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INTERNET OF THINGS BASED COAL MINE SAFETY MONITORING AND ALERTING SYSTEM

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Abstract
Coal mining is a vital process of extracting the coal from ground, whereas cement industries and steel industries used coal as a fuel for extracting the iron from iron ore. The only factor in the mining business is safety and security. The mining industry takes many safeguards to prevent accidents of any kind, including steel accidents. Underground mining requires continuous monitoring of every parameter like methane gas, high temperature, fire accidents monitored. Disasters in coal mines are due to the complexity of the mining environment. So, it is very important to monitor the working environment of coal mines. Coal mine monitoring system that plays an important role in the safe production of coal mines. Due to the continuous expansion and deepening of the exploitation areas of coal mines, many paths are turning into blind areas, which have a lot of hidden dangers. To overcome this problem, advanced mechanisms have been proposed in this article to provide a coal mine safety monitoring system that can improve the monitoring level of production safety and reduce accidents in coal mines. This framework utilizes the consolidated activity of a temperature, tension, and gas sensor, as well as an IOT module, to identify the temperature, strain, and climate in the coal mineshaft, as well as to log all information to the cloud utilizing information logging. The designed kit will monitor the detection of gas, carbon di oxide, high temperature, etc., and transfer the recorded data to the mine workers and higher officials for early protection of workers. The overall experimentation was carried out in a think speak platform. The future work is about to avoid disconnection of signal to transfer the observed data from the sensors for better communication using WSN.

Keywords — Internet of things, mining, worker safety, Sensors, Alert

1.INTRODUCTION

An accident that occurs while mining minerals or metals is known as a mining accident. Each year, tens of thousands of miners die in mining accidents, most of which occur in underground coal mining, while accidents also happen in mining [11]. Due to rock strata that are plain, typically incompetent rock, presence of CH4 gas, and coal powder, Coal mining is considered significantly more dangerous than hard rock mining. Most deaths nowadays occur in underdeveloped nations and rural areas of wealthy countries when safety precautions are not properly implemented [12]. As a result, it is critical to maintaining track of circumstances that

might contribute to an accident to protect human safety. If coal mine accidents are not adequately controlled, it may result in massive human fatalities. A monitoring system has been built to record the readings of dangerous gases and risky working conditions. The information gathered is subsequently forwarded to professionals for analysis and action. Over the years, it has been observed that coal mine contributes significantly to the country's rapid economic and social development. Scholars from around the world have undertaken substantial research to improve the degree of safety. Coal mines are an essential source of energy for human growth. Development. Mining failures may be exploited to increase security in the industry. Industrial series of failures or flaws are typically the cause of an accident. There are a number of practical measures available. Initiatives involving mines, such as the construction of safety lamps, can significantly impact. Law and creating a self-contained coal mine safety monitoring system are both in the works. The trajectory of China coal mine accidents over the last ten years were investigated, and the human elements involved in these accidents were investigated using multi-dimensional statistical analysis. The number of significant coal mine accidents and the number of people killed were constantly reducing, but occasional death accidents still accounted for most deaths. Human factors accounted for 94.09 percent of the causes of these incidents, with the willful violation, mismanagement, and flawed design accounting for 35.43 percent, 55.12 percent, and 3.54 percent, respectively [13]. A round penetrating synthetic pulse radar device to probe through a coal pillar in search of hidden structures or abnormalities was employed. To produce a velocity picture of the inside of the pillar, direct matrix inversion was performed. The reconstructed picture revealed the presence and position of a substance with a low velocity. A clay vein in the cores corresponded to the low-velocity material shown in the tomogram [14]. Technology alone will not be adequate to address the difficulties for a substantial number of individuals. The dangers of coal mining; proper education and training area also essential for mine safety [15],[16],[17,18]. Underground mines are prone to serious safety incidents. The development of safe mining technologies is critical. This problem can be solved with smart mining. Hence here the research was conducted for safety monitoring of mine in coal mines, fibre optic sensors have been developed and implemented. This project introduces a device used to keep track of the conditions within a coal mine, which might pose a threat to human life. The sensors are employed for monitoring in this system. All sensors are linked to specific applications and send an alert signal when it exceeds a particular value. The alarm message is sent to the control room to take the necessary action quickly. They might be utilized to create expert systems for the early identification and prevention of mining hazards. The main objective of the article is to develop an advanced mechanism using IoT to monitor changes in the mining environment. The following objectives are designed to achieve the goals

- To detect and prevent the occurrence of hazardous events earlier
- To develop an automated monitoring system for ensuring coal mine safety decision-making system.

