Real Time Hazardous Gas Emission Detection and Alert System in Thermal Power Plants

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***Abstract*—Thermal power plants are major contributors to hazardous gas emissions such as carbon dioxide (CO_2), carbon monoxide (CO), and methane (CH_4), which pose serious risks to worker safety, plant equipment, and the surrounding environment. Existing gas monitoring practices in many power plants rely on periodic manual inspection or isolated sensing units, which often fail to provide continuous surveillance, early warning, and timely response during sudden gas leakage or abnormal emission conditions. The absence of real-time alerts, automated ventilation control, and centralized monitoring increases the chances of occupational hazards, health complications, and accidental disasters. To address these challenges, this work focuses on a hazardous gas emission detection and alert system designed specifically for thermal power plant environments. The system continuously monitors gas concentration levels using multiple sensors and processes the data through a microcontroller for rapid decision-making. When unsafe gas levels are detected, the system automatically activates exhaust ventilation, triggers visual and audible alerts through LEDs and buzzers, and sends instant notifications to supervisors via mobile communication. Additionally, the integration of IoT-based cloud monitoring enables daily and weekly emission summaries, gas leakage zone identification, and future gas level prediction using recent sensor data. This approach enhances safety, ensures regulatory compliance, and supports proactive emission management in thermal power plants.**

I. INTRODUCTION

Thermal power plants remain one of the most widely used sources of electricity generation across the world due to their ability to produce large amounts of energy continuously. These plants operate by converting heat energy into electrical energy through high-temperature combustion processes. Although thermal power plants play a vital role in supporting industrial growth and economic development, their operation is closely associated with the release of harmful gaseous emissions. The uncontrolled or excessive emission of hazardous gases poses serious threats to human health, plant safety, and the surrounding environment. As industrial activity increases and environmental regulations become stricter, managing and controlling these emissions has become a critical challenge for the power generation sector.

The combustion processes involved in thermal power generation inevitably produce various toxic and polluting gases. When released into the atmosphere, these gases can accumulate within plant premises or disperse into nearby residential and ecological areas. Prolonged exposure to such emissions may result in respiratory disorders, cardiovascular complications, reduced air quality, and longterm environmental degradation. Workers within the plant are particularly vulnerable due to continuous exposure during operational hours. Even short-term exposure to elevated gas concentrations can lead to serious health emergencies, making safety monitoring an essential requirement rather than an optional measure. In many conventional setups, emission monitoring and safety management rely heavily on periodic inspections and manual supervision. Such approaches are often insufficient to handle sudden increases in hazardous gas levels caused by operational disturbances, fuel inconsistencies, or unexpected process failures. Delayed detection can lead to accidents, production losses, and severe environmental consequences. Therefore, there is a growing need for intelligent and automated monitoring approaches that can continuously assess emission levels and provide immediate warnings whenever unsafe conditions arise. Continuous surveillance ensures timely intervention and reduces the dependence on human observation alone. An effective hazardous gas emission detection and alert system is designed to continuously observe environmental conditions within and around thermal power plants. The primary objective of such a system is to identify abnormal emission levels at an early stage and issue prompt alerts to responsible personnel. Early warning mechanisms play a crucial role in preventing the escalation of hazardous situations by enabling quick corrective actions. This proactive approach enhances operational safety, minimizes the risk of occupational exposure, and helps prevent damage to infrastructure caused by prolonged exposure to toxic environments. Beyond safety considerations, emission monitoring also plays a significant role in environmental protection. Hazardous gases released from thermal power plants contribute to air pollution, acid rain, climate imbalance, and ecological harm. Continuous monitoring supports compliance with environmental standards imposed by regulatory authorities. By maintaining emissions within permissible limits, power plants can reduce their environmental footprint and demonstrate responsible industrial practices. Effective emission management also strengthens public trust and reduces conflicts with surrounding communities affected by industrial pollution. The integration of automated detection and alert mechanisms improves decision- making processes within thermal power plants. Real-time information about emission conditions allows plant operators to assess risks accurately and respond efficiently. The availability of historical data further supports trend analysis and helps identify recurring operational issues that may contribute to emission fluctuations. Over time, this data- driven approach assists in optimizing plant operations, improving efficiency, and reducing unnecessary emissions without compromising energy output.

