

# A Low-Cost Underground Mining and Miners Monitoring System Using Internet of Things

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**Abstract.** The safety of mine workers is a serious worry nowadays. The miners construct underground rooms to facilitate the minerals to be taken out of the mine at work in, which requires greater output and a larger workforce. In underground mining work locations, 2753 injuries were reported as non-fatal lost-time, resulting in 190,005 lost workdays. The main aim of this proposed system is to save workers from sudden falling and detect the toxic gases present in the mining area. Using the IOT technology, we created a system with different types of sensors to solve these issues. We used flame sensor, temperature and humidity sensor and Gas sensor, to detect the toxic gas environment inside the mining and detect the fire burst inside mining in the first module. Accelerometer sensor is used to detect the falling of the worker and the pulse sensor is used to detect the heartbeat of the worker in the second module. We have created the two modules where one module is for miners monitoring and another is for mining monitoring. All these sensors are integrated with the NodeMCU. All the obtained data is sent to thingspeak cloud and if any abnormality is detected we will receive a notification through email using alert API.

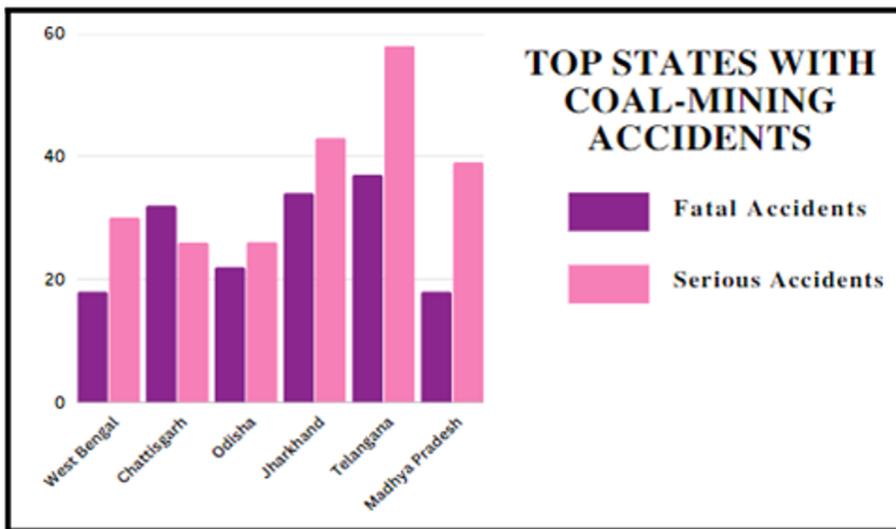
## 1 Introduction

Underground passageways and rooms are typically dug as part of underground mining operations. Surface mining is less costly, but underground mining can be risky. Only places where gold is contained in thin veins and other extraordinarily wealthy deposits are used for

this type of mining. In comparison with surface mines, it is a significant advantage in underground mining as here the mines can also be excavated underwater, which is a significant advantage over surface mines. The process of removing materials from underground using different underground methods is known as underground mining. Before beginning underground mining, it is important to be informed of the risks because it is a complex field of study and uses a variety of techniques.

The normal mining method entails sending large machines beneath to break up rocks and then dump the fragments into a tank or vat. However, the complete operation can be carried out above ground thanks to modern tools and methods. Today, a variety of methods have been created to make this simpler and secure.

We are putting more emphasis on research for injury reduction in this mining industry as a result of the higher rate in coal mining. In coal mining from 2001 to 2004, there were 33 fatalities per 100,000 full-time equivalents (FTE) and 18 in metal and nonmetal mining.