The rest of the paper is organized as follows: In section 2 the literature survey was illustrated. In section 3 the problem statement was illustrated. In section 4 methodology of the proposed system has been explained. In section 5 result analysis and discussion have been specified, and the end section tells us about conclusions and the future scope of the work.

2. RELATED WORKS

Molaei et. al.,[1] Reviewed the adaptability of the mining industry to IoT systems and its current development and investigated the significant challenges in the mining industry and provided recommendations to build an efficient model suitable for various mining sections such as exploration, operation and safety by deploying recent technologies such as IoT and Wireless Sensor Networks

Arif hussain et.al.,[2] Proposed ZigBee based wireless sensor network (WSN) for communication between sensors and coal mine safety monitoring system. The I Beacons were proposed for identification of miners. A service-oriented architecture (SOA) was employed to develop the system. The proposed system predicted the methane with the help of artificial neural network (ANN) technology. The proposed system was compared with other advanced systems. It was found that the proposed system outperformed all the other systems taken for comparative analysis.

Sathishkumar et.al.,[3] Proposed a uniform message space and data distribution model and implemented a lightweight services mashup method. By deploying Visualization Technology, the graphical user interface of different underground physical sensor devices was created. In addition to that, four types of coal mine safety monitoring and control automation scenarios were illustrated, and the performance was measured and analyzed. It was proved that the lightweight mashup middleware significantly reduced the costs and controlled the automation applications effectively.

Dheeraj et.al.,[4] Proposed framework that values of all the parameters that are monitored are stored and visualized in the cloud and those can be controlled using phone so that safety of the coal mine workers was maintained. The digital transformation is emerging as a driving force to revolutionize the world around us. Digitalization will play the mining industry too where connectivity plays a gigantic role. The idea is to embed more and more with electronic sensors, and software to allow things to communicate and exchange data with each other possibly but not necessarily with internet.

G. Saranya et al.,[5] Proposed a design of a wireless sensor network (WSN) with the help of ARM controller and able to monitor the temperature, humidity, gas, vibration and status of smoke in an underground mine. The system also controls the ventilation demand to mine workers depending upon present climate conditions within the mine field. The system was used low power, cost-effective ARM, DHT11 sensor, smoke detector, gas sensor for sensing the mine climate parameters and Wi-Fi for remote logging of data at central location to control the climate state with the help of motor. Traditional coal mine monitoring systems using wired network systems, plays an important role in coal mine safe production. The problems with the wireless sensor network-based coal mine safety monitoring system are improved to the point of monitoring production safety and lowering accidents in the coal mines.

M. Shakunthala et al., [6] discussed the IoT system which is built using particular sensors sort out subject to accelerometer used to screen the surroundings parameters of underground mine place and drives each and every identified parameter/characteristic to ARDUINO based ATmega2560 Microcontroller Unit (MCU). The MCU unit is were used to create an absolutely surveying system with high exactness, smooth control and constancy. Exactly, the essential condition is recognized and caution is given by the structure and comparative estimates are passed onto the webserver by beginning ESP8266 module subject to Wi-Fi correspondence.

The recognized assortments in the characteristics had appeared on web server pages that make less requests for the underground control center to screen and to make the damage. The ZIGBEE transceiver module transmitted the data from the mine section were monitored and to take immediate action.

Deokar et al., [7] discussed the coal mine system that increase the productivity and reduce the cost of mining along with consideration of the safety of workers and innovative approach are required. The Coal mine safety monitoring system based on wireless sensor network can timely and accurately reflect dynamic situation of staff in the underground regions to ground computer system and mobile unit. The air pollution from coal mines is mainly emissions of gases include Sulphur dioxide (SO2), nitrogen dioxide (NO2), carbon monoxide (CO) etc. To monitor the concentration level of harmful gases, semiconductor gas sensors were used. The main problems where numbers of miners were died. The system provides emergency alert to the supervisor if person fall down by any reason. Some workers are not aware for safety and they are not wearing helmet. A Limit switch was then used to successfully determine whether a miner has removed his helmet or not. This system also provides an early warning, which will be helpful to all miners present inside the mine to save their life before any casualty occurs. The alert switch at receiver and transmitter side for emergency purpose.

