller that employs a gas sensor as well as a GSM module, an LCD display, and a buzzer. The system was designed for gas leakage monitoring and alerts with SMS via an Arduino microcontroller with a buzzer and an MQ2 gas sensor.

The circuit contains a Microcontroller MQ2 gas sensor, buzzer, LCD display, and GSM module, when the sensor detects gas leakage it transmit the information to the Microcontroller while the microcontroller makes a decision and then forwarded a warning message to the user as SMS to a mobile phone for decision to be taken accordingly. The output of this research will be significant in averting problems associated with gas leakages now and in future. FPGA-GSM-based gas leakage detection system by Arpitha, T. K.Gas leakage is a major problem in industries, residential premises and gas powered vehicles. The leakage if not detected may lead to explosion and cause severe damages to life and environment. The conventional leakage detection system uses on-site alarms for warning.

In this paper, we propose a leakage detection method in which the leakage information is also sent to first response team through wireless media. This ensures preventive actions immediately even in the absence of people on-site. The detection system uses FPGA to detect the leakage and automatically initiate a warning call through a GSM. A prototype of the gas leakage detection system has been developed and tested with LPG (Liquefied Petroleum Gas). The experimental results show that the system is able to detect the leakage in less than a minute. Development of gas leak detection and location system based on wireless sensor networks by Chengjun, D. X.

Gas leakage detection and monitoring may cause heavy economic: losses and serious environmental pollution, through wireless sensor network is considered to be more economical for industries gas leakage. Main purpose of this system model is to avoid damages and locate the leakage point. These problems can be solved with the help of WSN based on ZIGBEE. The entire control system is based on low power ARM LPC 2103 microcontroller and ZIGBEE techniques. The gas sensor node helps in collecting data regarding gas leakage and provides the particular leakage area of sensor node address is located. The collected information is sent to the central monitoring unit to update the data. Data are continuously transmitted from ZIGBEE sensor nodes 2 to ZIG-BEE coordinator. This system provides performance and helps to detect automatic gas leakage location. This paper focus on overall design of a system.

Embedded real-time system for detecting leakage of the gas used in Iraqi kitchens by Kareem, H. A major issue that happens in kitchens of houses and/or restaurants is the leakage of gas used as a fuel for cooker stove, which is commonly referred to as LPG (liquefied petroleum gas). LPG leakage may lead to a serious fire or even a deadly explosion that might affect the surrounding people. A substantial solution to avoid such disasters is by stopping its main cause. Therefore designing a device capable of monitoring and detecting such gases can minimize the dangerous and unwanted incidents by LPG leakage. This paper introduces a low cost and energy efficient real-time monitoring system that able to sense different dangerous gases, specifically those used for stove cooker. This system considers the pros of the previously introduced systems and fixes the cons available in those systems. In addition, the manufacturing cost has been taken into consideration. If the system senses any type of LPG gas (there is a gas leakage), it will react by making three different actions. It will make an alert sound to notify the people around the leakage place, send an SMS to two cell phones, and show, on an LCD screen, the leakage location.

A survey in Gas leak Detection and localization technology by Murvaya, P. Gas leaks can cause major incidents resulting in both human injuries and financial losses. To avoid such situations, a considerable amount of effort has been devoted to the development of reliable techniques for detecting gas leakage. As knowing about the existence of a leak is not always enough to launch a corrective action, some of the leak detection techniques were designed to allow the possibility of locating the leak. The main purpose of this paper is to identify the state-of-the-art in leak detection and localization methods. Additionally we evaluate the capabilities of these techniques in order to identify the advantages and disadvantages of using each leak detection solution

3-EMBEDDED SYSTEM

An embedded system is a computer system designed to perform one or a few dedicated functions often with real-time computing constraints. It is embedded as part of a complete device often including hardware and mechanical parts. By contrast, a general-purpose computer, such as a personal computer (PC), is designed to be flexible and to meet a wide range of end-user needs. Embedded systems control many devices in common use today.Embedded systems are controlled by one or more main processing cores that are typically either microcontrollers or digital signal processors (DSP). The key characteristic, however, is being dedicated to handle a particular task, which may require very powerful processors. For example, air traffic control systems may usefully be viewed as embedded, even though they involve mainframe computers and dedicated regional ,national networks between airports and radar sites.

Since the embedded system is dedicated to specific tasks, design engineers can optimize it to reduce the size and cost of the product and increase the reliability and performance. Some embedded systems are mass-produced, benefiting from economies of scale. Physically embedded systems range from portable devices such as digital watches and MP3 players, to large stationary installations like traffic lights, factory controllers, or the systems controlling nuclear power plants. Complexity varies from low, with a single microcontroller chip, to very high with multiple units, peripherals and networks mounted.

