Available online at www.worldscientificnews.com

World Scientific News

An International Scientific Journal

WSN 184 (2023) 63-74 EISSN 2392-2192

Application of IOT for Fire and Gas Leakage Detection in Industries

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ABSTRACT

Safety is very paramount to our development as a society. Wherever we find ourselves, we strive to ensure that the environment is safe and conducive for people to live productive lives. The importance of safety in the work place cannot be overestimated, especially in industries that employ the use of heavy machinery, fire, gas and electricity. Care has to be taken when working with these tools as a malfunction could result to loss of life and damage to property. Hence the need for an IOT based mechanism to monitor certain factors that can result to accidents in industrial areas is important. Fires in industries are a big cause for concern as it impinges on the safety of workers, those living in the vicinity of the installation and on the environment. This study proposes an affordable system that can monitor fire and gas around industries to prevent the occurrence of fire disaster. Also, mobile and IoT technologies were integrated into the design to activate an alarm to prevent hazardous fire incidents.

***Keywords*:** industrial, safety, fire, gas, detection, IOT

(Received 16 August 2023; Accepted 15 September 2023; Date of Publication 17 September 2023)

1. INTRODUCTION

Fire disaster in industries and gas explosions are two of the biggest sources of industrial disasters that pose as hazards on the safety of workers, those living in and around the vicinity and on the environment. Companies and government lose billions of dollars annually to fire hazards and explosions [1]. According to the National Bureau of Statistics, Nigeria, between 2011 and 2014, there were 117 estimated occurrences of fires factories and industrial properties reported, with an associated estimate of 130 lives lost, and many millions of naira in direct property damage [2]. These accidents have an adverse effect on the environment through more difficulties by adding to the existing problem of pollution. Technological advancement has revolutionized the work environment, but a failure to carefully ensure safety of the workers could lead to a disastrous outcome.

Gases such as Carbon II Oxide (CO), methane gas (CH_4) can cause a great deal of harm to humans when they are exposed to them and could also lead to explosion in industrial areas. Air pollution is one of the most subtle forms of environmental pollution. This is because other forms of pollution that affect the environment can be detected visually or by taste with ordinary human senses, but air pollution can come in various ways that cannot be easily detected, even over a long period of time, due to its odorless, colorless and tasteless form. Liquefied petroleum gas (LPG) for example is an odorless gas which contains a blend of butane and propane and is widely used in industries as a substitute fuel because of its low cost compared to oil and diesel.

2. LITERATURE REVIEW

Noman *et. al*, developed a fire and LPG leakage detection system for industrial purposes which uses a global system for mobile communication (GSM) module to inform fire departments and other authorized persons of a fire or gas leakage fault in an industrial area [3]. The system makes use of a fire and natural gas sensor which are calibrated based on a given reference value. The sensors' values are sent to a microcontroller which will make an alarm when the value exceeds the threshold value programmed into it. The system also makes use of a liquid crystal display (LCD) to display the current status of the system. One major disadvantage of this design is that the GSM module only sends a short message service (SMS) to the nearest fire department but it does not make this information available to the owners of properties. It also does not include audio alarms to alert workers within the vicinity. Okeke and Ehikhamenle [4] presented a study on the design and simulation of a gas and fire detector coupled with an alarm system, water sprinkle and SMS feedback. The system used a PIC16F877A microcontroller, gas sensor, temperature sensor to develop the gas and fire detection unit. If fire is detected, the system activates the water sprinkler to mitigate the effects of the fire. The system makes use of a temperature sensor to detect fire (using heat) which has a slow response time as damage could have been done before the sensor reaches the predefined detection point [4]. Aishwarya et al. worked on the design of an automatic alarming system that is cost effective, which can detect and prevent the leakage of liquefied petroleum gas in the situated premises. An alarm system is included in the design system to alert those concerned by sound and also notifying them via SMS using a GSM module. Safety monitoring systems should not only be able to detect hazardous occurrences but should also be able to mitigate such events from escalating further and this design incorporates the features to address that by shutting down main power supply if the leakage reaches a certain set-point and using a stepper motor to close gas pipe valves.