S.U. Suganthi et al.,[8] discussed people working in the mining areas, who face risk factors. In order to safe guard the people working inside the mine where environmental parameters should be monitored. The electronic circuitry was used to a microcontroller for processing unit. A graphical user interface is also implemented. The monitoring was analysed like temperature, humidity and gas. Natural calamities like landslides occur due to soil erosion and heavy rainfall. This kind of natural disaster can be monitored using MEMS Sensor and Vibration Sensor. The technology was LORA and WUSN used to Wireless mesh network with accurate and optimized sensor systems has a potential strength to be suitable ultimately for underground mines but need further research to make it full proof with advances in technology.

Prof. A. H. Ansari et al.,[9] proposed the Safety monitoring system which is the most vital part of any type of industry. the mining industry safety and security is a fundamental aspect of all peoples to avoid any types of accidents in mining industry follows, some basic precautions. The accidents take place in underground mines due to rise in temperature, increased water level, and methane gas leakage. The workers can be in danger in the panic switch inform security. To enhance safety in underground mines, a reliable communication system must be established between workers in underground mines system. The communication network must not be interrupted at any moment and at any condition. The cost-effective used ZigBee technology based wireless mine supervising system with early-warning intelligence.

T Mary Santhi Sri et al.,[10] discussed global warming and climate changing of the coal mining industry. Nuclear power in the coal mining sector is actually needed to improve productivity, reduce costs were minimizes the efforts of miners. The technology used was Wireless Sensor Network (WSN) it was designed with the help of the Raspberry Pi Controller, which can monitor temperature, humidity, gas and smoke levels in an underground mine. The system limits the ventilation requirements of miners based on current weather conditions in the mining sector. The system uses low power, low-cost Raspberry Pi, Temperature Sensor LM35, Moisture Sensor SYSH 220, Smoke Detector, a gas sensor to parameters is used Wi-Fi to

record data in a central location. Traditional coal mine monitoring systems are wire networks that play an important role in the safe production of coal mining.

Dong et al.,[11] Proposed a coal Mine safety Monitoring framework dependent on Zigbee and GPRS remote transmission was established. With GPRS innovation, remote information transmission was accomplished and informed through the short message sent to his cell phone, which adds to the early ID of genuine mishaps and continuous treatment, subsequently expanding the security of coal mining.

3. PROBLEM STATEMENT

Workers in mining areas face many risk factors. However, accidents are happening in mines due to increasing landslides, gas leakage, low power supply, etc. To protect workers in the mining environment there is a need for developing an automated wireless monitoring system to safeguard the workers from the hazards in the different types of mining environments. Hence IoT based smart monitoring system can be implemented for reducing the risk factors in the coal mine.

4. PROPOSED WORK

The suggested technique presented in Fig.1 classifies the coal mine monitoring system in two ways. First, it alerts authorities when gases, lights, temperatures, and seismic activity go below predetermined limits. To ensure the safety of the workforce, a decision will be made depending on the seriousness of the issue and communicated to them. Second, in the event of an emergency, an automatic process will take care of any potentially dangerous conditions and ensure the safety of the workers. This system will allow for judgements to be made automatically and with high precision.

