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IoT Based Coal Mine Safety Monitoring and Alerting System

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Abstract: *Coal mines are one of the most important industries in the country, as they are used as fuel in the steel and cement industries to extract iron from the stone and create cement. The coal mining industry is known for its hazardous working environment, requiring stringent safety measures to protect miners and prevent accidents. The coal mine safety and monitoring project provides a comprehensive solution to enhance safety within coal mines. The objective of this project is to continuously monitor critical parameters such as temperature, gas concentration, and water level to ensure a safe working environment in coal mines. The continuous monitoring of temperature, gas concentration, and water level, along with remote communication capabilities and alerting mechanisms, contribute to minimizing the risk of accidents, improving response times, and overall safety standards within coal mining operations.*

Keywords: The project utilizes various components, including the NodeMCU ESP12E Microcontroller, I2C LCD, Buzzer, MQ Gas Sensor, LM35 Temperature Sensor, Float Sensor, NRF24L01 Wireless TX RX

I. INTRODUCTION

The mines are the world's most dangerous mining operation, with thousands of workers dying each year as a result of massive explosions. The course of Underground digging activity for human workers could be a very risky circumstance where the dangers increment with the ascent in separation from the underground. Coal is an important asset to every country since it has a few applications. It is used for nuclear energy, concrete, and creation and as a fuel for different applications. Safe production level of coal mine is still low, disasters in coal mine occur frequently, which lead to great loss of possession and life. The disasters happening in coal mine are due to the complexity of mine environment and the variety of work carried out in coal mine, so it is very necessary to monitor the working environment of coal mine.

II. LITERATURE SURVEY

Y ogendra S Dohare and Tanmoy Maity design surveillance and safety system for underground coal mines based on Low Power WSN. In this system a low power, cost-effective, and Zigbee protocol based wireless sensor network that provides an intelligent surveillance and safety system for underground coal mines. The system consists of wireless connection of several nodes. This network can be easily placed in underground mines and it provides an effectively surveillance and safety system for underground coal miners. Especially, it provides the real-time data communication between miners and surface control room through highly secure, reliable wireless sensor nodes. This system is placed in mine so problem is created when miner are not in range of the system. This system only monitor environmental condition of underground mine but not monitor the health condition of miner

Yongping Wu and Guo Feng implement coal mine monitoring using the Bluetooth wireless transmission system. As a standard of unified global short-range wireless communication, Bluetooth technology is to establish a common low-power, low-cost wireless air interface and controlling software opening system. This paper describes the development background, technical features and the structure of the protocol stack of Bluetooth technology, and proposed the solutions of the Bluetooth host controller interface (HCI) wireless communication for the complexity of its development.

Zhenzhen Sun proposed DCS Coal Mine Monitoring System Based on RS485 Bus, RS485 bus structure supports multi-point and two-way communication. So, this type of monitoring system can be developed using common 8-bit

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microcontrollers. It has the advantages of simple circuit structure and low costs. However, due to the adoption of master-slave structure network, it is difficult to guarantee the reliability of the network structure. Furthermore, the data transmission distance is limited with a poor realtime performance

Jingjiang Song, Yingli Zhu proposed automatic monitoring system for coal mine safety based on wireless sensor network. This system design monitoring for coal mine safety constructed by MSP430F and nRF2401. The sensor groups of the system intensively monitor temperature, humidity and other parameters in the underground mine, parameters measured are sent to wireless communication module by the microcontroller. The collected information is sent to long-distance monitoring center by cable. The problem of this implementation is that hardware is placed inside the coal mines, when a natural calamity or a roof fall occurred, the system is damage. So the reliability and long life of conventional communication system is poor. Due to the harsh environment inside the mine, the installation and maintenance of the system is very difficult. The another problem is that the working condition of coal mine is very noisy and if the distance of miner and system is long, miner not get proper message.

