



IOT BASED INDUSTRIAL ANOMALY DETECTION AND ALERT SYSTEM FOR ENHANCED WORKER AND EQUIPMENT SAFETY

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Abstract: In industrial settings, gas leaks, equipment overheating, and unlawful access into prohibited zones may cause serious accidents, equipment damage, and human lifethreatening situations. Manual monitoring of these parameters slows response time. This work presents an IOT-based Industrial Anomaly Detection and Alert System for gas leakage detection and restricted area incursion monitoring to safeguard workers and equipment. It employs IR and gas sensors. To improve safety, Machine Learning can identify dangers and categorize alerts. Microcontroller-based ML concept checks sensor data that pass the threshold range and sends an SMS to the authorized individual. Workers and equipment are protected by this system's swift response to risks. Cloud storage secures real-time sensor data from Arduino devices in industrial IoT safety solutions. It enables machine learning algorithms to easily assess and forecast gas leaks and overheating using three parameter measurement levels. Data centralization lets organizations monitor worker and equipment safety from anywhere. Integrating GPS tracking to monitor restricted areas in real time improves worker safety.

Keywords: IoT Integration with Microcontrollers, Machine Learning-Based Risk Prediction, Cloud storage.

I. INTRODUCTION

Industrial automation refers to the application of control systems, sensors, and information technology to operate industrial machinery and processes with minimal human intervention. It forms the foundation of modern manufacturing systems by improving accuracy, reliability, productivity, and operational efficiency. The integration of emerging technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), cyber-physical systems, and cloud computing has transformed traditional automation into intelligent industrial ecosystems capable of self-monitoring, data-driven decision-making, and autonomous control [5], [6], [10], [12]. A crucial component of industrial automation is the fault and anomaly monitoring system, which continuously evaluates the operational condition of machinery and industrial environments. Conventional manual inspection techniques are labor-intensive, time-consuming, and often incapable of predicting failures before they occur.

Automated monitoring systems address these limitations by deploying multiple sensors to collect parameters such as vibration, temperature, gas concentration, pressure, and motion. These sensor readings are transmitted to embedded controllers or IoT platforms, where real-time analysis is performed to detect deviations from normal operating conditions [1], [4], [7], [11]. The adoption of IoT technologies in industrial fault monitoring has significantly enhanced maintenance strategies. By interconnecting equipment through wireless sensor networks and cloud platforms, industries can implement predictive maintenance, reduce unplanned downtime, and optimize energy and resource utilization. Cloud-based data storage and processing enable centralized monitoring, scalability, and remote accessibility, which are essential for large-scale industrial deployments [3], [8], [10], [12]. Recent Studies Have also Highlighted The Role of intelligent Data Analysis and Machine learning Techniques in identifying abnormal patterns and classifying industrial hazards. Machine learning-based anomaly detection improves system accuracy by learning from historical sensor data and generating intelligent alerts before critical failures occur. Such approaches enhance operational safety and support proactive decision-making in industrial environments [9], [13], [15].

In modern Industry 4.0 frameworks, cyber-physical systems integrate sensing, computation, communication, and control to achieve intelligent automation. These systems facilitate real-time equipment health monitoring, predictive analysis, and automated response mechanisms, thereby improving worker safety and equipment reliability [5], [6], [14]. In the proposed system, multiple sensors are employed to monitor critical industrial parameters such as gas leakage, smoke presence, flame detection, temperature variation, and proximity intrusion. These parameters are carefully selected based on their potential risks to worker safety and machinery integrity. The system integrates embedded controllers, IoT communication modules, cloud storage, and alert mechanisms to provide real-time monitoring, anomaly detection, and rapid notification to authorized personnel. This integrated approach enhances industrial safety, ensures continuous equipment health assessment, and supports data-driven maintenance decisions in smart industrial environments [1], [4], [11], [14].

II. LITERATURE SURVEY

The rapid adoption of Internet of Things (IoT) technologies has significantly improved industrial monitoring, predictive maintenance, and safety management systems. Several studies have explored IoT-based approaches to detect anomalies, monitor equipment health, and enable real-time alert mechanisms in industrial environments.

Ganga and Ramachandran [1] presented an IoT-based vibration analytics framework for electrical machines, focusing on condition monitoring and fault detection. Their work demonstrated how sensor data collected from industrial equipment can be analyzed to identify abnormal vibration patterns, thereby preventing mechanical failures. This study highlights the importance of real-time data acquisition and analytics in enhancing equipment reliability and safety.