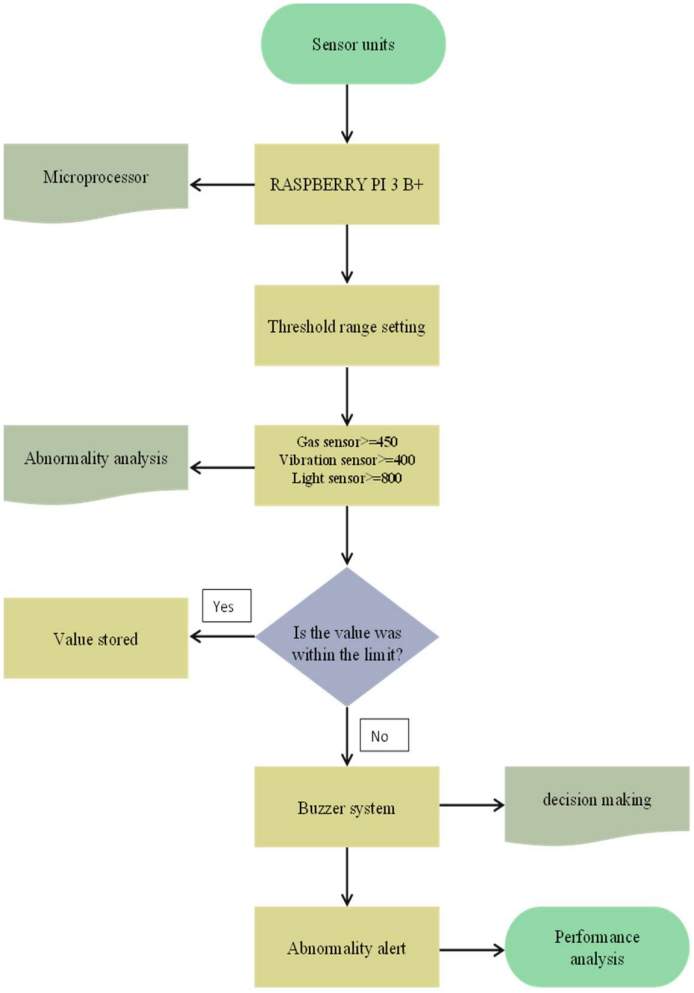

Fig:1 Schematic representation of the proposed Methodology

Three sensors namely gas, light and land vibration, are used to measure the underground mining environment. The gas sensor has 420 as the minimum and 450 as the maximum threshold. The mems (land vibration) sensor has 400 as the minimum and 450 as the maximum threshold. The light sensor will have 800 as the minimum and 850 as the maximum threshold. When any one of the sensors reaches or exceeds the minimum threshold value in the underground mine it sends the precautions alert to higher officials. Based on the sensor data and the current situation, decision will be taken under the decision-making mechanism following fig.1 depicts the process. The suggested system was developed to detect and prevent the occurrence of hazardous events in the mining area. Some of the device and sensors are used to monitor the mining area.

4.1 RASPBERRY PI 3 B+

Raspberry Pi is a mini computer. It used for provide connections to external electronic devices and therefore the development of IoT solutions. These GPIO pins can be connected to external sensors using jumper wire. The first step is latest operating system from official website. Then inserting the SD card into card reader and connect it to laptop and format it using SD card formatter software. Write Operating system to SD card. Once the SD card is ready,

insert it into your Raspberry Pi then connect the Raspberry Pi to power. Once it is completed, the green LED will blink rapidly in a steady pattern. Disconnect the device from power.
Here raspberry pi pin referenced in two different ways.
1. BCM mode (GPIO pins) for physical pin 3 '3' is board number and '2' is GPIO number.
2. BOARD mode (Physical pins) for physical pin 23 '23' is board number and '11' is GPIO number. The Fig.2 shows the representation of Raspberry pi board

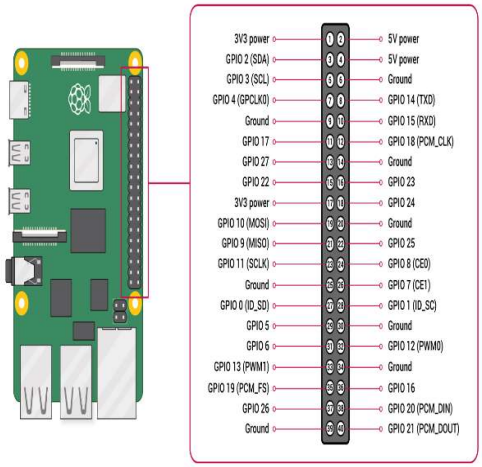

Fig.2 Raspberry pi Board pinout

4.2 GAS SENSOR

Sensor is used to detect the presence of hazardous gases in coal mines. The MQ-2 sensor is triggered when there is a high presence of Tin oxide (SnO2) in the air. Gas sensing is essential within the mining industry because ventilation with fresh air from the surface is used to dilute the methane concentration and reduce the risk of explosion

Methane level in the stale air will be monitored continuously and if it exceeds a certain threshold, then the exhaust fan will be automatically switched on to reduce the intensity of the Methane gas and alert message will be immediately sent to the higher authorities. The Fig.3 shows the representation of gas sensor

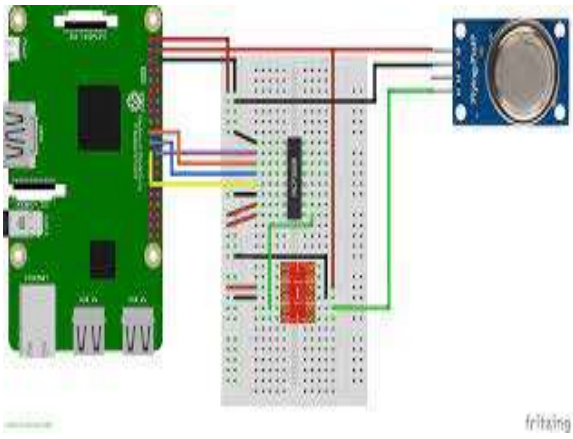

Fig: 3 Gas Sensor with Raspberry pi

Figure.3 depicts the gas sensor's circuit diagram. The sensor calls for a minimum load resistor value of 0.45kΩ, thus R_L is selected accordingly. The circuit voltage V_C is split between the gas sensor's R_S and R_L, making it a voltage divider. The value of R_S changes when the gas concentration shifts. Measuring the voltage across the load resistor is the first step in determining the sensor resistance R_S. After obtaining this voltage, D_S may be calculated using equation 1.