The hardware specifications of this system include MQ6 gas sensor, LPC2148 ARM7 microcontroller, GSM module, buzzer, relay and stepper motor. This design, however, although effective can only monitor leakage of gases [5]. Divya et al designed a gas monitoring system for industries and washrooms to detect certain poisonous gases around its situated premises. The main idea is that in most washrooms and industries where chemicals are used frequently, toxic gases are usually present as a result of poor hygiene or by product of chemical reactions. This gas monitoring system will detect and alert the user of such presence. The system monitors methane, carbon monoxide, Sulphur dioxide, alcohol and hydrogen Sulphide which are the most common gases present in washrooms and sugar industries. If the gas sensor detects the threshold, then the exhaust fan and the disinfectant releasing pump will be switched on. The system also includes a GSM module to notify the user via SMS that the environment should be cleaned. This design is only limited to the gas detection part of safety systems and is not flexible enough to be applied elsewhere [6].

Lakshmi et al. designed an internet of things (IoT) based LPG leakage sensing and alerting system using a raspberry pi and a gas sensor. It utilizes light emitting diodes (LED) and a buzzer to give audiovisual indication of a gas leak. The system goes at great length to ensure that people are alerted of the situation in case of a gas spillage by using sending SMS, emails and using a web page to display the status of the system to the user. This prototype did not solely offer safety to the users against harmful gases as it does not provide a mechanism for closing down the gas valves. It is however, a very good design for informative purposes, so quick actions can be taken by those contacted [7].

Vinoth et al. developed an LPG leakage monitoring system that is wireless for home safety. The system does the job of gas leakage monitoring and detection as most paper reviewed, incorporating a GSM module for SMS alerts and also has the added advantage of continuously monitoring the level of the LPG present in the cylinder using load sensor so users can automatically book a new cylinder or refill from gas agencies using a GSM module when the present LPG gas level reaches below a defined threshold limit. This design is limited however for uses in homes rather than industries. The design surmounted some of the drawbacks of other conventional systems by providing a direct current (DC) battery as a backup power source in case of power outage, it provides a means to shut down gas supply, power supply and also alerts the local fire departments in case of a fire.

The system uses a light dependent resistor as a fire sensor which triggers fire alarms based on the presence of light. One disadvantage of using this sensor is the slow response and rate of false alarms [8]. Islam *et. al.* [9] worked on a system that signals and controls accidents caused by gas leakages and short circuits using IoT technology to save lives and properties. Detecting short circuits was done by monitoring the voltage, current and temperature. When a short circuit is detected, the information would be relayed to the electricity board and the user by the use of GSM. Ilouno et al [10] worked on the use of GSM to trigger an fire alarm system.

3. INTERNET OF THINGS

In recent times, the internet of things (IoT) has become a major research area. This is because of the future prospects associated with the technology [11]. Though the idea of bringing together networks, computers, sensors and devices for their control has been on for several decades, the technology is fast becoming applicable in every facet of human activities due to the convergence of different technologies in existence [12]. The technology applies different models with their various characteristics to enable flexibility to the user [13]. This study has been able to resolve some of the major questions that are related to the IoT technology. These are (1) Security (2) Privacy and (3) Interoperability.

(1) Security: This is a major issue in the application of the IoT technology. This challenge appears in various dimensions. To resolve this issue, it is imperative to make security a leading important challenge to be addressed in IoT products and services. This will improve the trust of the consumers of the technology as it is gradually been integrated in daily activities. The consequences of an unsecured network will expose the data of the user making him unprotected. A network of IoT connected online, that is unsecured will result to a large-scale insecurity to the data of the users on the network. Collaborative efforts are required for the advancement of security features in IoT technologies for its products and services. Hence, the reason for the research.

(2) Privacy: This is an important aspect of the technology that needs to be addressed. The data of user needs to be respected. This concern is one of the impediments of the implementation of the IoT technology [12]. This challenge is surmountable through the use of strategies that will be relatively important to the technology.

(3) Interoperability: This is required to attract more users to the technology. Improved integration and flexibility will increase the users patronizing the products and services of the technology [14]. Poor communication among IoT devices will inhibit the resources and operations of the IoT network connecting to the internet [15].