**Fig. 1.** States with Coal-Mining Accidents [18].

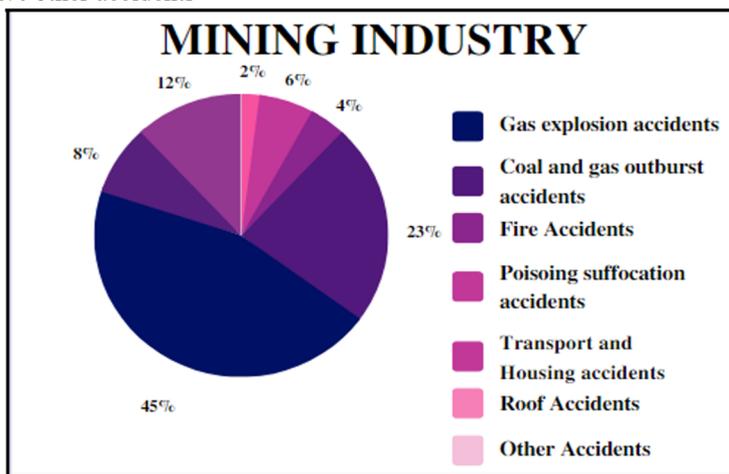
Extraction of minerals, rock, and industrial materials other than coal, gas and oil, which are from the developing entries or shafts from the surface to the seam or deposit from the recovering of the product which are the underground extraction method and the total process of extraction is called underground mining [18]. Underground mining can be done by using Internet of Things Technology. It has the potential to improve the production and business by extracting valuable items from industrial processing. The mining industry is using the traditional method for extracting the minerals which is a slow method and little dangerous because it is limited to the communication, data management, storage, and exchange of information from inside to the outside.

The technology that helps to have a safe transport and storage of all types of material which are extracted from the mining. Underground mining can be continued by the help of technology like IoT, AI, and many others [5]. Suppose someone who is working in the underground mining can be saved from their dangerous events before the event occurs. It can also help in making the decision more properly and give accurate data and so that people working in the mining area can be saved. We have to do the research properly for which technology will give us more benefits and which is more accurate for the particular work.

The operation of underground mining will be continued till the minerals are within the earth crust. Many other industries use underground mining like limestone mining, gold mining, slate mining, iron ore mining, petroleum extraction, coal mining, and many others. It is a very stable business where there is always a need for minerals to be extracted out of the ground, such as coal and gold [20-21].

The six leading major causes of underground mining fatalities were as follows:

- 45% gas explosion accidents
- 23% coal and gas outburst
- 12% fire accidents
- 8% poisoning suffocation accidents
- 6% transport and housing accidents
- 4% Roof falling accidents
- 2% other accidents



**Fig. 2.** Mining Industry Accidents Statistics [20]

In India there are a total of 493 coal mines.[20] Coal is the most required resource in the universe. These products are earthly resources that help to generate electricity and are used for various purposes. Losing of many miners' life during coal mining process is an unfortunate thing, because coal is a non-sustainable resource that cannot be regularly replaced by humans. In Coal mine accidents occur frequently and miners' lives are in danger by working in coal mines [17].

## 2 Literature Survey

Xiao et al proposes an observation platform for a UCG system is for Internet of Things and a maximum UCG controlling model. about an in-depth study providing an overview of moisture-proof and heat-insulated package structure design, breakthroughs in key technologies related to antenna design, energy management optimization strategy.[1]

Srinivas et al discussed about accidents involving harmful gas leaks which lead to the death of workers in the industry that use chemicals. Gas leaks detected and managed easily using information technology using the Internet of Things. The aim of this project was to prevent incidents and monitor hazardous gas and send a warning message to an industrial safety monitoring center by Arduino UnoR3 and IoT. An Arduino UnoR3 microcontroller board is used for connecting the sensor. It monitors the relevant environmental parameters. This

device can be used as a multiple gas detector. The data received is stored on the server, which can be used for future processing and analysed to improve security requirements. This model can be expanded in the future to provide a living environment for people.[2]

