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Gas Monitoring and Testing in Underground Mines using Wireless Technology

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***Abstract*— Mining is a risky activity, the risk factor increases exponentially when it comes to underground mine. Working conditions in underground coal mines are much more dangerous than in underground metal mines, as it incorporates the risk of roof fall due to soft strata and the hazardous gases that may be present in an influential quantity that can have physiological effects on the human body and can even be lethal. Timely Detection of these hazardous gases is a major challenge and needs to be followed for the safety of the miners present in the mine. In this paper we have discussed about different gases and their effects; we have proposed to create a mine gas detection system that will consist of gas detecting sensors, a wireless network provider and a microcontroller. MQ-4 and MQ-7 will be used for the detection of CH_4 and CO respectively. These sensors will be connected to Arduino board which will be connected to an LCD display that will regularly show the percentage of CH_4 and CO. The wireless network will be provided by using Zigbee wireless network. In this paper we have also discussed the places in the mine where the sensors will be installed and the steps that has to be taken by the required professional once the gas has been detected.**

Keywords*—Risk Factor, Gas Monitoring, Zigbee, Wireless Network.

I. INTRODUCTION

An underground mining operation proves to be a risky venture as far as the safety and health of workers are concerned. These risks are due to different techniques used for extracting different minerals. The deeper the mine, the greater is the risk. These safety issues are of grave concern especially in case of coal industries. Thus, safety of workers should always be of major consideration in any form of mining, whether it is coal or any other minerals. Underground coal mining involves a higher risk than open pit mining due to the problems of ventilation and potential for collapse. However, the utilization of heavy machinery and the methods performed during excavations result into safety risks in all types of mining. Modern mines often implement several safety procedures, education and training for workers, health and safety standards, which lead to substantial improvements in safety, level both in opencast and underground mining.

A worker in a mine should be able to work under conditions which are safe and healthy for his body. At the same time the environmental conditions should be such as will not impair his working efficiency. This is possible if mine air is nearly the same as on the surface without toxic and inflammable gases.

The gases are the present in the underground mines are flammable gas (CH4), Noxious gases (NO2, NO3, N2O5), Carbon Monoxide (CO), Carbon Dioxide (CO2). Hydrogen Sulphide (H2S), Sulphur Dioxide (SO2). The permissible limit set for these gases are as follows

- Underground air should not have more than 0.5% CO2 or other noxious gases.
- Inflammable gas should be below 0.75% in the general body of return air and below 1.25% at any place in the mine.
- The general air on road must not normally contain more than 0.005% of CO[1].

Different gases that are present in the mine have different effects on the human body and can also cause explosion if reaches above a certain limit. The effects of some of the harmful gases are as follows:-

- Carbon Dioxide – on 3% (breathing gets doubled), 6% (headache, exhaustion), 15 %(consciousness loss), 25% (death after hours).
- Carbon Monoxide – on 0.02 %(headache, discomfort), 0.12 %(palpitations after 10 minutes of work), 0.2% (unconsciousness after 10 minutes of work), 0.5%-1.0% (death after 10-15 minutes of work).
- Methane – This is the gas which is responsible for most of the underground mine explosions. It forms a layer just below the roof of the mine. The gas is not poisonous but can suffocate a person due to lack of oxygen[2].

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Name	Primary sources in mines	Hazards	Flammability limits in air (%)
Methane (CH4)	Strata	Explosive, Breathing problem	5 to 15
Carbon dioxide (CO2)	Oxidation of carbon, fires, explosions	Increased heart rate and breathing	N/A
Carbon monoxide (CO)	Fires, Explosions, blasting, incomplete combustion of carbon compounds	Highly toxic, Explosive	12.5 to 74.2
Sulphur dioxide (SO2)	Oxidation of Sulphides, acid water on sulphide ores	Toxic, irritant to eyes, Throat and lungs	N/A
Nitrogen dioxide (NO2)	IC engines, blasting, fumes, welding	Toxic, Throat and lung infections	N/A
Hydrogen Sulphide (H_2S)	Acid water on sulphides, Strata decomposition of organic materials	Highly Toxic, irritant to eyes and explosive	4.3 to 45.5