In general, "embedded system" is not a strictly definable term, as most systems have some element of extensibility or programmability. For example, handheld computers share some elements with embedded systems such as the operating systems and microprocessors which power them, but they allow different applications to be loaded and peripherals to be connected. Moreover, even systems which don't expose programmability as a primary feature generally need to support software updates. On a continuum from "general purpose" to "embedded", large application systems will have subcomponents at most points even if the system as a whole is “designed to perform one or a few dedicated functions”, and is thus appropriate to call “Embedded”. In many ways, programming for an embedded system is like programming PC 15 years ago. The hardware for the system is usually chosen to make the device as cheap as possible. Spending an extra dollar a unit in order to make things easier to program can cost Millions. Hiring a programmer for an extra month is cheap in comparison. This means the programmer must make do with slow processors and low memory, while at the same time battling a need for efficiency not seen in most PC applications. Below is a list of issues specific to the embedded field.

RESOURCES:

To save costs, embedded systems frequently have the cheapest processors that can do the job. This means your programs need to be written as efficiently as possible. When dealing with large data sets, issues like memory cache misses that never matter in PC programming can hurt you. Luckily, this won't happen too often- use reasonably efficient algorithms to start, and optimize only when necessary. Of course, normal profilers won't work well, due to the same reason debuggers don't work well.

Memory is also an issue. For the same cost savings reasons, embedded systems usually have the least memory they can get away with. That means their algorithms must be memory efficient (unlike in PC programs, you will frequently sacrifice processor time for memory, rather than the reverse). It also means you can't afford to leak memory. Embedded applications generally use deterministic memory techniques and avoid the default "new" and "malloc" functions, so that leaks can be found and eliminated more easily. Other resources programmers expect may not even exist. For example, most embedded processors do not have hardware FPUs (Floating-Point Processing Unit). These resources either need to be emulated in software, or avoided altogether.

REAL TIME ISSUES:

Embedded systems frequently control hardware, and must be able to respond to them in real time. Failure to do so could cause inaccuracy in measurements, or even damage hardware such as motors. This is made even more difficult by the lack of resources available. Almost all embedded systems need to be able to prioritize some tasks over others, and to be able to put off/skip low priority tasks such as UI in favor of high priority tasks like hardware control.

4-REQUIREMENT ANALYSIS

HARDWARE COMPONENTS

The hardware components required for the project are:

1. Arduino UNO Board
2. Neo-6M GPS Module
3. GSM 900A Module Micro Sim Card
4. Batteries
5. Gas Sensor
6. Buzzer
7. Jumpers

ARDUINO UNO CONTROLLER

The Arduino UNO is a widely used open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc. The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits The board features 14 Digital pins and 6 Analog pins. It is programmable with the **Arduino IDE** (Integrated Development Environment) via a type B USB cable.[4] It can be powered by a USB cable or by an external 9 volt battery, though it accepts voltages between 7 and 20 volts. It is also similar to the Arduino Nano and Leonardo. The hardware reference design is distributed under a Creative Commons Attribution Share-Alike 2.5 license and is available on the Arduino website. Layout and production files for some versions of the hardware are also available. "Uno" means one in Italian and was chosen to mark the release of Arduino Software (IDE) 1.0 The Uno board and version 1.0 of Arduino Software (IDE) were the reference versions of Arduino, now evolved to newer releases The Uno board is the first in a series of USB Arduino boards, and the reference model for the Arduino platform. The ATmega328 on the Arduino Uno comes preprogrammed with a bootloader that allows uploading new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol. The Uno also differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter

Background

The Arduino project started at the Interaction Design Institute Ivrea (IDII) in Ivrea, Italy. At that time, the students used a BASIC Stamp microcontroller at a cost of $100, a considerable expense for many students. In 2003 Hernando Barragán created the development platform *Wiring* as a Master's thesis project at IDII, under the supervision of Massimo Banzi and Casey Reas, who are known for work on the Processing language. The project goal was to create simple, low-cost tools for creating digital projects by non-engineers. The Wiring platform consisted of a printed circuit board (PCB) with an ATmega168 microcontroller, an IDE based on Processing and library functions to easily program the microcontroller.[9] In 2003, Massimo Banzi, with David Mellis, another IDII student, and David Cuartielles, added support for the cheaper ATmega8 microcontroller to Wiring. But instead of continuing the work on Wiring, they forked the project and renamed it *Arduino*. Early arduino boards used the

FTDI USB-to-serial driver chip and an ATmega168.[9] The Uno differed from all preceding boards by featuring the ATmega328P microcontroller and an ATmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.