S. Vasavi et al discussed in embedded technology, Zigbee is used in many use cases. It designs a safety monitoring system for mines using a wireless Zigbee sensor network. It transfers the data to an ARM-based computing terminal. The system sends the data on the server via Zigbee, and the processing terminal in the ground part monitors and sends the data to be stored in the computer and queried by remote users. A text message is also sent to the corresponding member. Via a GSM modem connected to the controller. The audio signal is turned on. So this warning to employees happens.[3]

Anas et al mentioned underground coal mines are dangerous, because they include the risk of roof collapse due to layers and dangerous gases that can be present. Continuous detection of these dangerous gases is challenging and must follow in the mine to ensure the safety of the miners. They proposed a mining detection system consisting of gas detectors. Sensors are connected to a microcontroller board.[4]

Manohara K M et al built a system for mining monitoring which only detected the temperature, checked if there is any gas leak in the mining sector which caused many circumstances and they also reported about any fire breaker inside the coal. They ordered all the sensors in the one unit and used them in the mining sector. Placed the system where major mine work is going on,[5]

M S Vinmathi et al proposed an articles consist of the tracking system for the miners and locate them where they are currently in the mine. Which also detected the gas leaks, explosion, and changes in the mining sector where the miners are working. The article was totally based on the miner's health and condition in which they were working, and checked if there were any incidents or accidents that happened in the mining sector. The author used LiFi system in underground for the transmitting of the data in emergency purpose.[6]

Chetana Y P et al mentioned very important things to consider when mining: security and legality. This project helps detect illegal mining and thus prevent natural incidents. Energy efficiency is practiced when nodes transmitting data are dynamically selected based on battery life. The tool also monitors mining in remote locations.[7]

Rajkumar et al built mining safety monitoring on wireless sensor networks. It can increase production safety monitoring and decrease accidents in the coal mine. The purpose of this research is to provide a solution that is relevant for wireless communication mining, security monitoring, to provide evidence for further research.[8]

Venkata et al discussed a mine safety system uses the Thingier Io platform as a data transmission. All sensor values are continuously loaded into the object. If there is uncertainty in the gas level, an audible signal warns the workers. The system is mainly applied enhance the conditions of coal mines and also to provide the safety of workers.[9]

Kanmani et al propose a system which uses 2 modules in their system: one module is for mining and the second is for miners. They collected the data of the miner when their body temperature or the heart rate changes. And for the mining system they collected the data of the gas explosion and atmospheric condition in the mining sector.[10]

The author built a system for the mining to prevent the sudden incidents and safe the miner at the correct time. The author used the Wi-Fi module which is amble to the internet connection. The data is visible from the thingspeak server.[11]

Kannapan et al developed a project. This project prevents industrial accidents and monitor pollution. An Arduino Uno r3 board is used and connected to the sensor. A sensor that receives information about the environment during a spill. This device was used to detect as many gases. The program has been tested with one or more harmful gases and the resulting radiation discharge is fast and the response time is long. Sound signals produced by industries surrounding living people are used as alarms. If the level of gases and radiation is

expected to exceed the normal level, it means to show through a certain web page as well as a notified Android application. Initially, the system was developed the times to create a single website and Android application. Many users also see this information about radiation and gas leaks as an important bonus [12].

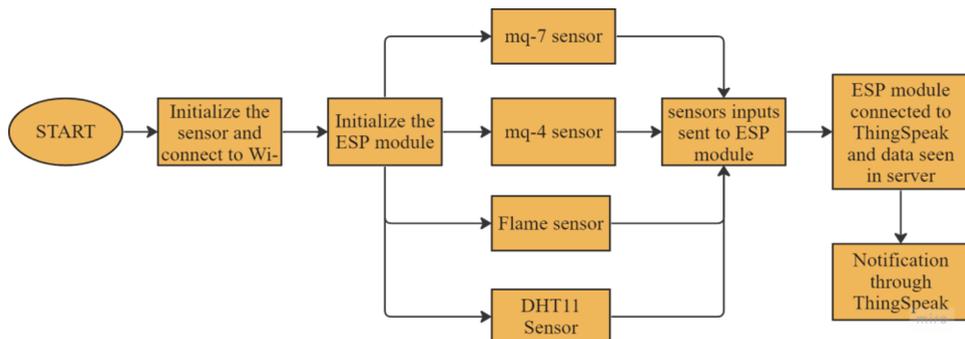
Mandal et al underground mining safety system, requires equipment and labour to work underground. The underground atmosphere can be polluted with toxic gases that displace the oxygen necessary for life, or with flammable gases that can cause an explosion. Therefore, to ensure the safety of underground coal mines, The article lists the principle of operation, mode of operation and applications of various types of sensors for monitoring toxic and flammable gases in hazardous areas [13].

