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COAL MINING SAFETY MONITORING SYSTEM – A REVIEW

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Abstract: Coal mines are prone to a lot of fatalities. In order to reduce fatalities, it is better to keep the mine under constant monitoring which can send alerts when there is a change in parameters like temperature, fire and leakage of gases like methane which are likely a potential fatality. In order to avoid it we propose a monitoring system that can monitor basic safety measures and regulate such parameters. All the sensors can be assembled into a single unit and then placed in a coal mine for it to be monitored constantly.

I. INTRODUCTION

In order to protect employee safety and avoid accidents, coal mining requires a safety monitoring system. Conventional measurement techniques, however, place a premium on numerical accuracy, making it challenging for non-experts to understand the implications of the data. Furthermore, it is extremely difficult to efficiently monitor safety due to the intricate and dangerous nature of coal mines. A rising understanding of the necessity to use cutting-edge technology, such as fuzzy theory and neural networks, has emerged in recent years in order to get beyond these constraints. This review paper investigates the use of intelligent fuzzy measurement systems that make use of tools like RBF neural network technology in order to enhance coal mine safety monitoring and deliver more insightful and sensible data.

The importance of monitoring coal mine safety and the limits of conventional numerical measurement techniques. In order to overcome the difficulties in comprehending expert data and monitoring state security in intricate coal mine environments, it suggests combining fuzzy theory and neural network technology. The use of RBF neural network technology to create fuzzy membership functions and build a reliable safety monitoring system is covered in this research [1]. During the "12th Five-Year Plan" period, an analysis of coal mine accidents showed numerous major causes of accidents. Employees' lack of awareness of safe production, unlawful and illegal production, insufficient safety management systems, inadequate gas control measures, poor water pollution prevention and control, insufficient leadership by state-owned coal mining enterprises, failure to learn from previous accidents, gaps in local safety supervision, and the need to improve roof management technology are among these [2]. A wireless sensor network-based monitoring system for managing dangers in underground coal mines. The system monitors gas concentration, temperature, and humidity, and generates alarms when these parameters are exceeded. It improves mine safety by providing constant performance and exact measurements. The ZigBee wireless sensor nodes, routers, coordinators, switches, and monitoring computers comprise the system. For wider wireless coverage, the nodes use CC2530 ZigBee microcontroller chips and sensor modules, while the routers/coordinators use CC2591. The software architecture contains sensor node, coordinator, and monitoring computer program architectures. It can be upgraded to include video data capture for real-time mining operations monitoring [3,4]. This paper describes a coal mine safety measurement system that makes use of a wireless sensor network (WSN) and an Arduino UNO controller. The WSN incorporates gas, temperature, humidity, vibration, and MEMS sensors that send data to the Arduino UNO in real time. The technology improves safety control and informs miners if any parameter exceeds predefined limits. WSN is helpful in coal mines because to its low cost and ease of deployment without the need for elaborate cable installations [5]. Bluetooth wireless transmission, CAN bus technology, RS485 bus, WSN, and gas-sensor-equipped safety helmets have all been proposed as coal mine monitoring system implementations. While each implementation has advantages, such as increased communication range and safety precautions, they also have limitations in terms of data transfer distance, network dependability, real-time performance, and installation/maintenance problems in an underground mining environment. A three-dimensional ventilation network experimental model was used in a specific scenario to govern fan frequency conversion and control gas emission in a Yangquan coal mine. By creating wind regulation criteria and accomplishing automatic control of ventilator frequency depending on gas emission conditions, this dynamic control idea significantly minimised the chance of gas mishaps [6,7]. The incorporation of digital twin technology into coal mine safety management for intelligent and effective accident prevention.

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The research looks into the twin model architecture in order to create a safety management model for coal mine gas incidents. The benefits of the twin model are highlighted, and technical criteria are presented to help with practical implementation. The research also investigates the use of close-range protective layer mining (PLM) as a solution to reduce gas outbursts in the Hezhuang Coal mine. The authors use simulation models to examine the stress evolution and deformation of the overlaying coal seam during PLM at various mining depths, providing useful insights for lower PLM engineering applications [8,9]. To replace wired networks, cut costs, and eliminate blind spots, a wireless sensor network-based coal mine safety monitoring system based on ZigBee technology is proposed. The system monitors gas concentrations, temperature, humidity, wind speed, and miners' locations, providing flexibility and automatic alarms when environmental restrictions are exceeded. This technology improves worker safety, substitutes for traditional security measures, and minimizes coal mine accidents [10].

Development of Intelligent Coal Mining

The emergence of sophisticated technologies is a significant breakthrough for the coal mining industry. By utilizing automation, artificial intelligence (AI), and data analytics, intelligent coal mining aims to increase productivity, enhance security, and maximize operational performance. This review looks at the main characteristics and potential benefits of intelligent coal mining.