The scope of this project is to develop a comprehensive hazardous gas emission detection and alert framework tailored for thermal power plant environments, with the primary focus on enhancing worker safety, operational reliability, and environmental protection. The project aims to enable continuous monitoring of hazardous gas concentration levels and ensure early identification of abnormal emission conditions that may arise due to process inefficiencies, leakage, or operational faults. By incorporating real-time analysis and automated alert mechanisms, the system is intended to support timely preventive actions, reduce occupational health risks, and minimize potential damage to plant infrastructure. The scope also includes centralized monitoring and data analysis to support emission trend assessment, safety compliance, and informed decision-making. Overall, the project emphasizes proactive emission management, improved safety response, and sustainable operation of thermal power plants under varying industrial conditions.

II. PROPOSED SYSTEM

The proposed hazardous gas emission detection and alert system is specifically designed for thermal power plant environments, where continuous monitoring of toxic and combustible gases is essential to ensure operational safety, environmental protection, and worker well-being. The block diagram illustrates a compact, intelligent, and real-time monitoring framework that integrates multiple sensing units, a processing core, alert mechanisms, and response modules into a unified safety solution. Each block in the system plays a critical role in detecting abnormal gas concentrations and initiating timely preventive actions. At the core of the system lies the Arduino Nano, which functions as the central processing and control unit. The Arduino Nano is responsible for acquiring sensor data, processing gas concentration values, executing decision logic, and coordinating all output responses. Its compact size, low power consumption, and real-time processing capability make it well suited for deployment in industrial environments such as thermal power plants. The microcontroller continuously polls all connected sensors and evaluates the incoming data against predefined safety thresholds. The system incorporates multiple gas sensors, each dedicated to monitoring a specific hazardous gas commonly present in thermal power plant operations. The carbon dioxide (CO_2) sensor monitors elevated CO_2 levels that can result from combustion processes and insufficient ventilation. Excessive CO_2 concentration poses serious health risks to workers, including dizziness, respiratory distress, and unconsciousness. The carbon monoxide (CO) sensor detects the presence of CO gas, which is particularly dangerous due to its colorless, odorless nature and high toxicity even at low concentrations. The methane (CH_4) sensor identifies combustible gas leaks that may arise from fuel handling systems, posing significant fire and explosion hazards. These sensors continuously feed analog or digital signals to the Arduino Nano, enabling uninterrupted surveillance of the plant environment. Power for the entire system is supplied through a battery unit, as depicted in the block diagram. The battery ensures uninterrupted operation even during power outages or emergency situations, which are common in industrial settings. Once sensor data is received; the Arduino Nano performs real-time analysis to determine the current safety status of the environment. Based on the evaluated gas concentration levels, the system categorizes conditions into safe, cautionary, or dangerous states. This decision-making process enables automated responses without the need for manual intervention, significantly reducing reaction time during critical situations. One of the primary response mechanisms shown in the block diagram is the exhaust fan control unit. When hazardous gas levels exceed permissible limits, the Arduino Nano activates the exhaust fan automatically. The exhaust fan helps remove contaminated air from the affected area and promotes the inflow of fresh air, thereby reducing gas concentration and preventing accumulation. Automated ventilation plays a crucial role in mitigating immediate risks and limiting the spread of hazardous emissions within the plant. In addition to ventilation control, the system features a buzzer that provides an audible alert when dangerous conditions are detected. The buzzer serves as an immediate warning signal for nearby workers, prompting them to evacuate the area or take necessary safety precautions. Audible alerts are particularly important in noisy industrial environments where visual indicators alone may not be sufficient. The notification and visual alert module is another key component of the system. This module controls three different LEDs green, yellow, and red each representing a specific safety status. The green LED indicates normal operating conditions where gas concentrations are within safe limits. The yellow LED signifies a warning or cautionary state, alerting personnel to rising gas levels that require attention. The red LED indicates a critical condition, signaling the presence of dangerously high gas concentrations and the need for immediate action. This color-coded alert mechanism provides intuitive and instant visual feedback, enabling quick interpretation even by non- technical personnel. The system also includes an LCD display unit, which continuously displays real-time gas concentration values and system status messages. The LCD provides clear and readable information regarding the levels of CO_2, CO, and CH_4, along with warning messages when thresholds are exceeded. This feature enhances situational awareness and allows operators to monitor environmental conditions directly at the installation site. Displayed data can assist maintenance teams in diagnosing issues and verifying system performance. All detected gas data and system responses can be logged for historical analysis and compliance verification. The system's modular design allows easy scalability and future enhancements, such as integration with wireless communication modules or cloud-based monitoring platforms.