III. PROPOSED SYSTEM/ METHODOLOGY

3.1 Block Diagram:

The coal mine safety and monitoring system project utilizes various components to create a comprehensive monitoring system. Here's a block diagram for the coal mine safety and monitoring system project:

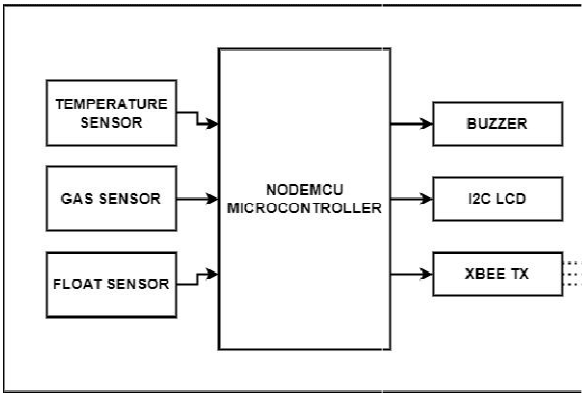

Figure 1:- Block Diagram of the System

The block diagram above represents the components and their connections in the coal mine safety and monitoring system project.

3.2 Description:

The block diagram illustrates the major components and their interconnections in the coal mine safety monitoring and alerting system. The system is built around the NodeMCU ESP12E Microcontroller, which serves as the central control unit. The NodeMCU is responsible for gathering data from various sensors, analyzing it, and triggering appropriate actions based on the sensor readings.

At the core of the system, there are three primary sensors: the MQ Gas Sensor for smoke detection and gas monitoring, the LM35 Temperature Sensor for temperature measurements, and the Float Sensor for water level detection. These sensors are connected to the NodeMCU, which collects data from them.

The NodeMCU also interfaces with other components, including an I2C LCD and a Buzzer. The I2C LCD is used to display real-time information such as sensor readings, alerts, and status updates. The Buzzer provides an audible alarm in case of emergencies or abnormal sensor readings.

To enable wireless communication, the system incorporates the NRF24L01 Wireless Transmitter and Receiver modules. These modules establish a wireless connection between the

coal mine monitoring system and a central control unit located outside the mine. The central control unit is another NodeMCU connected to a display or monitoring system.

The communication between the NodeMCU and the central control unit is bidirectional. The NodeMCU transmits sensor data wirelessly to the central control unit, allowing real-time monitoring and analysis of the mine's safety

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parameters. The central control unit can also send commands or alerts back to the NodeMCU, enabling remote control and emergency response.

The power supply for the system is not explicitly shown in the block diagram but is an essential component. It ensures a stable and reliable power source for all the system components, considering the mine's challenging environment.

Overall, the block diagram depicts the integration of various components, sensors, and wireless modules to create a comprehensive coal mine safety monitoring and alerting system. The NodeMCU acts as the brain of the system, collecting sensor data, processing it, triggering alarms if necessary, and facilitating wireless communication with the central control unit for real-time monitoring and response.