Robotics and automation: it used in intelligent coal mining to perform a number of tasks that were previously handled by human miners. Automated machinery can operate in hazardous or challenging locations, reducing accident risk and raising overall safety. Robotic coal loaders, autonomous haul trucks, and drilling devices are a few examples. Additionally, automation reduces downtime and permits continuous operation, which can boost output.

Artificial intelligence (AI) and machine learning algorithms: These are crucial to intelligent coal mining systems. These technologies enable the analysis of vast amounts of data amassed by sensors, equipment, and geological surveys in order to enhance mining operations. AI algorithms have the ability to recognize patterns, predict equipment failure, optimize the drilling and blasting processes, and control mining operations in real-time.

Real-time Monitoring and Control: Intelligent coal mining systems integrate sensors and IoT (Internet of Things) devices to provide real-time monitoring and control of multiple parameters within coal mines. Important factors such as ground stability, temperature, humidity, and gas concentrations can all be detected by these sensors. Real-time data analysis and visualization insights assist decision-makers and action-takers in maximizing resource extraction, ensuring effective ventilation, and avoiding accidents.

Safety and Risk Mitigation: One of the key objectives of intelligent coal mining is to increase miner safety. Risk reduction is an additional. Real-time monitoring enables early detection and quick response to minimize risks in potentially hazardous circumstances like gas leaks, collapses, or fires. Intelligent technologies can provide location tracking and emergency response capabilities in the event of an incident or evacuation to protect the safety of miners.

Operational Efficiency and Cost Reduction: Operational efficiency can be improved through intelligent solutions for coal mining, which reduces costs and raises profitability. Through data-driven analysis, AI systems may maximize equipment utilization, cut energy use, reduce waste, and streamline logistics and transportation. Predictive maintenance algorithms can identify potential equipment failures before they occur, which reduces equipment downtime and maintenance costs.

Environmental Impact Reduction: The goal of intelligent coal mining is to lessen the environmental harm caused by the mining and processing of coal. By enhancing waste management strategies, reducing emissions, and maximizing resource utilization, these technologies aid in sustainable mining practices. Utilizing intelligent systems to control dust suppression systems, monitor air and water quality, and regulate water use can lead to improved environmental performance.

II. LITERATURE SURVEY

Hua FU Tao WANG Cui YANG *et al*.,[1]- Have detailed discussion about the intelligent fuzzy sensing system for coal mine safety combines neural networks and fuzzy theory to transform parameters into language descriptions for outputting the safety state of the mine. The membership function generation network is used to obtain appropriate membership functions based on 100 groups of data, which are then used as input for the fuzzy reasoning network. The monitoring results of ten groups of testing samples show that the system accurately determines the safety state of the mine based on multiple parameters. The system overcomes the difficulties of accurately measuring parameters in a complex environment and provides easily understandable output for professionals, making it highly practical.

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Xuelong Li *et al.*, [2]- Have examined that During the 12th Five-Year Plan period in Guizhou province, coal mine safety was generally good with decreasing accidents and fatalities. Preventive measures, including safety law enforcement and technology, helped decrease accidents and improve mines safety. The analysis of coal mine accidents during the "12th Five-Year Plan" period revealed several main causes of accidents. These include a lack of awareness of safe production among employees, unlawful and illegal production, incomplete safety management systems, inadequate gas control measures, poor water pollution prevention and control, inadequate leadership by state-owned coal mining enterprises, failure to learn from previous accidents, gaps in local safety supervision, and the need to improve roof management technology. These issues should be addressed to improve the safety of coal mines in the future.

Zhang Yi *et al.*, [3]- Reviewed a detailed discussion about a wireless sensor network-based monitoring system to manage explosive, corrosion, and accident hazards in underground coal mines. The device can monitor characteristics such as gas concentration, temperature, and humidity and alarm when they exceed present limits. The proposed system has a consistent performance, precise measurement, and contributes to increased mine safety while lowering accidents. The ZigBee wireless sensor nodes, routers, coordinators, mine network switches, and monitoring computers comprise the system. The wireless sensor nodes employ CC2530 ZigBee microcontroller chips and sensor modules to pre-process environmental monitoring signals. Gas sensors, carbon monoxide sensors, and temperature and humidity sensors are also included in the sensor nodes. The router/coordinator nodes employ the CC2591, which combines a high-gain power amplifier, a balanced converter, and an RF matching network to increase wireless coverage range. The software architecture of the system includes sensor node program design, coordinator program design, and monitoring computer program design. The system can be extended to include video data acquisition to enable real-time monitoring of mine site operations.