This study adopted the device to cloud model as the method of communication of data. This model initiates the communication data through the application service provider for the coordination of messages [16]. This is used to provide real time communication to the safety system **Figure 1** shows the representation of the device to cloud communication model.

3. 1. Google Cloud IOT Platform

The Google IoT cloud platform is one of the biggest cloud platforms [17]. In this study, the Google cloud IoT platform was used because it provides enormous benefits and services such as machine learning and stores a lot of documents in its databases [18]. Also, the Google cloud IoT platform has quite a number of features such as cloud IoT core, cloud pub/sub, cloud IoT edge. In addition, it possesses firebase which is an IoT advancing platform that permits device to cloud and cloud to device communication hypertext transfer protocol (HTTP) and extensible messaging and presence protocol (XMPP) [19].

3. 2. Design Architecture

The system consists of a microcontroller, a flame sensor to detect fire outbreak, a temperature sensor to detect overheating with a gas sensor used to detect gas leakages. The system is integrated with an alarm unit, to produce sound and an LCD which gives a visual indication of the LPG leakage and also makes the information available online through an IoT server. If one of the sensors picks a value that can be potentially hazardous it forwards the details to anyone with access wherever they are with the required information. It also provides a feature that shuts down the main supply of the gas and power using an Emergency Shutdown System (ESDS). This chapter entails the design procedure of the system detailing the theoretical analysis, choice of components, values, construction and packaging materials. **Figure 2** shows a representation of the block diagram.