$$D_S = \frac{V_C - V_{DL}}{V_{DL}} \times D_L \qquad (1)$$

Methane concentration may be calculated from the voltage measured across the load resistor by first determining its value, D_S. The sensor's resistance at 5000 parts per million of methane is 2.3kΩ, denoted by the value D_o. As can be seen in Figure 14, the value of $\frac{D_S}{D_o}$ controls the sensors' connection.

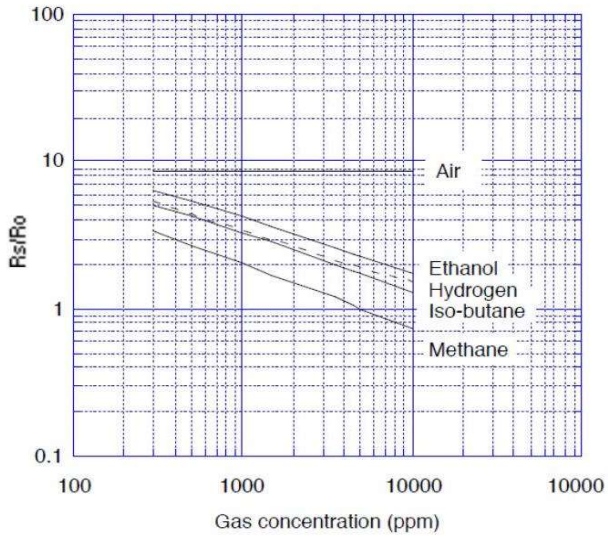

Fig:4 Gas sensor characteristic response.

Using knowledge of logarithmic graphs together with the graph intercept method, a relation is derived for the line i. This relation is given by equation 2:

$$\frac{D_S}{D_o} = 41.792 \times \text{ppm}^{-0.43987} \qquad (2)$$

This equation is then manipulated in order to make the concentration (ppm) the subject of the equation. This resulted in equation 3.

$$ppm = \left(\frac{R_S}{R_o \times 41.792}\right)^{-2.273} \qquad (3)$$

This is the final equation used to convert the measured voltage into a gas concentration in parts per million.

4.3 MEMS SENSOR

The MEMS sensors are tri-axial, meaning they can measure vibrations in all three directions. Mine condition monitoring is made easier with this capability of spatial awareness. Monitoring the state of a mine relies heavily on acceleration signals. It's a warning sign for issues like unstable buildings or accidents that might cause a mine to collapse. The MEMS Sensor can detect tremors and landslides in the mining region, sounding an alarm to warn the workers. The microelectromechanical system (MEMS) sensor is shown in fig 5.

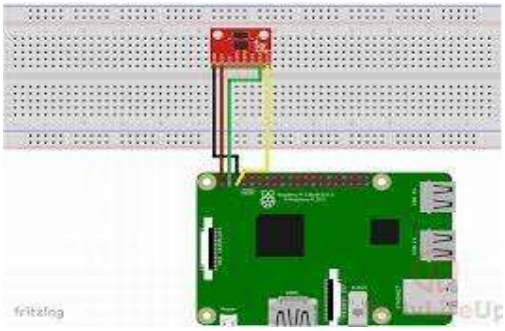

Fig: 5 MEMS (Micro-electromechanical systems) **Sensor**

The final mathematical relationship between the voltage and the vibration pressure level is extracted and is shown in equation 2.

$$\begin{aligned}\text{Vibration Pressure} = \; & 0.91650 \times P^6 - 11.40170 \times P^5 \\ & +55.5430 \times P - 130.520 \times P^3 \\ & +140.2880 \times P^2 - 32.53240 \times P \\ & +50.66470\end{aligned} \quad (4)$$

4.4 LDR SENSOR

The LDR sensor is a resistor whose resistance varies depending upon the amount of light falling on its surface. When the light falls on the resistor, then the resistance changes. These resistors are often used in many circuits where it is required to sense the presence of light. These resistors have a variety of functions and resistance. When the LDR is in darkness, then it can be used to turn ON a light or to turn OFF a light when it is in the light. Hence the LDR sensor automatically controls the light using the relay switch to keep the miners aware of the light level; prevent accidents and inform the higher authorities concerned. The Fig.6 shows the representation of LDR sensor