Yongping et al used Bluetooth-based coal mine gas monitoring to improve coal mine production safety. The system combines Bluetooth technology and CAN bus technology for wired and wireless data transmission. A block diagram and schematic of the system are presented. The article says that Bluetooth technology could provide a new way of transmitting data for coal mine security and monitoring [14].

Lalendu Muduli et al discussed as underground coal mining is prone to various hazards. Mining fire is one of the most vulnerable hazards that cause human casualties and other mine resources. Wireless sensor networks are widely used to monitor coal mines. However, data collected by sensor nodes is inherently imprecise and this data must be analysed to take preventive measures. In this paper, they propose an optimised logic-based fire monitoring system for a wireless sensor network that enhances the reliability of decision-making in mine fire prevention. The system is using BPSO algorithm and MATLAB built-in fuzzy logic [15].

### 3 Methodology

The system consists of 2 modules where one module is for Mining Monitoring and the other one is for Miner health Monitoring. Module-1 consists of 4 sensors and 2 sensors for Module -2 i.e., Mq-4, Mq-7, temperature, humidity, and flame. And M PU6050 accelerometer and pulse sensor respectively. Below is the Block diagram for Module 1 and Module 2.



**Fig. 3.** Block diagram for Module-1: Mining monitoring

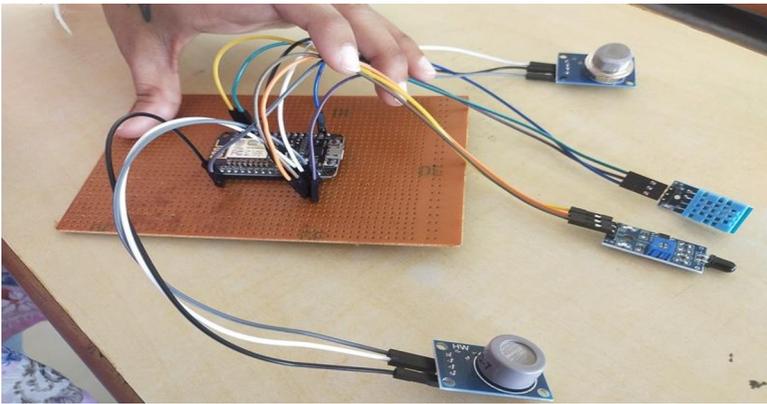
In Module-1 we have used 4 sensors and those are Mq-4, Mq-7, DHT-11 and flame sensor. Mq-4 is an analog device where it detects the Methane gas concentration in the mining industry. Sensor consists of aluminium-oxide based ceramic, coated with Tin-dioxide, enclosed in stainless-steel mesh. Whenever gas meets a sensing element, the resistivity of the element changes. Its sensing range of 300-10000 PPM is suitable for gas leak detection.[24]

Mq-7 uses an analog pin to get output accurately. It is mainly used to detect Carbon Monoxide. Whenever CO gas meets the sensing element, the resistivity of the element changes. It can detect CO gas in the range of 20 ppm to 2000 PPM in the air.[23]

A flame sensor is a detector that is used to detect and react to occurrence of fire or flame. It utilizes to notice the flame compared to heat and smoke sensors. These sensors are also used in an ignition system to get precise actions otherwise to inform the operator. The detection angle is from 0 to 60 degrees.[25]

