IOT Based Advanced Underground Coal Mine Detection and Auto Alert System for Coal Mine Workers

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***Abstract*—Underground coal mining poses serious safety risks due to toxic gases, high temperatures, and rising water levels. This project introduces an IoT-based Coal Mine Safety Monitoring System using the ESP32 microcontroller for real-time hazard detection. It integrates BMP180 for pressure/temperature, MQ2 for flammable gas detection, and a soil moisture sensor for water level monitoring. A red LED and buzzer alert in unsafe conditions, while a green LED indicates safety. A relay-activated DC fan provides ventilation during poor air quality. Sensor data is displayed locally via an I2C LCD and remotely through the Blynk IoT app, allowing mobile-based monitoring. This smart, low-cost system improves mine safety through automation, wireless alerts, and quick emergency response—making it ideal for scalable deployment in modern mining operations.**

***Keywords*—Coal Mine Safety, Real-time Monitoring, Hazard Detection, ESP32, BMP180**

I. INTRODUCTION

Mines are among the most hazardous workplaces globally, with explosions and toxic gas leaks leading to the loss of thousands of lives each year. Reports estimate around 12,000 fatalities annually due to mine-related incidents. Despite coal being a non-renewable resource, it remains a key energy source, and coal mining continues—often at the cost of worker safety. Many of these accidents are due to outdated machinery, poor electrical systems, and undetected release of toxic or explosive gases such as methane, carbon monoxide, and hydrogen sulfide. These gases accumulate in the confined spaces of coal mines, posing serious risks due to their flammability and toxicity.

To address these challenges, this project introduces a wireless, IoT-based coal mine safety monitoring system. Traditional wired monitoring systems often fail during explosions, making repairs difficult and dangerous. By contrast, our system eliminates complex wiring by using a Wireless Sensor Network (WSN), built around the Arduino Nano and NodeMCU microcontrollers. These compact, low-cost sensor nodes are easily deployable across the mine for real-time monitoring.

The system includes various sensors: AM2302 and DHT11 for temperature and humidity, MQ6 and MQ7 for gas detection, and a flame sensor to detect fire. It uses a buzzer for immediate alerts and an LED display for local data visualization. The NodeMCU sends sensor data to the Blynk IoT platform and uses MQTT for efficient cloud communication, enabling remote monitoring and fast response.

By detecting early signs of hazardous conditions and triggering alerts, this solution enhances miner safety and operational awareness. The system is low-cost, easy to deploy, and highly scalable, making it suitable for modern mining environments where quick detection and preventive action are crucial to saving lives and avoiding disasters.

II. METHODLOGY

The methodology for this project involves designing, assembling, and deploying an IoT-based real-time monitoring system tailored for underground coal mine environments. The system utilizes an ESP32 microcontroller as its core unit, which communicates with various environmental sensors to continuously monitor hazardous conditions such as toxic gas presence, high temperatures, and increased moisture levels (indicative of rising underground water).

The system is composed of multiple sensors: the MQ2 gas sensor is used for detecting flammable gases like methane and LPG; the BMP180 sensor

monitors atmospheric pressure and temperature; and a soil moisture sensor helps detect the presence of excess underground water. These sensors are strategically connected to the ESP32 board, which reads and processes their output in real time.

A critical component of the system is its alert mechanism. When readings from any sensor exceed safe thresholds, the ESP32 triggers a buzzer and activates a red LED, signaling danger. Under normal conditions, a green LED remains lit. Furthermore, to handle poor air quality, a DC fan connected via a relay module automatically activates for ventilation.

For data visualization and remote monitoring, the system is connected to the Blynk IoT platform. The ESP32 sends live sensor readings to the cloud using Wi-Fi, allowing supervisors to monitor conditions through a mobile app from any location. An I2C LCD module is also integrated into the circuit to display sensor values locally within the mine in real time.

This integrated approach not only ensures early detection of dangerous conditions but also enables faster decision-making and emergency responses. The combination of real-time sensing, wireless communication, local alerts, and remote monitoring offers a scalable, low-cost solution for enhancing mineworker safety in hazardous environments.