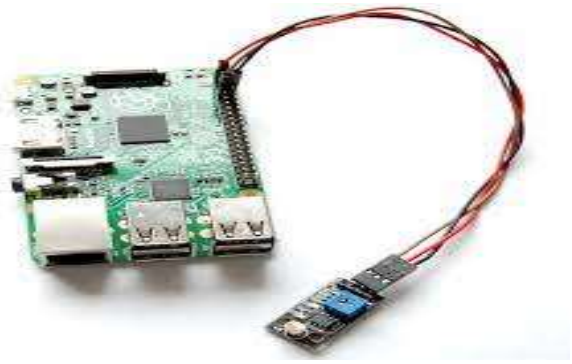

Fig.6 LDR sensor

The microcontroller has a timer which is used to calculate the corresponding light falling by using equation 5.

$$RPM = \frac{60}{\text{light source} \times 0.001} \quad (5)$$

Here the timer produces a number of ticks between each interrupt light signal. The timer has been setup such that each clock cycle is 0.001 seconds. Each minute contains 60 seconds and the duration between each interrupt forms the divider to produce the number of revolutions per minute. Once the number of revolutions per minute has been found, the theoretical light speed can be found using equation 6.

$$\text{Light Speed} = RPM \times r \times \frac{2\pi}{60} \quad (6)$$

where r = Radius (m).

4.5 Buzzer

Buzzer is a kind of voice device that converts audio model into sound signal. It is mainly used to prompt or alarm. Based on the various designs, it can generate different sounds like alarm, music, bell & siren. In the mine area any gas leakage, landslides, accident occurs the buzzer will actuate and alert the mining workers.

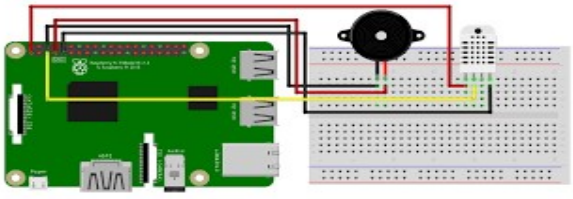

Fig .7 Buzzer

5. PERFORMANCE ANALYSIS

In this proposed system the coal mine safety systems are fixed with gas sensor modules, light sensor, MEMSsensor and buzzer. We integrate all the sensors to the controller. First, we need to create an account in the Thing Speak platform. In this system we mainly have monitoring and controlling systems. In monitoring system, we monitor all the data from

different sensors. In the control system buzzer system was executed. The IoT based Coal mine safety system used in this article is given in the fig.8

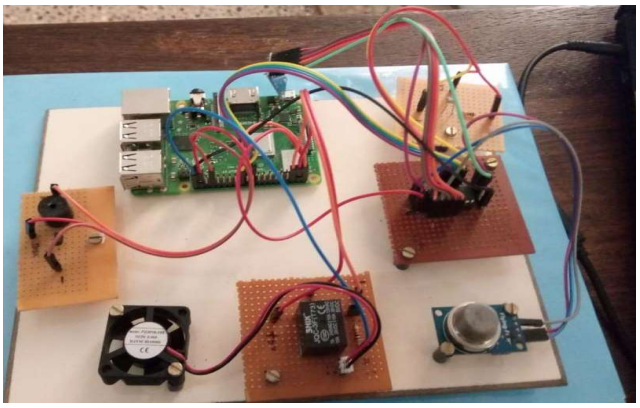

Fig 8. Hardware part of Coal mine safety system design

Table 1 Result analysis of monitoring system

Sl.No	Parameter	Threshold Value	Sensor Reading	Remark
1.	LDR	800	841	Safe condition
2.	GAS	450	484	Safe condition
3.	MEMS	400	444	Safe condition

The sensors are used to detect or measure the coal mine area. According to the gas level, MEMS level, LDR level, the output of the graph will be varied. The output of result is shown in table 1. From the obtained value it can be clarified that there will not be an existence of abnormal values