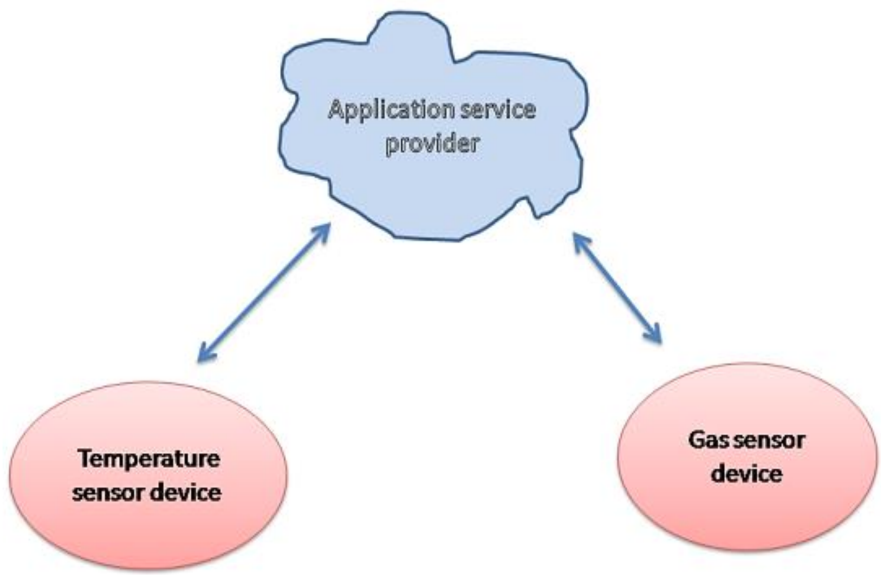

Figure 1. Diagram of Device to cloud communication model

Figure 2. Design Block Diagram

4. MATERIALS AND METHODOLOGY

Figure 3 shows the component design of the system

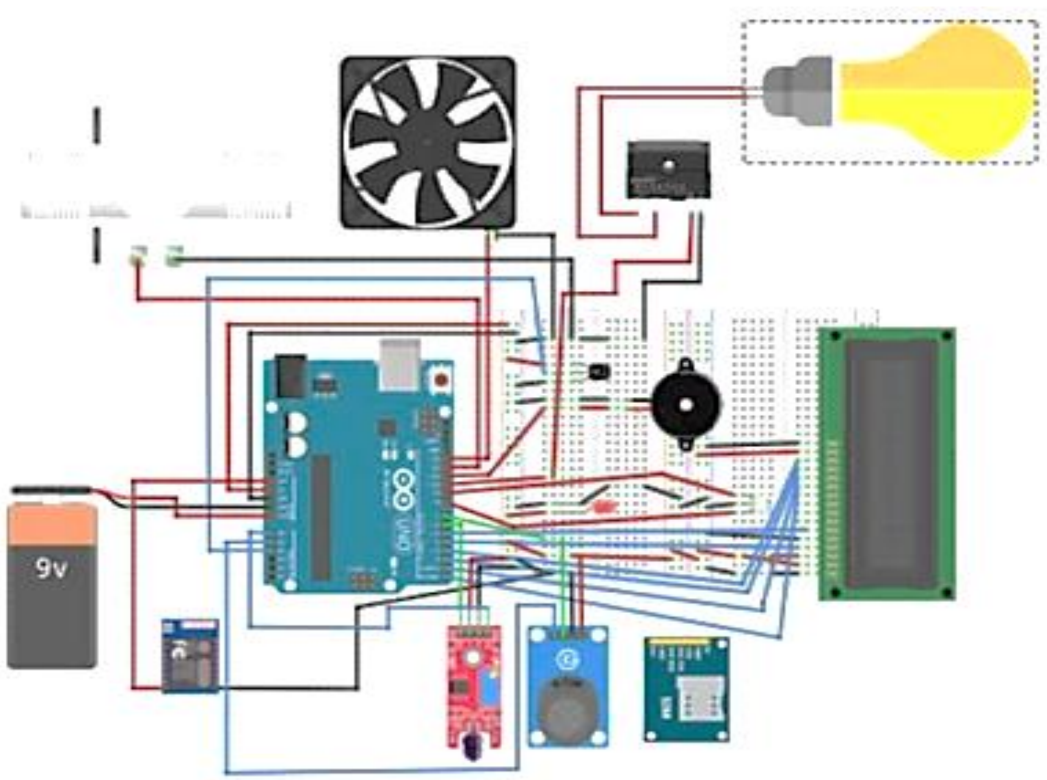

Figure 3. Design Circuit

A. The Control Unit

The control unit is made up of the Arduino development board with the ATmega32 micro-controller chip. The chip is programmed with a subset of the C++ language using the official Arduino IDE. Once this code is uploaded to the board, the board begins to receive data from the sensors and giving output signals as expected.

B. The Sensing Unit

The sensing unit for this project includes a couple of sensors which serve as input. These sensors include the LM35 temperature sensor, the flame sensor, the MQ-9 and MQ-2 gas sensors. With these devices the system is able to detect high temperature, presence of fire and gas particles.

C. The Alarm Unit

The alarm system built for this project includes an audio-visual alarm system using a buzzer and LEDs. These devices are activated whenever the sensors pick an undesirable value in all parameters it is looking out for. The system also uses mobile networks and IoT to send results to a GSM mobile number and an online server where the current status can be monitored. An LCD screen also displays the status of the system.

D. The Emergency Shutdown Unit

This unit consists of a fan and a solid state relay. The fan is used to evacuate smoke or gas particles and the relay is used to shut down power supply. The relay is connected to the mains and acts as a switch from the mains to the rest of the electrical connections. Once the relay is activated, it switches OFF the connection to the mains, so electricity is cut off from the building. This unit will be activated if nothing is done within a certain time range to mitigate the danger status after the alarm has been triggered.

E. Power Supply

This device is powered by a 12 Volts DC supply and DC-DC power regulators are used to step up/step down the voltage for the sensors as needed. Some of them only worked on voltages between the range of 3.3 - 5 V. The supply unit was built with a 220V AC- 12V DC 450 mA step down converter. This was to ensure that the power requirements of all components were met.

F. Programming

The code was written in a C++ kind of language and contains all logic for the system to work. The project also includes a web server written in Go that receives information about the alarm raised by the device.

G. Temperature Sensing

The measurement of temperature was done with LM35. The LM35 sensor uses analog signals (voltage) to determine temperature changes. This has to be digitized using an analog to digital converter built in to the Arduino board. For every 1 °C drop in temperature in the surrounding, there is a 10 mV drop in the voltages between the terminals of the device. With this information, temperature can be calculated, using a reference voltage to compare the current voltage the sensor sends to the Arduino. The Arduino has an internal reference voltage of 1.1V which is used as a base for temperature calculation. The sensor activates the alarm when the temperature exceeds a threshold of 45 degrees since humans shouldn't work under such conditions.