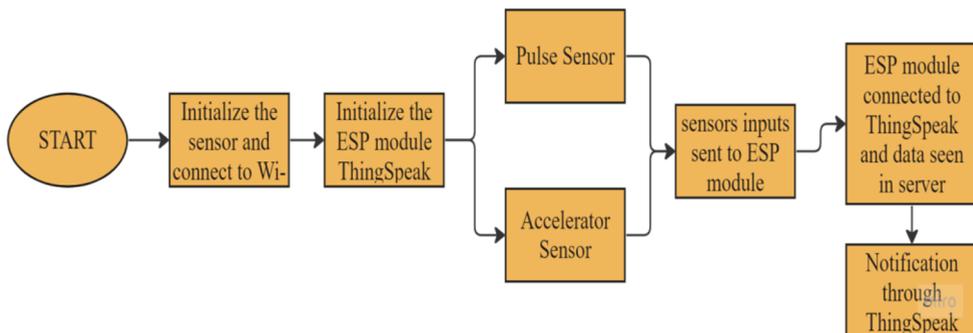
DHT-11 is humidity and temperature sensing module which captures the data instantaneously. The range of temperature is from 0 to 50 degrees and the range of humidity is from 20 to 80 % with 5% accuracy respectively. With the sampling rate is 1 Hz, it takes one reading in one second as; 3 to 5 volts is its operating voltage range [26].

All the above sensors are interfaced with NodeMCU i.e ESP8266. Which is a Wi-Fi module.



**Fig.4.** Hardware connection of Module-1

NodeMCU is then interfaced with a computer where in Arduino software the code is dumped to the NodeMCU and sensor is used to sense the output and give output in the serial monitor. Then serial monitor output will be sent to the Thingspeak server. Output can also be viewed from the Thingspeak channel. If any trigger occurs then the Thingspeak server is interfaced with Things HTTP and React. We will receive notification through mail.

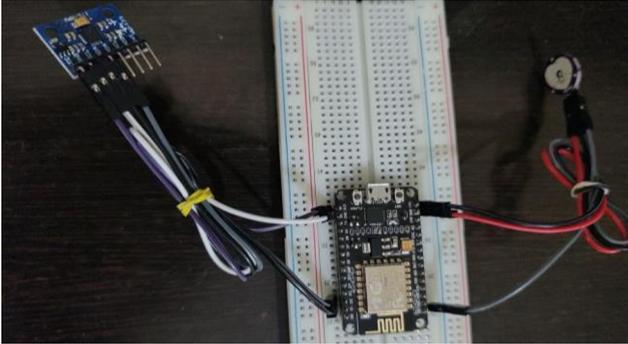


**Fig. 5.** Block diagram for Module-2: Miner's health monitoring

In module-2 we have used 2 sensors which will be attached to the miner's body. The sensors are pulse sensor and accelerometer sensor.

A pulse sensor works with photoelectric method. The pulse sensor monitors the volume of blood vessels when the heart pumps. It requires +5V otherwise +3V is the operating voltage. This is a heartbeat detecting and biometric pulse rate sensor[28].

MPU6050 sensor module is a Motion Tracking Device. It uses a 3-axis Gyroscope, 3-axis Accelerometer and Digital Motion Processor all in one sensor. Also, it has the additional feature of Temperature sensor. It is used to detect the falling of a person. When the miners fall inside the mine. It will send notification to the miner outside the mining area [29].



**Fig. 6.** Hardware connection of Module-2

These two sensors are interfaced to the NodeMCU and in Arduino software, the code is created and copied to the NodeMCU and sensors will detect the activity and send data to the thingspeak. Output can be seen from the Thingspeak and the serial monitor of the Arduino software application. Miners will receive notification if their pulse is not correct to save the miners who work in the underground mining from sudden heart attacks. Sometimes due to sudden heart attack and lack of breathing, the miner collapses. It will save miners from the many health issues

## 4 Results

The underground mining and miners monitoring system is designed and tested for two different levels of monitoring through IoT discussed as.