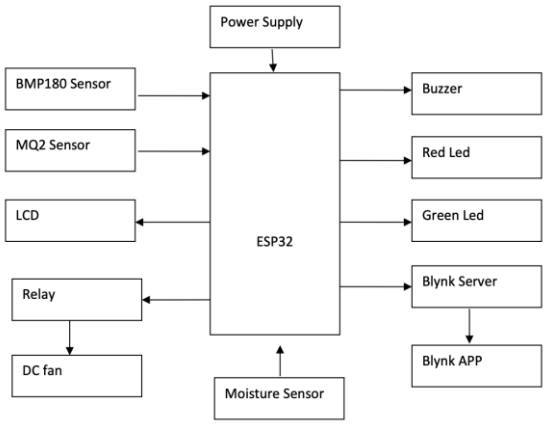

Fig 1: Block diagram

The IoT-based coal mine safety monitoring system, as depicted in the block diagram, is a sophisticated solution designed to enhance the safety of miners by continuously monitoring the environment within the mine. At the heart of this system is the ESP32 microcontroller, a versatile and powerful device that serves as the central processing unit. This microcontroller is equipped to handle multiple sensors, each playing a crucial role in detecting potential hazards.

The BMP180 sensor is responsible for measuring pressure and temperature levels. These measurements are vital for identifying any changes in the mine's atmospheric conditions that could pose a risk to miners. The MQ2 sensor, on the other hand, is specifically designed to detect the presence of flammable gases. This is particularly important in coal mines, where methane and other combustible gases can accumulate, leading to explosions if not detected early. Additionally, a moisture sensor is included to monitor water levels, which can indicate flooding or other water-related hazards.

Upon receiving data from these sensors, the ESP32 processes the information to determine the current safety conditions. If any hazardous conditions are detected, such as high levels of flammable gases or poor air quality, the ESP32 triggers a buzzer and a red LED to alert miners. Conversely, if the conditions are safe, a green LED is activated to provide reassurance. To improve air quality during poor conditions, a relay-controlled DC fan is activated, ensuring that fresh air is circulated throughout the mine.

IoT-based solution enhances coal mine safety with real-time data visualization, remote monitoring, and immediate alerts.

III. SCHEMATIC DIAGRAM

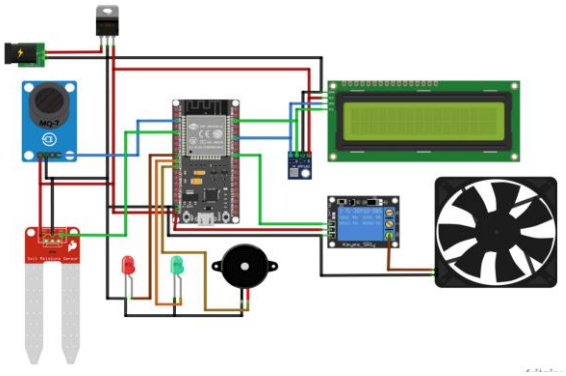

Fig 2: Schematic diagram

The given circuit diagram illustrates an IoT-based environmental monitoring and safety system designed using the ESP32 microcontroller. This system is particularly suited for applications in underground coal mines, industrial zones, or smart agriculture, where continuous monitoring of

environmental parameters is critical for safety and efficiency.

At the heart of the system lies the ESP32, a powerful microcontroller with built-in Wi-Fi capabilities. It collects data from various sensors and drives output devices based on programmed safety thresholds. One of the primary sensors used is the MQ-7 gas sensor, which detects the presence of harmful gases such as carbon monoxide. In parallel, a soil moisture sensor is integrated to detect rising water levels, which is essential for flood detection in mines or assessing soil health in agriculture. Additionally, a BMP180 sensor monitors atmospheric pressure and temperature, offering critical data for environmental tracking.