H. Gas Sensing

The MQ-9 and MQ-2 gas sensors are used to detect the presence of a range of combustible and toxic gases. The sensors constantly read the amount of gas pollution in air and are calibrated to give the appropriate response. It activates an alarm whenever the gas pollution in air is over 400 ppm. This is because toxic gases are dangerous to humans. An example is carbon monoxide.

I. Detecting Flame

When fire occurs, the flames produced gives off some form of radiation; the flame sensor is an infrared (IR) sensor that works by detecting radiation in the IR spectrum. Although this device has a space limit, it is good for building simple fire detection circuits. The fire detection is effective up to a distance of one foot.

5. GAS DETECTTOR DESIGN

Detection of high temperatures, Temperature values were detected and when the values exceed a predetermined value, the system was able to display a notification of the status on the LCD, Detection of gas in air, The presence of gas and smoke was also detected with the help of the gas sensors and the current level of gas particles in air was also captured, Detection of flame, The system was able to detect flames within one foot. Application of IoT: The fire and gas sensing device was able to incorporate the application of modern internet of things technology [18-20], providing the advantage of real time communication to the safety system.

The results of the temperature and gas reading are displayed in **Figures 4** and **5** respectively.

Figure 4. Temperature Reading Display

Figure 5. Gas Reading Display

5. 1. Testing procedure

The principle of gas and fire leakage has been established in this research. A design has been proposed, designed and implemented using a prototype however the protype is also being subjected to appropriate test. In this section the procedure employed for the testing is discussed. Unit testing approach is employed first, to ensure each of the components are in good order before, these include the Buzzer for sound as a form of alarm system in case of leakage, the LCD showing the temperature and the system status. Other components being checked are the Wi-Fi system (ESP8266), a sample test IoT server online, the gas sensor, temperature sensor, fire sensor, fan, relay for switching and the power source.

For overall system testing and performance check, a gas cylinder was used and exposed to the system and a sample fire from stove was also employed for demonstration purpose on the prototype. An asynchronous testing approach with respect to variables influence analysis as discussed by Martins et al [21] coupled with a simple way approach of activating the system input one at a time [22]. With the gas, the sensors were able to sense the presence of gas and eventually through the Arduino codes, the LCD display shows feedback and the buzzer created an awareness which was reported accordingly on the remote server. This makes a successful test from the gas presence which can be implemented on a large scale. On the other way round the fire sensor was tested accordingly, although without an independent fire incidence, the gas could also generate fire as illustrated in the testing procedure highlighted in **Figure 6**, this can be likened to a smoke-exhaust tunnel fire [23]. It is pertinent to note that the two unwanted incidences could occur simultaneously in a synchronous manner.