3.3 Circuit Diagram:

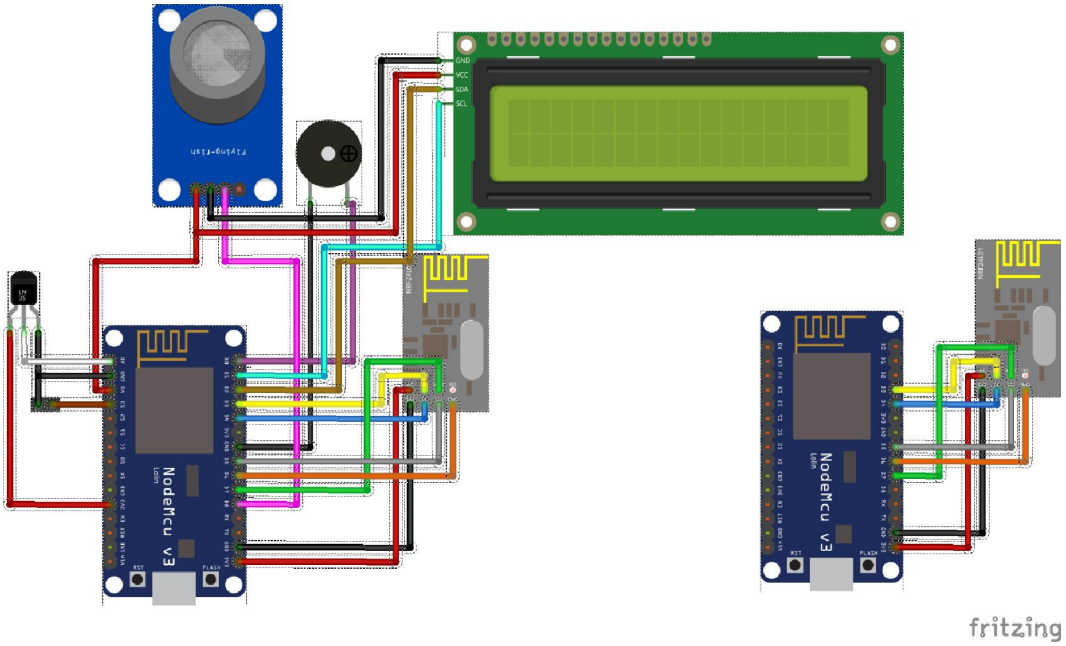

Figure 2:- Circuit Diagram of the System

3.4 Hardware and Software Requirements Hardware:

NodeMCU ESP12E Microcontroller:

NodeMCU is an open source IoT platform. It includes firmware which runs on the ESP8266 Wi-Fi SoC from Espressif Systems, and hardware which is based on the ESP-12 module. The term "NodeMCU" by default refers to the firmware rather than the development kits. The firmware uses the Lua scripting language. It is based on the eLua project, and built on the Espressif Non-OS SDK for ESP8266. It uses many open-source projects, such as lua-cjsonand SPIFFS.

Figure 3:- NodeMCU ESP12E Microcontroller

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Temperature Sensor: LM35 is a precession Integrated circuit Temperature sensor, whose output voltage varies, based on the temperature around it. It is a small and cheap IC which can be used to measure temperature anywhere between -55°C to 150°C.There will be rise of 0.01V (10mV) for every degree Celsius rise in temperature. It Measures the ambient temperature within the coal mine and provides the temperature data to the microcontroller.

Figure 4: - LM35 Temperature Sensor

MQ Gas Sensor: The MQ-135 Gas sensor can detect gases like Ammonia (NH3), sulfur (S), Benzene (C6H6), CO2, and other harmful gases and smoke. Similar to other MQ series gas sensor, this sensor also has a digital and analog output pin. When the level of these gases goes beyond a threshold limit in the air the digital pin goes high. This threshold value can be set by using the on-board potentiometer. The analog output pin, outputs an analog voltage which can be used to approximate the level of these gases in the atmosphere.The MQ135 air quality sensor module operates at 5V and consumes around 150mA. It requires some pre-heating before it could actually give accurate results.

Figure 5: - MQ Gas Sensor

Water Level Sensor/ Float Sensor: A float switch is a device used to sense the level of liquid within a tank, it may actuate a pump, an indicator, an alarm, or other device.A float switch is a device used to sense the level of liquid within a tank. The switch may actuate a pump, an indicator, an alarm, or other device. It can be easily converted from normally open to normally close by inverting the float.

Figure 6: - water Level Sensor

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I2C LCD: The character LCD is ideal for displaying text and numbers and special characters. LCDs incorporate a small add-on circuit (backpack) mounted on the back of the LCD module. The module features a controller chip handling I2C communications and an adjustable potentiometer for changing the intensity of the LED backlight. An I2C LCD advantage is that wiring is straightforward, requiring only two data pins to control the LCD. A standard LCD requires over ten connections, which can be a problem if your Arduino does not have many GPIO pins available. If you happen to have an LCD without an I2C interface incorporated into the design, these can be easily acquired separately.

Figure 7:- I2C LCD

NRF24L01 Wireless TX RX: The nRF24L01 is a single chip 2.4GHz transceiver with an embedded baseband protocol engine (Enhanced ShockBurst™), designed for ultra-low power wireless applications.
The nRF24L01 is designed for operation in the world-wide ISM frequency band at 2.400 - 2.4835GHz. An MCU (microcontroller) and very few external passive components are needed to design a radio system with the nRF24L01. The nRF24L01 is configured and operated through a Serial Peripheral Interface (SPI.) Through this interface the register map is available. The register map contains all configuration registers in the nRF24L01 and is accessible in all operation modes of the chip.