TABLE-1 (In the above table the sources and the explosives limits of the common gases that are found in the mine are shown)[4]

Coal has always been the primary resource of energy in India, which has significantly contributed to the rapid industrial development of the country. About 70% of the power generation is dependent on it. Thus, the importance of coal in energy sector is indispensable. But the production brings with it the other byproducts, which proves to be a potential threat to the environment and the people associated with it. Present work is a sincere attempt in analyzing the graveness and designing a Gas Monitoring system of detection by using the Zigbee technology.

A wired communication system inside underground mines is not effective, efficient, economic and reliable. Due to unexpected roof fall at any moment the entire communication system of the total network may collapse. Effective communication is critical to the success of response and rescue operations; however, unreliable operation of communication systems in high-stress environments is a significant obstacle to achieving this. To improve security, protection and productivity in underground mines, a consistent communication system must be established between personnel, working in the premises of underground mine, and the control room. A wireless communication system is must for the safety point of view of the personal working inside the underground mines. Therefore a fast, accurate, flexible, and reliable Zigbee Wireless network technology is used in our work[3].

The key issue of researches on wireless sensor networks is to balance the energy costs across the whole network and to enhance the robustness in order to extend the survival time of the whole sensor network. Zigbee technology is given preference over others such as Wi-Fi or lifi for establishing of wireless network because it provides a large range of coverage and less fluctuation in the signals.

II. ADVANCEMENTS IN UNDERGROUND GAS TESTING

A. detection by warm blooded birds

In the earlier days for the gas detection the warm blooded birds like munia were commonly used as they as they are affected much earlier than man by CO. such birds forms essential equipment for the rescue party enterning into the mines after an explosion or fire. With 0.15% of CO present in the air a bird shows distress (ruffing of feathers, pronounced chirping and loss of liveliness) in 3 minutes and fall of the perch in 18 minutes. With 0.3% CO the bird shows almost immediate distress and fall of its perch in 2-3 minutes. Immediate signs of distress are not likely to be observed on birds when exposed to only 0.1% CO.

Figure (1) - Munia bird as a part of search rescue team of a mine.

B. Color charting detactors

These type of detectors are filled with some chemicals and changes the color according to the concentration of a particular gas present in the atmosphere. Later the color of the tube is matched with the chart and the percentage of the harmful gases can be determined. Eg- P.S detector, Hoolamite detector, Dragermultigas detector.

Figure(2)- dragger multigas detector

C. Automatic fire damp detector

Many companies have now started producing automatic detectors which tells the exact concentration of the gases present in the mine environment, these devices are able to detect even a very small amount of gas percentage. some of the leading companies that manufactures these kind of devices are EMCOR, M.S.A Ltd. , Uptron etc. these gas detecting devices are also featured with adjustable probe in order to take the readings from the roof. E.g.- Automatic fire damp detector, Interference methanometer, memacs I etc.

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Figure(3)- Automatic fire damp detector

D. Gas detecting sensors

These sensors are used in the chemical plants to detect the gas leakages. These sensors have now started to find application in the underground mines for the continous monitoring of the harmful gases. Eg- MQ4, MQ7.