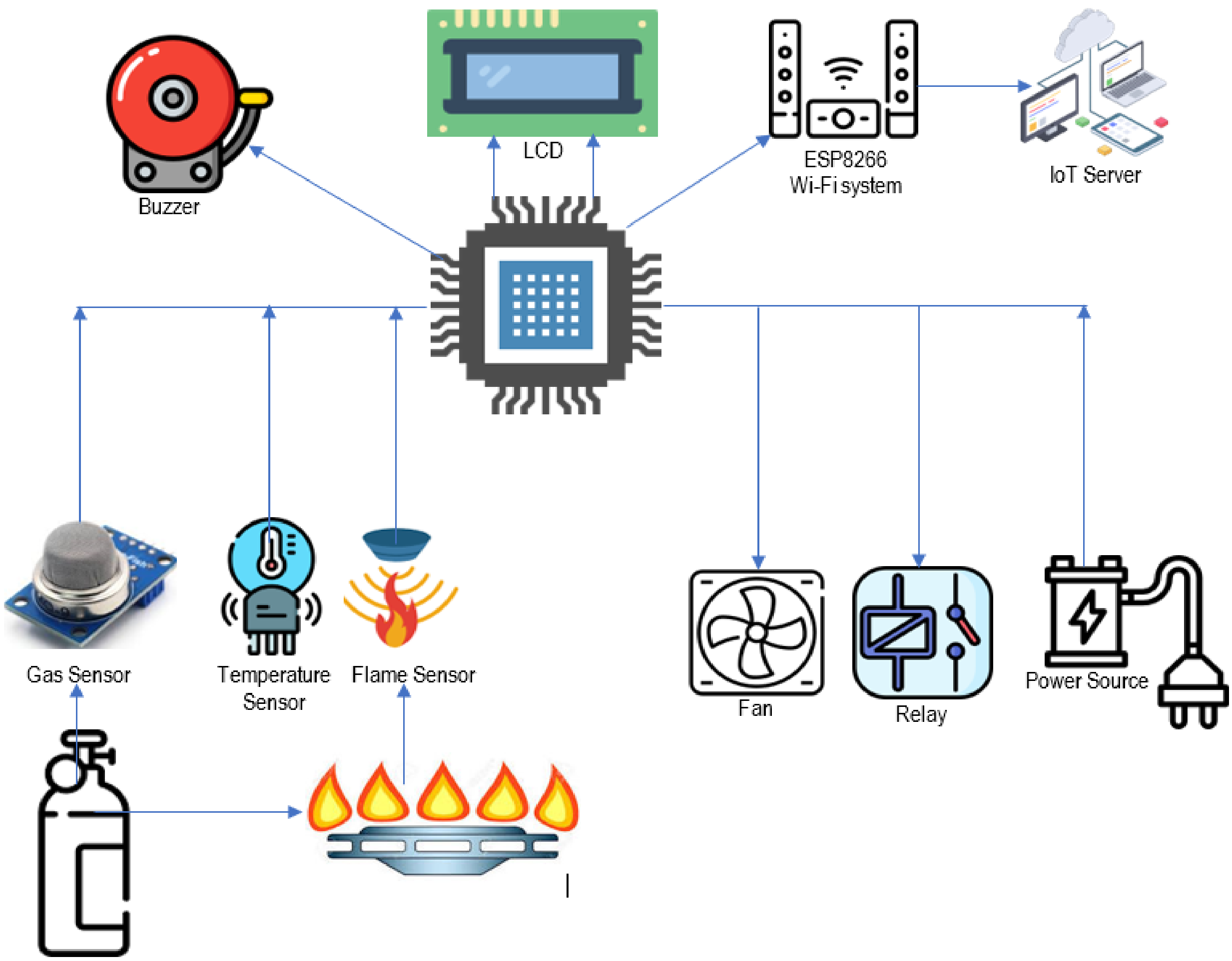

Figure 6. Testing Procedure of the entire system developed

6. DISCUSSION OF RESULT

Based on the testing outcome, in section 5.1 the result of this research can be scaled up for implementation in industrial gas pipelines to reduce risk associated with habitation in places where gas pipelines were laid in line with accommodation and community development in urban expansion. Most of the habitants in rural areas who tends to be exposed to gas and fire leakage exposure can enjoy the impact of the findings of this research due to remote monitoring on Internet of things servers at the time of occurrence. The result of the output could also be associated to financial gain of organisations with related enterprise such that in case of theft and artificial leakages, such could be seen through the server and necessary actions could be taken from the stakeholders.

Although risks could be categorized as low or high but the results from this work are limited to the prototype being designed for experimental purpose of possible integration of remote servers for effective monitoring of fire and gas leakages to mitigate the current challenges of this sector.

7. CONCLUSION

Summarily, fire disaster has been wreaking havoc globally. This work provided a significant improvement in the detection of industrial hazards as a result of fire and gas leakages using a cost-effective Internet of things solution incorporating modern technology including real-time sensors. By using these technologies, home and industrial safety can be enhanced and early detection of fire or gas leakage will greatly reduce the occurrence of hazards. Since this device uses network communication, the environment where the system is installed can be monitored remotely. This provides flexibility in the monitoring operation of protecting the industries and houses from fire disaster. In future, concurrent monitoring channels from various devices can be deployed.

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