### I. Module-1:

Module-1 output of serial monitor and thingspeak server output with hardware connection of Mining Monitoring.

The experimental setup consists of sensor network connected with an MCU that takes the reading in every 15s from the atmosphere and the parameters displayed on the Arduino IDE serial display and output can also be viewed from the Thingspeak server from any corner of the world. The below are the outputs from the sensors.

Serial monitor and thingspeak server output from Mq-4 Sensor: The sensor consists of the output in the units of ppm (i.e., part per million) the average meter the sensor detects the higher ppm then the methane gas is surrounding is more and when the ppm value is low then there is no risk. Methane is a flammable gas and can pose a risk of fire or explosion if it accumulates in confined spaces.

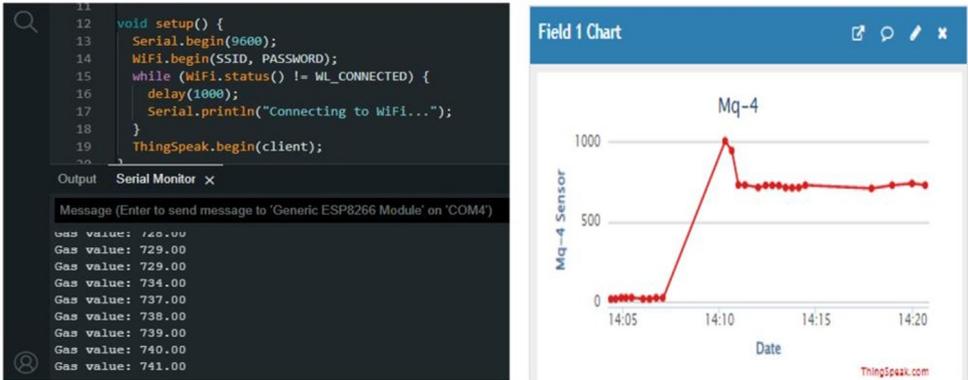


Fig. 7. Mq-4 Gas detection Serial monitor and Thingspeak records

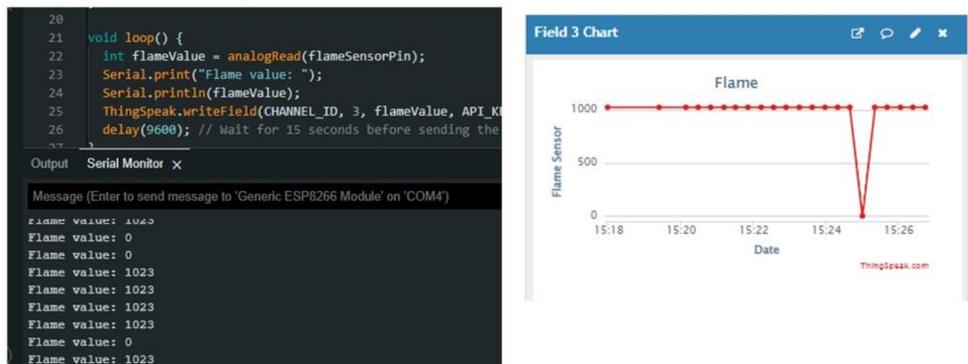
Serial monitor and thingspeak server output from Mq-7 Sensor:



Fig. 8. Mq-7 Gas monitoring with Serial monitor and Thingspeak server

The sensor consists of the output in the units of ppm (i.e., part per million) the average meter the sensor detects the higher ppm then the carbon monoxide gas is surrounding is more and when the ppm value is low then there is no risk. Carbon monoxide (CO) is a toxic gas that can be harmful to human health even at relatively low concentrations. The safe range of CO concentration depends on several factors, including the duration of exposure and the individual's health condition.