Figure(4)- MQ4

III. FAMOUS MINE DISASTERS DUE TO GAS LEAKS

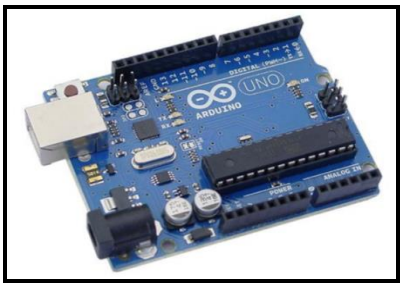
S.no.	Date	Place of Accident	Cause of Accident	Fatalities
1.	Sep 6, 2006	Nagda incline of Bhatdihcolliey, BCCL, India	Explosion in the mines due to the acummalation of methane	50 miners were declared dead
2.	Feb 22, 2009	Tunlan, Underground coal mine, Northern China	Poor ventilation responsible for the accumulation of the methane gas	77 miners were dead and 114 were hospitalized
3.	Oct 28, 2013	Underground coal mine, North Western area, Spain	Accumulation of methane gas	6 miners have been recorder dead

IV. COMPONENTS OF THE WIRELESS NETWORK

This monitoring system contains several components like boards (Arduino board and Zigbee USB interfacing board), LCD (Liquid crystal display), different sensors and other small electronic components.

A. Arduino UNO

The Arduino board is a specially designed circuit board for programming and prototyping with Atmel microcontrollers. The microcontroller on the board is programmed using the Arduino Programming Language (based on Wiring) and the Arduino development environment (based on Processing). It is relatively cheap and plug straight to computer's USB port or power it with an AC-to-DC adapter or battery to get started [5].



Figure(5)- Arduino UNO Board

B. Zigbee USB Interfacing Board

Zigbee (Xbee) USB Interfacing Board is used to interface Xbee wireless module with computer systems. This Board is used to connect Zigbee modules to make communication between PC to PC or laptop, PC to Mechanical Assembly or robot, PC to embedded and microcontroller based Circuits. As Zigbee communicates through Serial Communication so other end of USB which is connected to a PC, treated as COM port for Serial Communication. It is provided with indication LEDs for ease[6]

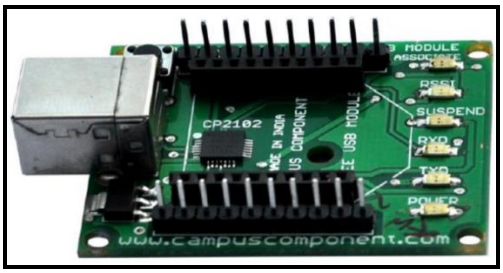


Figure (6)-Zigbee USB interfacing Board

C. Carbon Monoxide Sensor (MQ7)

Various types of sensors are available in the market in which semiconductor sensors are considered to have fast response. MQ7 semiconductor sensor is mainly used for detecting carbon monoxide (CO).

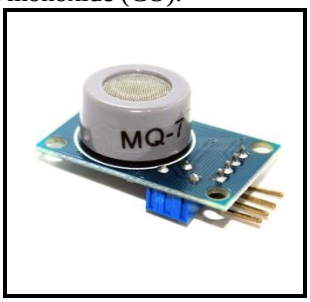


Figure (7) - carbon mono-oxide sensor

MQ-7 gas sensor composed of micro Al2O3 ceramic tube and Tin Dioxide (SnO2). Electrode and heater are fixed into a crust. The heater provides required work conditions for the work of sensitive components. The conductivity of sensor is higher along with the gas concentration rising. When the sensor, heated by 5V it reaches at high temperature, it cleans the other gases adsorbed under low temperature. The MQ-7 have 6 pins in which 4 of them are used to fetch signals and other 2 are used for providing heating current[7].

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D. Methane Gas Sensor (MQ4)

MQ-4 gas sensor composed of ceramic tube and Tin Dioxide. Electrode and heater are fixed into a layer. The heater provides required work conditions for the work of sensitive components.

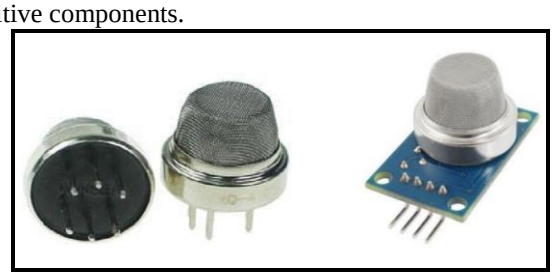


Figure (9)-MQ-4 Sensor and MQ-4 Module

When the target combustible gas present, the conductivity of sensor is higher along with the gas concentration rising. The MQ-4 sensor has 6 pins in which 4 of them are used to fetch signals and other 2 are used for providing heating current[8].