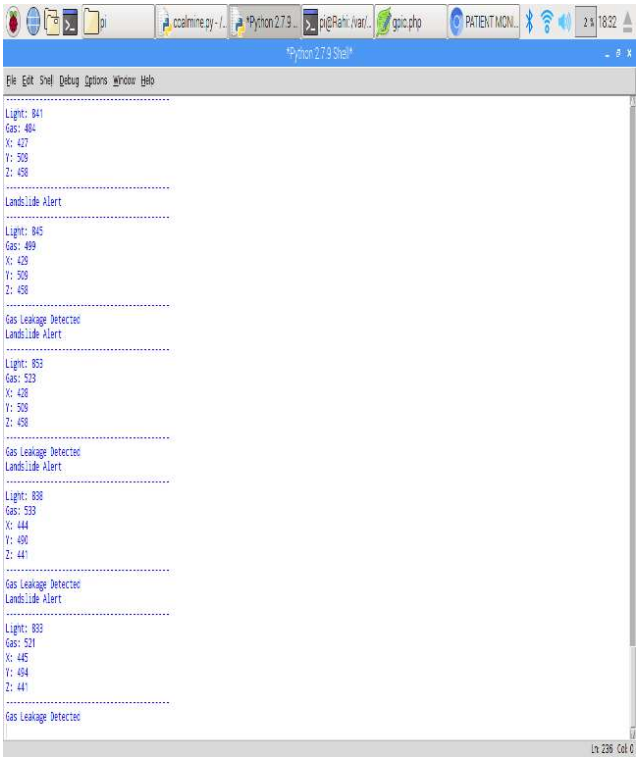

Fig 9. Measure the sensors level

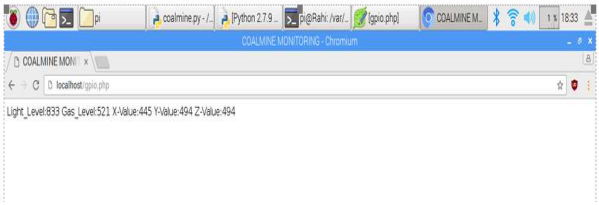

Fig 10. The output of Sensors value

The obtained sensor values are illustrated in figure 9,10

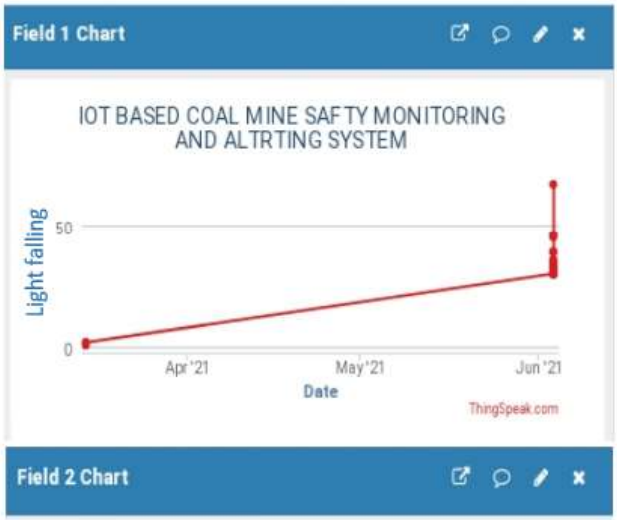

Fig 11. Light falling analysis

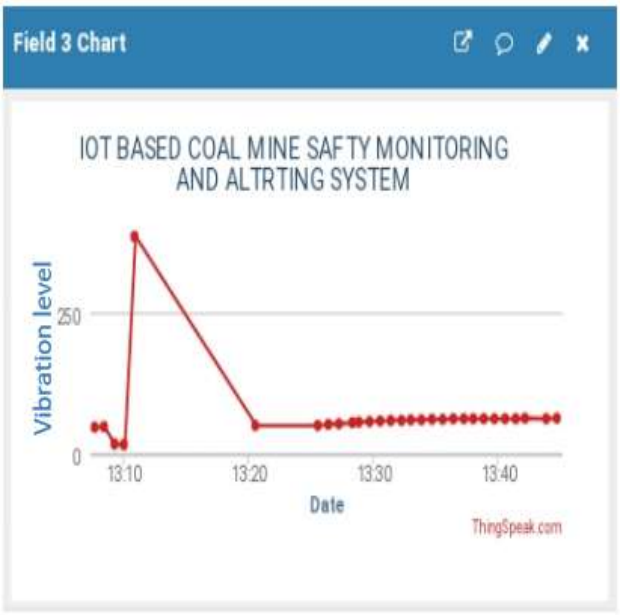

Fig.12 Vibration level analysis

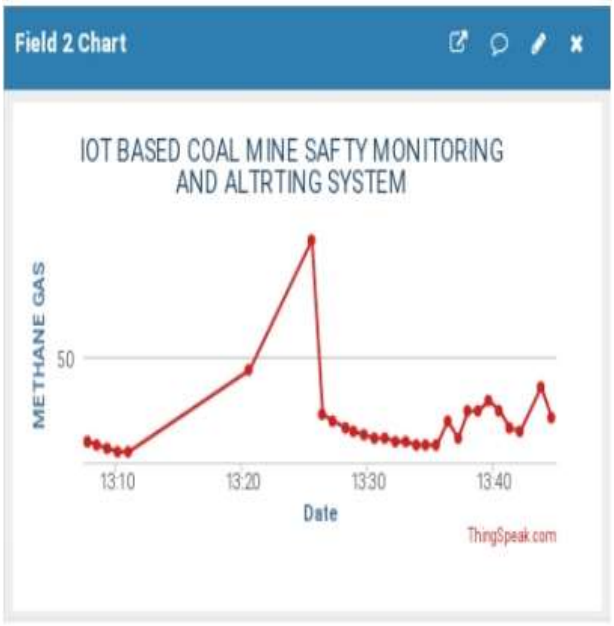

Fig 13. Gas level analysis

The vibration rate, light falling and gas emission rate was clearly monitored and pointed as a graph for abnormality level analysis by using the fixed threshold value as depicted in figure 11,12,13.

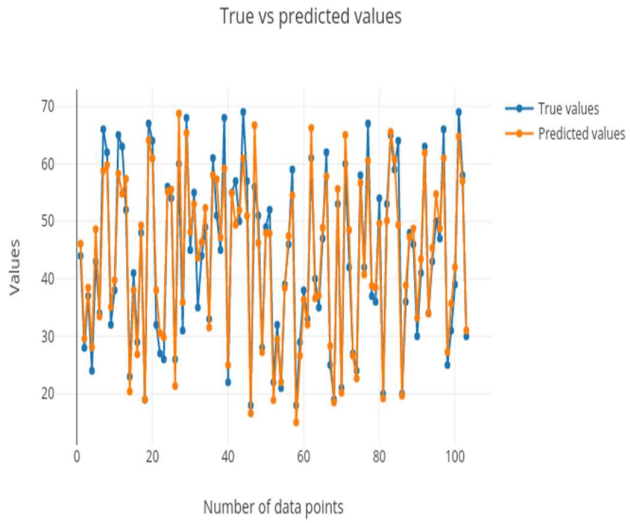

Fig 14. Prediction rate analysis

The overall ground truth and the predicted values are clearly illustrated in figure 14 which illustrates acceptable variation shows the efficiency of the monitoring mechanisms**.**

Table 2 Comparison analysis

Performance metrics	**ARIMA [19]**	**RNN[19]**	**LSTM[19]**	**GRU[19]**	**ADI-LSTM[19]**	**Suggested decision making**
RMSE	2.07090	2.11230	2.08380	2.06880	2.02180	1.210
MAPE	3.10860%	4.05650%	4.29270%	3.47003%	3.10830%	2.90

Table 2 reveals that the highest error rate is between 1.21% and 2.9%, as is evident from the data shown there. The overall level of relative error that exists between the numbers that were predicted and those that were actually measured is rather low. In instance, the majority of the prediction mistakes are acquired with reduced error and greater prediction accuracy. The efficacy of the proposed Internet of Things–based decision making process for coal mine safety is shown by the absence of a significant mistake in the prediction of gas emissions, light dropping, and vibration rate analyses.

6. CONCLUSION

In this study, an Internet of Things-based monitoring system for coal mines is presented. The suggested system's functions include monitoring the subsurface properties of a coal mine, which will contribute to the reduction of the likelihood of accidents occurring in mines. The

Internet of Things (IoT) technology is characterized by a simple and versatile networking concept, a diminutive size, low power consumption, and a low error prediction rate. As a direct consequence of this, this constitutes an improvement above the conventional coal mine safety system. In addition, the system may be used in the areas of industry and security in many capacities. It is simple to update and change it even more when new developments EMERGE. AS new information becomes available and technologies advance, it is possible that further work on this experiment will include making larger advancements to the structure by making use of additional advanced sensors to examine the subsurface. Dangers. Similarly, each and every one of the jobs that take place underneath may be accomplished from the very beginning. In conjunction with perceptive sensors for determining the state of the mine, new developments in establishing communication may be used to facilitate the rapid transfer of information. In addition, further Internet of Things-enabled frameworks may be built for further developed applications.

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