LED: There is a built-in LED driven by digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.

VIN: The input voltage to the Arduino/Genuino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.

5V: This pin outputs a regulated 5V from the regulator on the board. The board can be supplied with power either from the DC power jack (7 - 20V), the USB connector (5V), or the VIN pin of the board (7-20V). Supplying voltage via the 5V or 3.3V pins bypasses the regulator, and can damage the board.

3V3: A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.

GND: Ground pins.

IOREF: This pin on the Arduino/Genuino board provides the voltage reference with which the microcontroller operates. A properly configured shield can read the IOREF pin voltage and select the appropriate power source or enable voltage translators on the outputs to work with the 5V or 3.3V.

Reset: Typically used to add a reset button to shields which block the one on the board.[7]

SOFTWARE REQUIREMENTS

The Arduino Software (IDE) is anything but difficult to-use for fledglings, yet sufficiently adaptable for cutting edge clients to exploit too. For instructors, it's helpfully in view of the Processing programming condition, so understudies figuring out how to program in that condition will be acquainted with how the Arduino IDE functions. Arduino is a model stage (open-source) in perspective of an easy to-use gear and programming. It includes a circuit board, which can be tweaked (suggested as a microcontroller) and a moment programming called Arduino IDE (Integrated Development Environment), which is used to make and exchange the PC code to the physical board.

1.Arduino sheets can read straightforward or propelled data signals from different sensors and change it into a yield, for instance, starting a motor, turning LED on/off, connect with the cloud and various distinctive exercises.

2. Unlike most past programmable circuit sheets, Arduino does not require an extra piece of gear (considered a product build) with a particular ultimate objective to stack another code onto the board. You can simply use a USB interface.

3. Additionally, the Arduino IDE uses a streamlined interpretation of C++, making it less requesting to make sense of how to program.

4. Finally, Arduino gives a standard edge factor that breaks the components of the scaled down scale controller into a more open package.

5-DESIGN

Block Diagram

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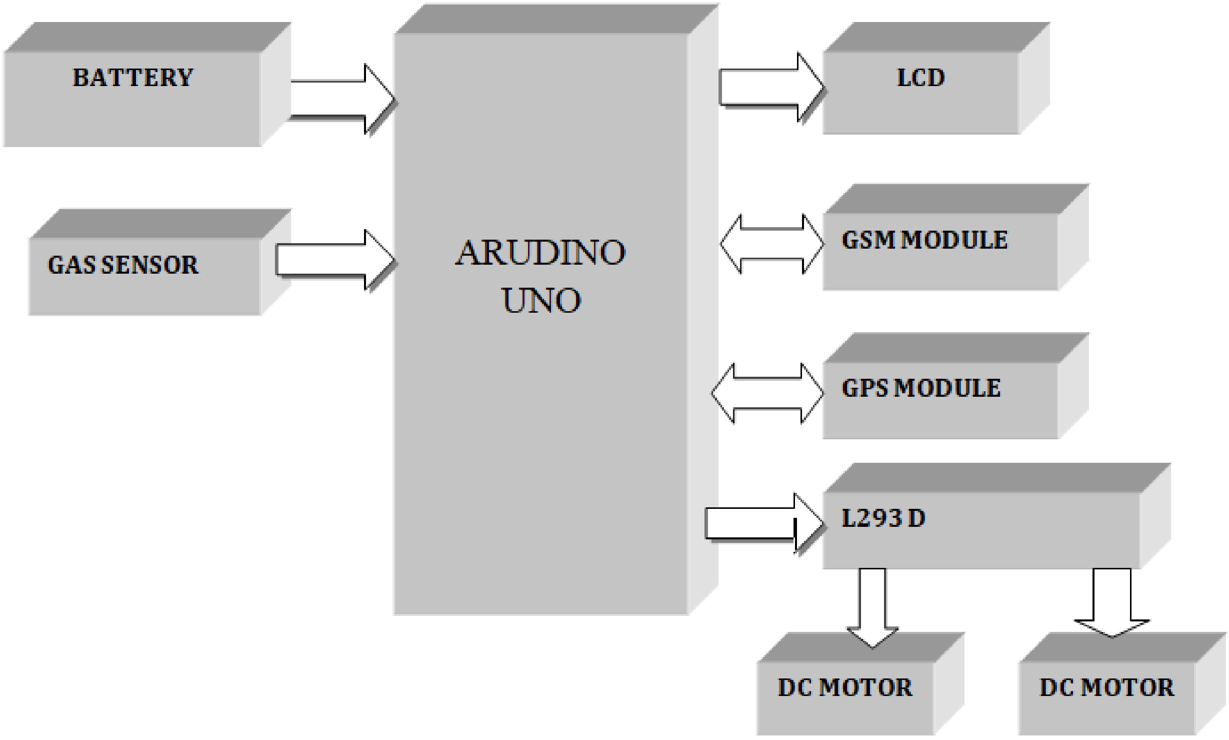