Figure 8:- NRF24L01 Wireless TX RX

Piezoelectric Buzzer: An audio signaling device like a beeper or buzzer may be electromechanical or piezoelectric or mechanical type. The main function of this is to convert the signal from audio to sound. Generally, it is powered through DC voltage and used in timers, alarm devices, printers, alarms, computers, etc. Based on the various designs, it can generate different sounds like alarm, music, bell & siren. It will Produce audible alerts and warning signals to notify miners and personnel in hazardous situations or emergencies.

Figure 9:- Piezoelectric Buzzer

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Softwares:

1. Arduino IDE:

The Arduino integrated development environment (IDE) is a cross-platform application (for Windows, macOS, Linux) that is written in the programming language Java. It is used to write and upload programs to Arduino board. The source code for the IDE is released under the GNU General Public License, version. The Arduino IDE supports the languages C and C++ using special rules of code structuring. The Arduino IDE supplies a software library from the Wiring project, which provides many common input and output procedures. User-written code only requires two basic functions, for starting the sketch and the main program loop, that are compiled and linked with a program stub main() into an executable cyclic executive program with the GNU tool chain, also included with the IDE distribution. The Arduino IDE employs the program avrdude to convert the executable code into a text file in hexadecimal encoding that is loaded into the Arduino board by a loader program in the board's firmware. In our project, it is used for uploading code to ESP32 Board.

2.ThingSpeak:

According to its developers, "ThingSpeak is an open-source Internet of Things (IoT) application and API to store and retrieve data from things using the HTTP and MQTT protocol over the Internet or via a Local Area Network. ThingSpeak enables the creation of sensor logging applications, location tracking applications, and a social network of things with status updates".

ThingSpeak was originally launched by ioBridge in 2010 as a service in support of IoT applications.

ThingSpeak has integrated support from the numerical computing software MATLAB from MathWorks, allowing ThingSpeak users to analyse and visualize uploaded data using MATLAB without requiring the purchase of a MATLAB license from MathWorks.

ThingSpeak has a close relationship with MathWorks, Inc. In fact, all of the ThingSpeak documentation is incorporated into the MathWorks' MATLAB documentation site and even enabling registered MathWorks user accounts as valid login credentials on the ThingSpeak website. The terms of service and privacy policy of ThingSpeak.com are between the agreeing user and MathWorks, Inc.

ThingSpeak has been the subject of articles in specialized maker websites like Instructables, Codeproject and Channel 9

Flowchart

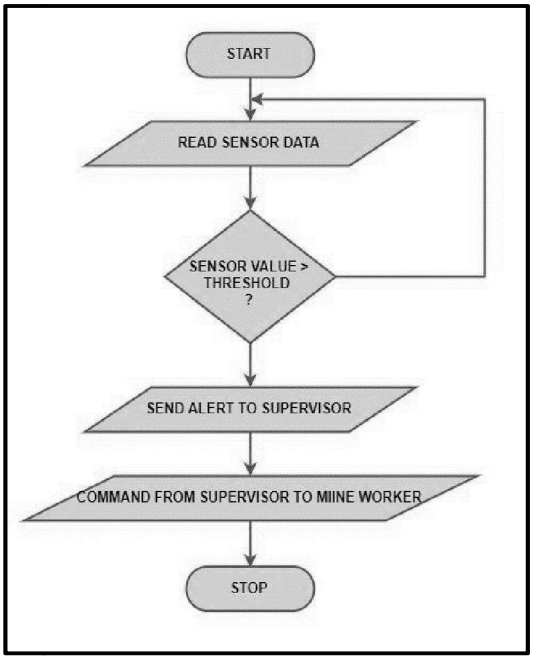

Figure 10:- Flowchart

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Working of the Coal Mine Safety and Monitoring System:

Here is a step-by-step overview of the working of the proposed system:

1. On the transmitter side the Zigbee is connected to the NodeMCU.
2. The NodeMCU reads all the sensor values and encodes it and sends it using the Zigbee connected on system.
4. The Zigbee on another end receives this data and decodes it.
5. This decoded data is then sent to ThingSpeak Cloud Server over Wi-Fi.
6. If any of the sensor value goes beyond threshold then the system notifies both; the user as well as the supervisor using buzzer indication.
7. The supervisor can then take action as well as the mine worker can also take action accordingly.