Dai [2] proposed an embedded control system integrated with IoT for managing complex wind power generation parameters. The system emphasized continuous monitoring and intelligent control to optimize industrial operations. Although primarily focused on power generation, the work underscores the effectiveness of IoT-enabled embedded systems in handling critical industrial parameters and responding to abnormal conditions.

Wang and Cai [3] introduced an efficient IoT cloud framework based on named data networking to support scalable data transmission and processing. Their approach improves data availability and communication efficiency in IoT environments, which is essential for real-time industrial monitoring and centralized safety management systems.

Saha and Majumdar [4] developed an ESP8266-based wireless sensor network for temperature monitoring in data centers, integrated with a cloud-based dashboard and real-time alert system. The study demonstrated how temperature anomalies can be detected and communicated instantly, validating the role of IoT and cloud platforms in preventing overheating and ensuring operational safety.

Lee et al. [5] proposed a cyber-physical systems architecture for Industry 4.0-based manufacturing environments. Their work emphasized the integration of sensing, computation, and communication for

intelligent industrial automation. This architecture supports real-time monitoring, predictive analysis, and enhanced safety through interconnected industrial systems.

While these studies successfully demonstrate IoT-based monitoring and anomaly detection across various industrial applications, most systems focus on single-parameter monitoring or lack integrated alert and access control mechanisms. The proposed system extends existing research by combining multi-parameter sensing, microcontroller-based machine learning, real-time alerts, and cloud-based data analysis to enhance worker and equipment safety in industrial environments.

III. EXISTING METHODOLOGY

Sensors are essential to the defect detection system since they provide all the necessary information, however data from production management systems may also be beneficial in some instances. In some instances, such sensors may be used for additional functions such as control or monitoring, and they are integrated into the machine or plant during the design phase. However, in the majority of instances, predictive maintenance is not considered during the design phase of machines, necessitating the incorporation of additional sensors. This arises particularly when predictive maintenance must be performed on aging machinery, as they begin to become a bottleneck in the plant owing to unforeseen malfunctions. Monitoring individual sensors is a challenging and complex endeavor.

IV. PROPOSED SYSTEM AND WORKING METHODOLOGY:

This suggested system has an innovative method for monitoring industrial parameters with IoT technology. Various sensors are used to monitor parameters including LPG, temperature, and flame. Arduino consistently monitors this data and uploads it to the Blynk Server. The user may monitor this data globally with the IoT Blynk application. The RFID-based restricted zone is meant to prevent worker access and produce alert SMS using a GSM modem. A DC motor is used to mimic machine shutdown when the temperature exceeds the threshold limit.