Fig. 5.1: Block Diagram of Under ground Gas pipeline leakage detection and location send to control room

The main objective of the proposed project is to develop a robot that travels along the length of underground pipelines and pipelines in industries such as oil refineries and petrol chemical industries to detect damages. The robot detects damage in pipelines, send the location of damage and alert about gas leakage at the detected location in real time to the user.

6-RESULTS

The project "Underground Gas pipeline leakage detection and location send to control room" was designed. And when gas detected the system will send sms. The device incorporates a GPS module that allows tracking of the user's location, ensuring their safety. It is equipped with a shock sensor which can apply controlled shocks as a defense mechanism, which provide an added layer of protection for women.

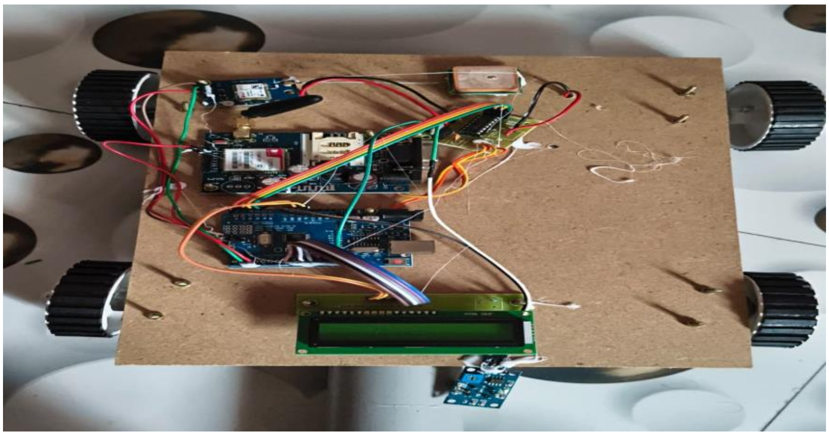

Fig. 6.1: Block Diagram of Under ground Gas pipeline leakage detection and location send to control room

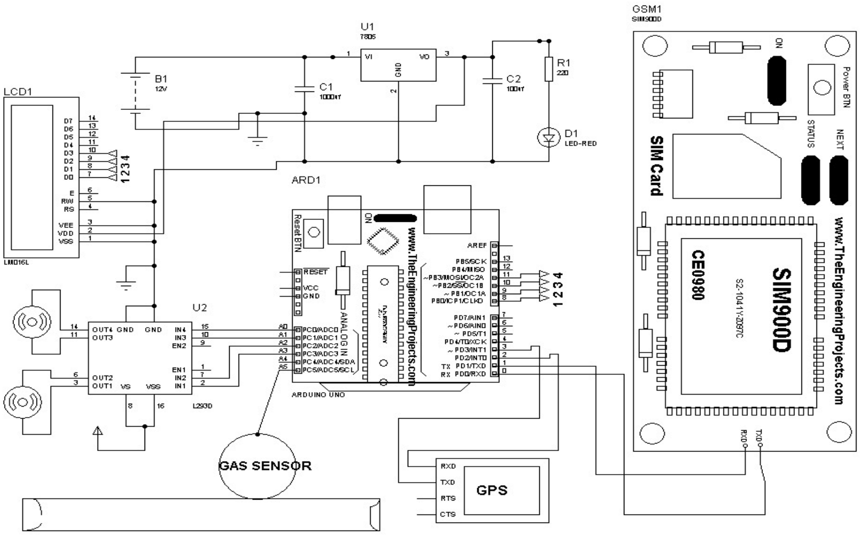

Fig. 6.2: Circuit Diagram of Under ground Gas pipeline leakage detection and location send to control room

7-CONCLUSION

The integration of underground gas pipeline leakage detection and location systems with real-time communication to a control room is vital for ensuring the safety, efficiency, and sustainability of gas distribution networks. By utilizing advanced sensors and automated monitoring technologies, such systems enable early leak detection, precise localization, and rapid response, significantly reducing the risk of accidents and environmental harm. Although initial setup and maintenance can be costly, the long-term benefits in terms of safety, regulatory compliance, and operational reliability outweigh the challenges. This smart infrastructure is essential for modern energy management and the prevention of potentially catastrophic incidents.

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