BLOCK DIAGRAM

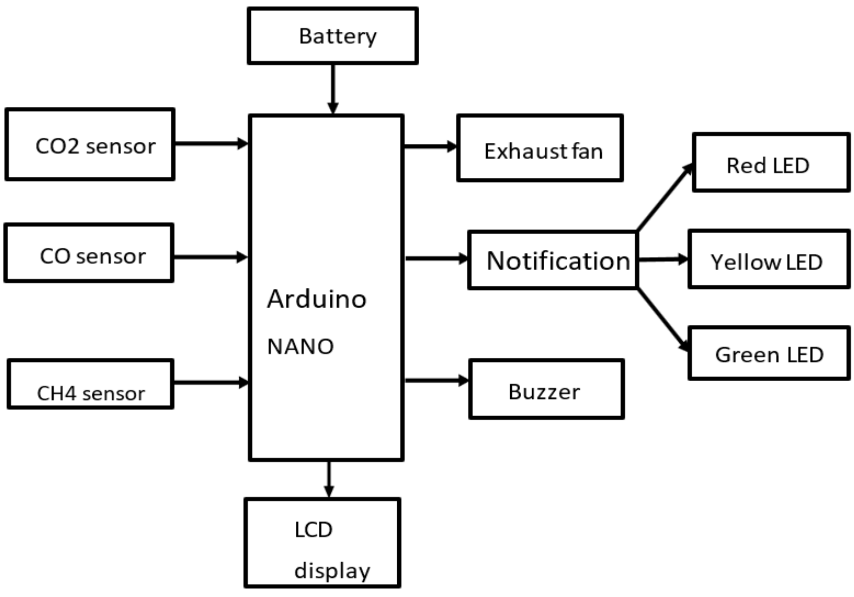

Fig 1 Block Diagram

III. RESULT

The implementation of the hazardous gas emission detection and alert system in thermal power plants demonstrates significant improvements in safety, operational efficiency, and environmental monitoring. During testing, the system effectively monitored real time concentration of hazardous gases such as carbon dioxide (CO_2), carbon monoxide (CO), and methane (CH_4) across various operational zones of the plant. The data processing module consistently identified unsafe gas levels and triggered immediate alerts, ensuring that plant personnel were promptly informed of potential hazards. The automated ventilation control system successfully activated in response to elevated gas levels, reducing the concentration of harmful gases and maintaining safe air quality for workers. The cloud-based monitoring and reporting feature provided comprehensive summaries of gas levels over daily and weekly periods, allowing operators to analyze trends, identify high-risk areas, and predict potential future leaks based on historical data. Notably, the integration of real-time notifications enhanced decision-making efficiency, enabling supervisors to respond quickly to hazardous conditions and implement preventive measures. Compared to traditional manual inspection and isolated sensor methods, the proposed system significantly reduced response time and minimized the risk of accidents or occupational health issues. The results indicate that continuous monitoring not only improves safety but also aids in compliance with environmental regulations, as all emission events were recorded and logged systematically. Furthermore, the system's ability to predict potential hazardous gas build-ups allows for proactive maintenance, minimizing operational downtime and preventing equipment damage. Overall, the deployment of this system in thermal power plants proves its effectiveness in creating a safer work environment, mitigating environmental impact, and supporting sustainable operational practices. These outcomes underscore the importance of automated gas detection systems as a crucial component of modern industrial safety and environmental management frameworks.

IV. CONCLUSION

The hazardous gas emission detection and alert system for thermal power plants provides a comprehensive solution to the critical challenges associated with toxic gas exposure. By continuously monitoring gas concentrations, generating real-time alerts, activating automated ventilation, and delivering instant notifications to supervisors, the system ensures enhanced worker safety and operational reliability. The integration of cloud-based monitoring enables systematic logging, trend analysis, and proactive management of hazardous emissions, supporting regulatory compliance and environmental responsibility. Overall, the deployment of this system demonstrates a significant improvement over traditional manual inspection methods, reducing response time, minimizing occupational hazards, and promoting sustainable operational practices within thermal power plants.

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