To provide visual and real-time feedback to users, an I2C-based LCD display is connected to the ESP32, showing current sensor readings. When a hazard is detected—like high gas levels or excess moisture—the buzzer is triggered to provide an audible alert, and a red LED is turned on to indicate danger. Under safe conditions, a green LED remains active, signaling normal operation.

For air quality control, the system uses a relay module to drive a DC fan. If poor air quality is detected, the ESP32 activates the relay to turn on the fan, ensuring ventilation in confined environments. This automation enhances safety without human intervention.

The system is not only reliable for real-time monitoring but also expandable to cloud-based platforms like Blynk, enabling remote access through mobile apps. Overall, it represents a low-cost, scalable, and effective safety solution, ideal for high-risk environments where automated monitoring is essential.

IV. RESULT

With the integration of IoT technology, this project significantly enhances the monitoring of various environmental conditions within coal mines, with a special focus on air quality and gas detection. The system employs an advanced combination of sensors designed to detect dangerous gases such as methane and carbon monoxide, as well as monitor atmospheric pressure and temperature levels. These sensors are connected to a centralized IoT module that collects and transmits real-time data to a monitoring station, enabling quick analysis and responsive action.

Fig 3: Real-Time Sensor Dashboard

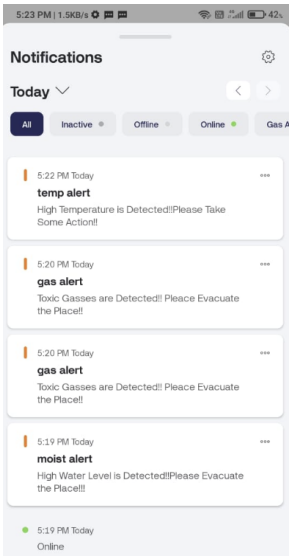

Fig 4 : Real-Time Alert Notification System

By providing continuous, real-time monitoring, the system ensures that any hazardous changes in the environment are immediately identified. This proactive approach helps in preventing potential accidents, safeguarding the health and safety of mine workers. Additionally, the system includes alert mechanisms that can trigger alarms when gas concentrations exceed safe limits. Overall, the incorporation of IoT technology fosters a safer working environment, enhances operational efficiency, and supports stringent safety compliance in coal mining operations.

V. ADVANTAGES

1. Cost is less

2. Provide wireless connection security
3. Improved services in coal mine

VI. APPLICATIONS

1. Indoor Air Quality Monitoring System
2. Outdoor Air Quality Monitoring System
3. Particulate Matter (PM) Monitoring
4. Gas Detection System
5. Industrial Gas Monitoring System

VII. CONCLUSION

The proposed IoT-based underground coal mine safety monitoring system successfully addresses the critical challenges faced in hazardous mining environments. By integrating the ESP32 microcontroller with various sensors—such as the MQ-2 for gas detection, BMP180 for temperature and pressure monitoring, and a soil moisture sensor for water level tracking—the system provides real-time environmental data to ensure the safety of mine workers. Visual and audio alerts through LEDs and a buzzer enhance immediate awareness during emergencies, while a relay-controlled DC fan offers ventilation in poor air quality conditions. Moreover, remote monitoring is enabled via the Blynk IoT platform, offering mobile access to real-time data. This solution reduces the dependency on manual supervision and provides timely alerts that can prevent accidents and improve emergency response. The system's cost-effectiveness, scalability, and reliability make it a valuable tool for modern mining safety and a strong step toward smart industrial automation.

VIII. FUTURE SCOPE

Real-time deployment of the proposed model is scheduled to be carried out in the near future. This process will involve rigorous planning and execution to ensure optimal performance in diverse environments. One of the primary challenges is the maintenance of the equipment under varying and often harsh weather conditions. Ensuring that the equipment remains functional and resilient during extreme temperatures, heavy rainfall, and high humidity levels will require advanced protective measures and regular servicing protocols. Additionally, the effective transmission of data is another critical hurdle. This includes establishing reliable communication channels that can handle large volumes of data without latency or loss, even in remote or challenging terrains. Addressing these challenges will be crucial for the successful and sustainable operation of the model in real-world applications.

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