Serial monitor and thingspeak server output from Flame Sensor:



**Fig. 9.** Flame Sensor Serial monitor and Thingspeak response

In a flame sensor when the value is detected 0 it means there is a flame or fire in the surrounding. When the value is 1000 then there is no fire detected or there is no flame detected. flame sensors are designed to detect flames at a safe distance from the source of the flame, which helps to prevent the risk of fire or explosion. The distance at which a flame sensor can detect a flame depends on its sensitivity and the strength of the UV radiation emitted by the flame.

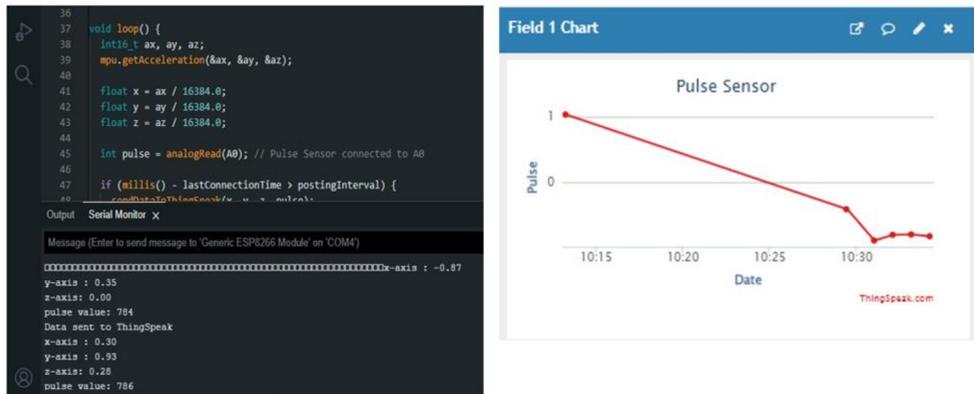
Also, a temperature and humidity measuring through DHT11 is carried out for live updation of both readings. If found any mismatches with environmental conditions required a necessary action will be taken accordingly.

#### I. Module-2:

Module-2 output of serial monitor and thingspeak server output with hardware connection of Miner Monitoring.

Serial monitor and thingspeak server output from Pulse Sensor:

Pulse sensors are used to measure a person's heart rate by detecting the pulse of blood flowing through the arteries in the wrist, fingertip, or earlobe. The safe range of a pulse sensor depends on the individual's health condition and age, as well as the specific application in which the sensor is being used.

**Fig. 10.** Miners Pulse Monitoring and plotting using Thingspeak

The MPU6050 is a commonly used accelerometer and gyroscope sensor module that can measure linear acceleration and angular velocity in three axes. The safe range of an MPU6050 accelerometer sensor depends on the specific measure accelerations ranging from  $\pm 2g$  to  $\pm 16g$ , where  $1g$  represents the acceleration due to gravity. This means that the sensor can detect acceleration from slow, steady movements up to rapid, abrupt movements. The MPU6050 sensor can be affected by external factors such as vibration, shock, and temperature changes. Therefore, it's important to ensure that the sensor is properly calibrated and installed in a location that is free from external interference.

Thingspeak server output from Accelerometer Sensor:



Fig. 11. Miners fall detection through Accelerometer Sensor and Thingspeak cloud.

## 5 Conclusion

An IoT based Mining and Miner Monitoring system for the Underground Mining is developed in this project. This is used to prevent hazardous accidents in the Underground Mining. This project consists of two modules where one module is used for checking the fire accidents, toxic gas explosions and environmental condition inside the Underground Mining. Sometimes, Miner collapses due to heart attacks and breathing issues. So, second module is used to detect the heartbeat and position of the Miners inside the Mining Monitoring. This can be used to save Miners in Underground Mining. All the data can be seen from the cloud server and locally in the system. It collects the data in every 15 seconds. It is a more user-friendly system developed by using mobile app and can be continuously monitored from thingspeak cloud server. Finally, this system can be used to take actions fast when any accidents take places in the Underground Mining

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