IV. RESULTS AND DISCUSSION

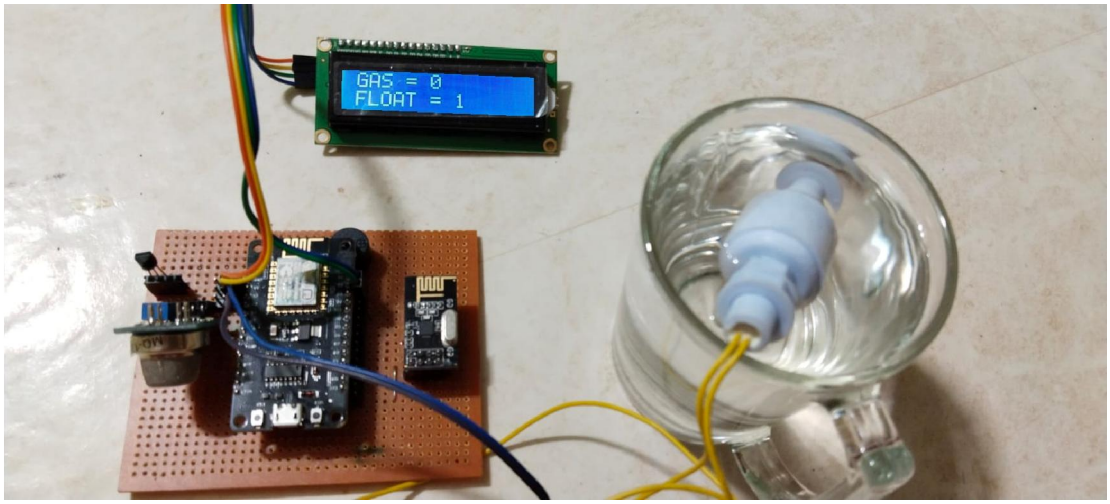

Figure 11:- Prototype Of Water Level Record in Coal Mine

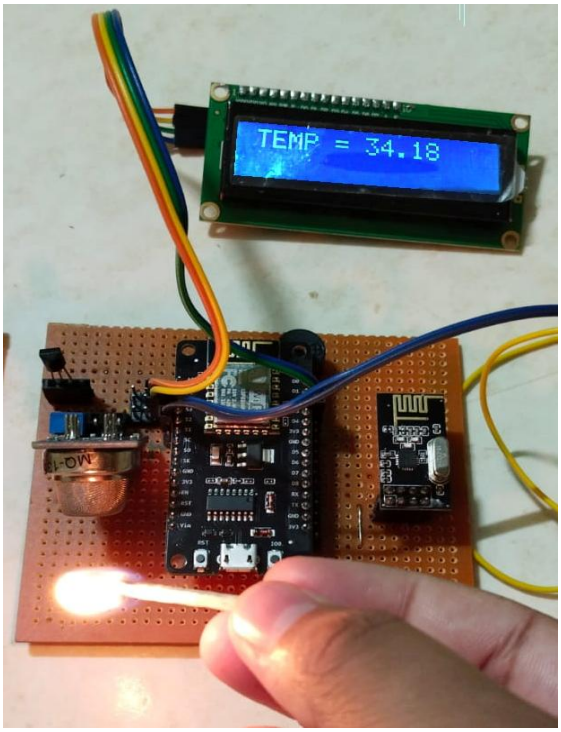

Figure 12:- : Prototype Of Temperature Record in Coal Mine

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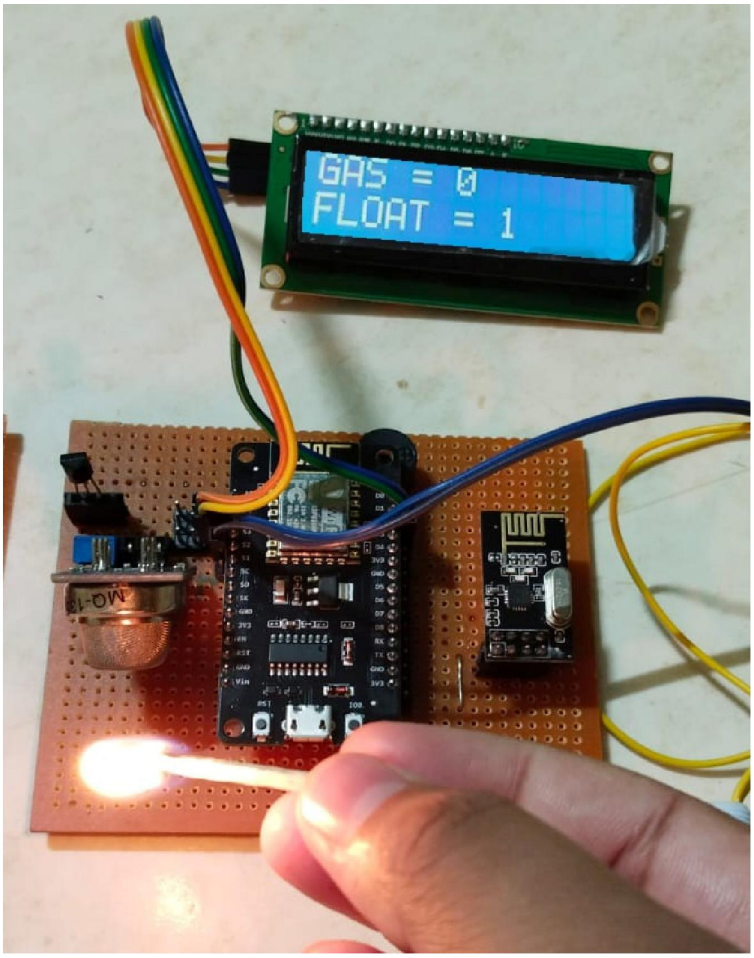