V. SYSTEM ARCHITECTURE

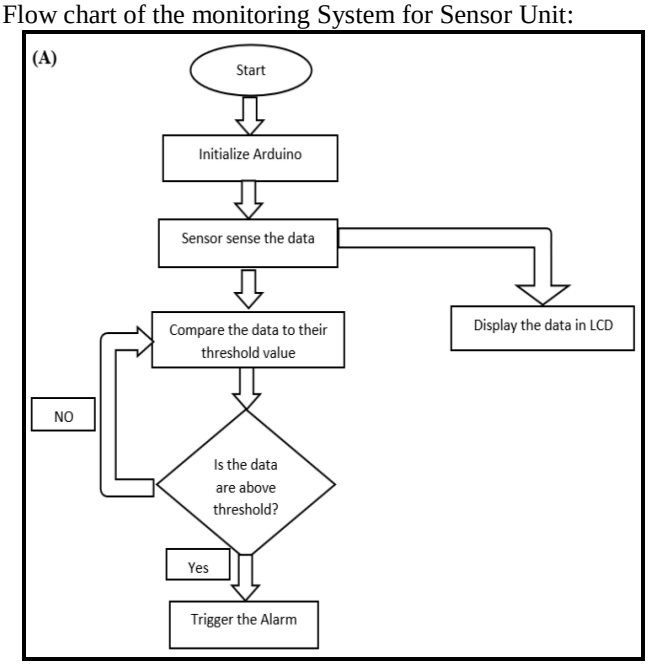
This monitoring system mainly consists of two units. First one is Sensor Unit another one is Monitoring unit.
Sensor unit contains two parts:-

A. Display Unit

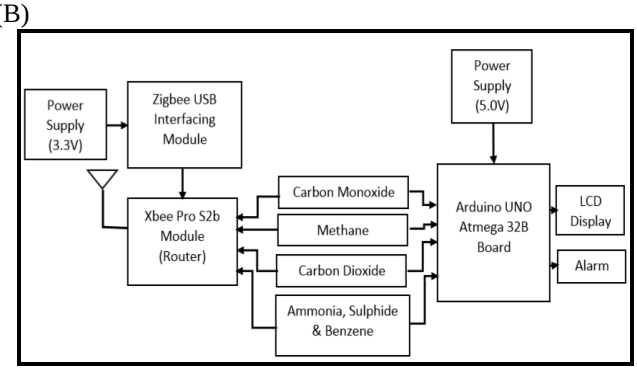
B. Transmitter Unit

Display unit consist of the Arduino board, sensors and the LCD. The transmitter unit consists of a router and the sensors.

Flow chart of the monitoring System for Sensor Unit:



Block diagram of Sensor Unit:
(B)



VI. INSTALLATION ZONE

The following are the main places to install the detector:-

- Goaf area- This is one of the main places from where gas can be leaked
- Return airway- The importance of return airway cannot be underestimated. It can carry sufficient amount of the hazardous gases
- Near faults, fractures or any such geological discontinuity- These places are also prone to gas leaks
- Where the percentage of organic matter is high- High percentage of organic matter means more gases. So, where coal percentage is higher than the rest, we must put the sensors.
- Near the roof in order to detect methane layering.
- Near the working face[9].

VII. CONCLUSION

This paper deals with the hardware implemented for the real time monitoring system and how to procede if the presence of any of the harmful gas have been detected. The details of each components used were described briefly based on its functionality and specifications. The flow chart and block diagram shows the organization and working of the system. This system also stores all the data in the computer for future inspection

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