Madhu Nakirekanti *et al.*, [4]- The article outlines the architecture of a coal mine safety monitoring system based on ZigBee wireless sensor networks (WSNs). Using multiple sensors, the system seeks to monitor environmental characteristics in the mine, such as temperature, humidity, and carbon monoxide gas levels. The sensor node data is wirelessly delivered to the controller section, which then delivers the information to the ground monitoring centre through ZigBee connection. As the controlling core for the WSNs nodes, the system additionally incorporates an ARM CPU module. Furthermore, miners employ frequency-based ID cards for access, and emergency services can be accessible via GSM connectivity. The technology is intended for use in coal mines because it is low-power and cost-effective. The article includes an overview of the system architecture and the different components used in the system design.

N Sathish Kumar *et al.*, [5]- Have examined that, A wireless sensor network (WSN) and an Arduino UNO controller are used in a coal mine safety measurement system. By monitoring the status of the underground mine, this system intends to improve production safety control and prevent coal mine accidents. The WSN is comprised of a variety of sensors, including gas, temperature, humidity, vibration, and MEMS sensors. The information gathered by these sensors is sent to the Arduino UNO, which displays it on an LCD panel. If any parameter exceeds a specified limit, the system notifies the miners. WSN is advantageous over wired networks in coal mines because it is less expensive and can be put anywhere without the need for sophisticated and time-consuming cable-laying operations.

S. R. Deokarl *et al.*, [6]- Have reviewed that Several researchers have proposed various coal mine monitoring system implementations. Bluetooth wireless transmission, CAN bus technology, the RS485 bus, wireless sensor networks (WSN), and safety helmets equipped with gas sensors are among the implementations. Each implementation has benefits and drawbacks, such as limited data transfer distance, difficulty ensuring network reliability, and poor real-time performance. Some implementations also encounter installation and maintenance issues in the hostile underground mining environment. However, these technologies provide vital safety measures for miners and improve the communication range within the mine, preventing accidents and enhancing coal miners' safety conditions.

Xiaodong Pei *et al.*, [7]-Have detailed discussion about the three-dimensional ventilation network experimental model was utilised to govern fan frequency conversion and control gas emission. The gas concentration in the stope had a power function relationship with the fan's operating frequency, and five wind regulation rules were established to match supply and demand during the working day. The dynamic control concept was effectively implemented in a Yangquan coal mine, lowering the danger of gas mishaps. To monitor and control airflow in a coal mine, a comprehensive experimental platform was created. Five regulation rules were developed, and automatic control of ventilator frequency and air supply depending on gas emission conditions was achieved. The software successfully controlled gas concentration and mitigated gas disaster risk, confirming the software's viability and efficiency.

Jiaqui Wang *et al.*, [8]- Have proposed a method to achieve intelligent and effective management of coal mine safety accidents, digital twin technology is being integrated into coal mine safety management. The twin model architecture is investigated in order to build a twin safety management model for a coal mine gas accident. The advantages of the twin model are highlighted, and essential technical criteria are provided to expedite field use of the gas accident twin model.

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Hongtu Zhang *et al*., [9]-This paper studies the effect of close-range protective layer mining (PLM) as a technique to prevent gas outburst in Hezhuang Coal mine. Using a simulation model, the authors analyzed the stress evolution and deformation of the overlying coal seam (II1) after lower PLM in working face at different mining depths. The study provides a theoretical basis for the engineering application of lower PLM This paper simulates the stress and deformation of an overlying coal seam during lower protective layer mining (PLM). Results show that PLM can effectively release pressure and prevent gas outburst. The stress distribution of the overlying coal seam can be divided into three parts in both strike and dip directions, with unobvious deformation in the original stress zone, compressive deformation in the stress concentration zone, and expansive deformation in the pressure relief zone.

Rajkumar Boddu *et al*., [10]- Have discussed to replace wired networks and avoid costly cable laying and blind spots, a wireless sensor network-based coal mine safety monitoring system is proposed. In coal mines, ZigBee technology is employed to increase production safety and decrease accidents. The purpose of the study is to open the door for future research by offering a solution for wireless communication and safety monitoring in mine. An underground mine's gas concentration, temperature, humidity, wind speed, and miners' locations are all tracked via a wireless sensor network-based system. It increases the flexibility and usefulness of monitoring and automatically sounds an alarm when environmental factors go beyond the limit. This technology efficiently replaces conventional mine security measures, improves worker safety, and lowers coal mine accidents.

Nasution Harahap *et al*., [11]- predicts the percentage of temperature sensor readings from the LM35 that will be inaccurate using a simple linear regression method. The LM35 sensor is a well-liked alternative for monitoring temperature because of its low cost and ease of use. It is prone to inaccuracies, though, just like any sensor, thus it's critical to properly estimate these for accurate temperature readings. The authors advise using a simple linear regression model to calculate the fraction of temperature observations that are inaccurate. They conducted experiments and collected data from the LM35 sensor to test their model. The results demonstrated that the proposed model can predict with accuracy the percentage error of readings from LM35 temperature sensors, which can aid in improving the accuracy of temperature measurements in a variety of applications.

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