Figure 13:- Prototype Of Gas Record in Coal Mine

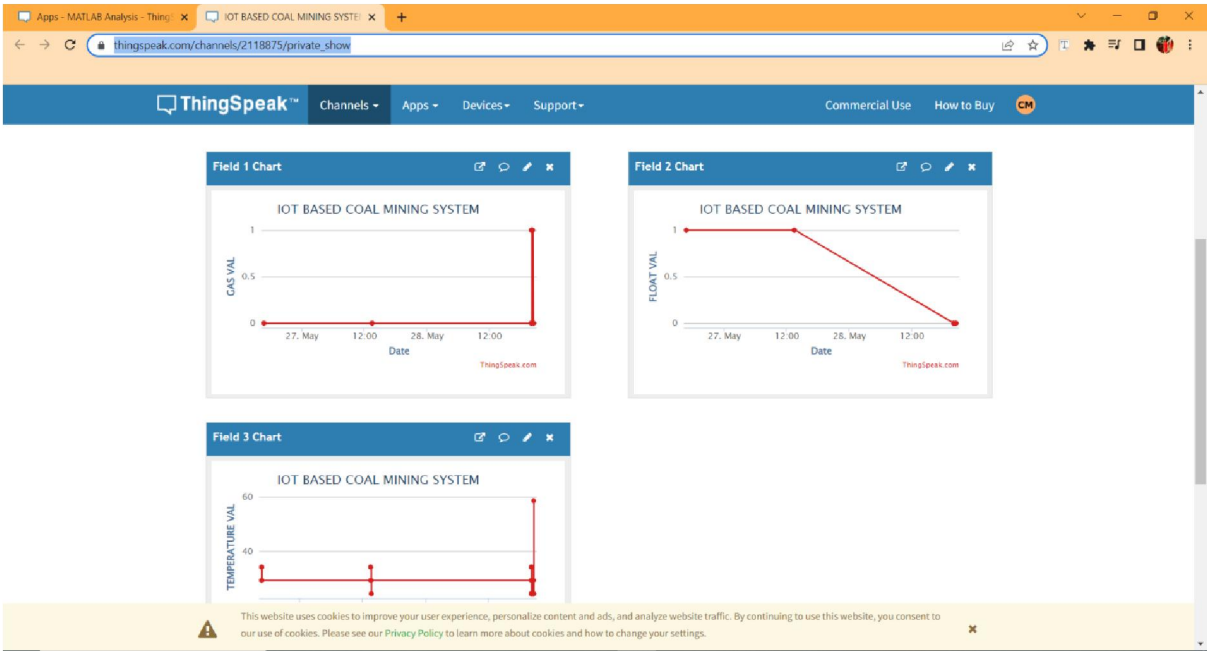

Figure 14:- Output on IOT website ThingSpeak

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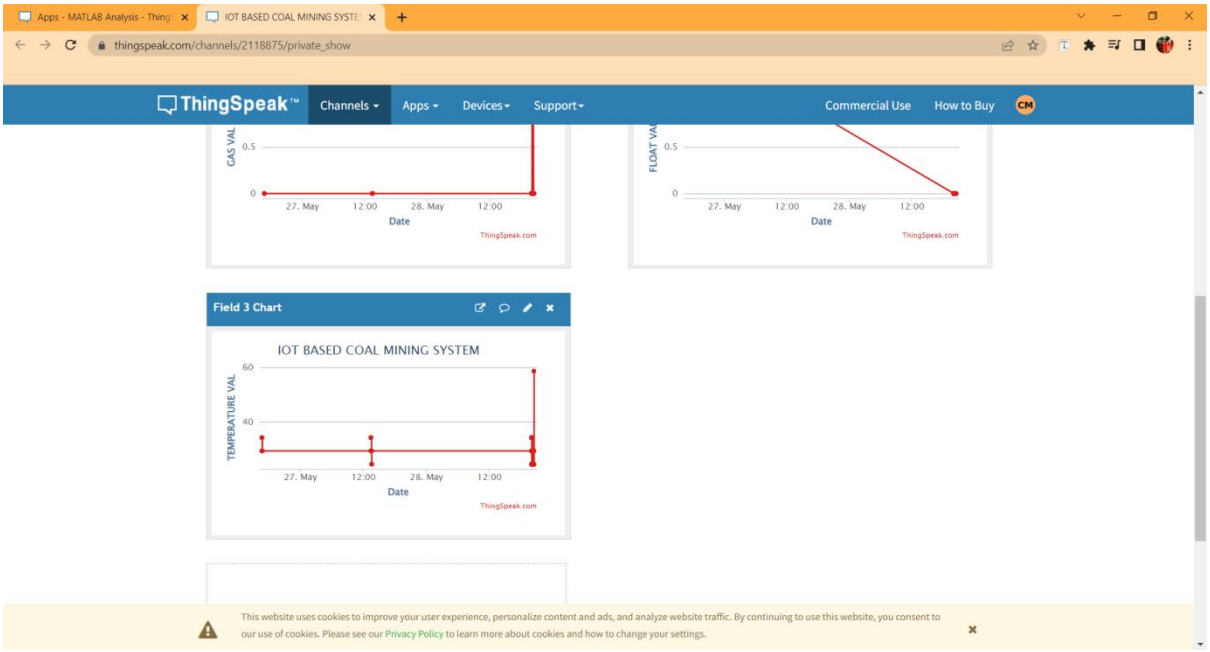

Figure 15:- Output on IOT website ThingSpeak

V. CONCLUSION

The system ensures the safety of miners and personnel by continuously monitoring the sensor readings and triggering the piezoelectric buzzer in the event of hazardous conditions exceeding predefined thresholds. The audible alerts serve as immediate warnings, enabling prompt action and evacuation if necessary.

The coal mine safety and monitoring system offers an efficient solution to mitigate potential risks and enhance safety in coal mines. The project demonstrates the effective utilization of microcontroller-based systems, wireless communication, and sensor technology to ensure the well-being of miners and facilitate proactive safety measures in coal mining operations.

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