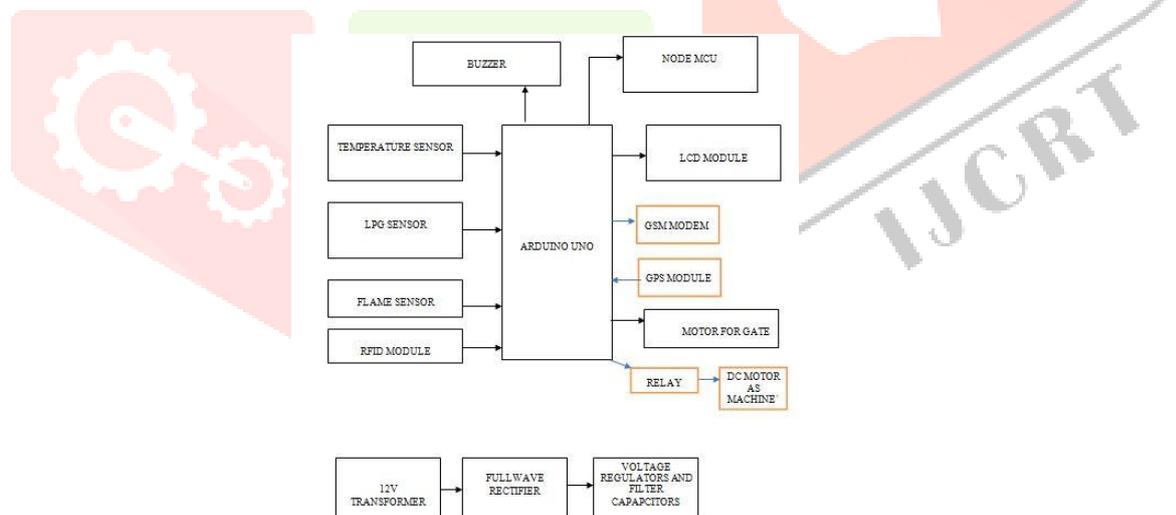


Figure 1. System Architecture

V. HARDWARE COMPONENTS:

- **Arduino UNO**

Arduino UNO, based on the ATmega328P microcontroller, serves as the core control unit of the industrial anomaly detection system. It interfaces with multiple sensors and actuators to continuously monitor industrial parameters and execute real-time safety control actions.

- **NodeMCU**

NodeMCU, powered by the ESP8266 Wi-Fi module, enables IoT connectivity within the industrial environment. It facilitates real-time data transmission to remote monitoring platforms and supports cloud-based analysis for proactive safety management.

- **LPG Sensor – MQ6**

The MQ6 gas sensor is employed to detect hazardous LPG, propane, and butane gas leaks in industrial settings. Early identification of gas leakage anomalies helps prevent fire hazards and ensures worker safety.

- **Flame Sensor – IR Sensor**

The infrared flame sensor detects fire incidents by sensing infrared radiation emitted by flames. This enables rapid identification of fire-related anomalies and triggers immediate safety alerts to reduce damage to personnel and equipment.

- **Temperature Sensor – DS18B20**

The DS18B20 digital temperature sensor continuously monitors ambient and equipment temperature. Abnormal temperature variations are identified as potential anomalies, allowing early intervention to prevent equipment overheating and industrial accidents.

- **RFID – 125 KHz**

The 125 KHz RFID module is integrated for secure personnel identification and access control. It ensures that only authorized workers can access restricted industrial zones, enhancing workplace safety and accountability.

- **DC Motor**

The DC motor is used to perform automated mechanical responses such as ventilation activation or emergency system operation. It responds to detected anomalies to minimize risk during hazardous conditions.

- **IR Sensor**

The IR sensor detects motion or obstacles within industrial premises. It supports anomaly detection related to unauthorized entry, unsafe movement, or equipment obstruction, contributing to overall operational safety.

- **Servo Motor for Gate**

The servo motor enables precise gate or barrier control in access-restricted industrial areas. It operates in coordination with RFID authentication to ensure controlled and secure entry during normal and emergency conditions.

- **GSM Modem – SIM800L**

The SIM800L GSM module provides reliable wireless communication for alert generation. It sends real-time SMS notifications to supervisors or safety personnel when critical anomalies are detected, ensuring rapid response.

- **Buzzer**

The buzzer functions as an on-site audible alert system. It immediately warns workers of detected anomalies such as gas leaks, fire, or abnormal temperature conditions.

- **12V Transformer**

The 12V transformer supplies regulated power to the industrial monitoring system. It ensures safe and reliable power delivery to all components under industrial operating conditions.

- **Voltage Regulators**

Voltage regulators provide stable operating voltages required by sensitive electronic modules. They protect the system from voltage fluctuations and ensure uninterrupted monitoring and alert functionality.

- **Other Miscellaneous Components**

Additional components such as resistors, capacitors, diodes, relays, and connecting wires support circuit protection, signal conditioning, and seamless integration of the industrial safety monitoring system.

Methodology

In figure1 shows that an innovative way for monitoring industrial failures and preventing accidents before they occur. This system utilizes an Arduino-based controller board, NodeMCU, and GSM modem, including many sensors as essential components. Data from sensors, including temperature, flame, and gas, are processed by Arduino and displayed on an LCD module.

Project Working Steps:

- Sensor Data (Temp, Gas and Flame – Processed using Arduino and Update on LCD Module)
- Processed Sensor sent to IoT blynk based Cloud Server for Remote Monitoring using Android Application
- If Temperature Sensor of Machine Increases, DC Motor Switch off along with Continue Buzzer Indication
- If any Unauthorized person trying to access the restricted Zone, Buzzer will be generated along with GPS Location using SMS Sent. RFID Tag is used access the gate of Restricted Zone for Open and Close
- If Gas Leakage is detected and Person enters danger Zone, then it is sensed by IR Sensor and Continue Buzzer sound is activated and SMS.
- A multilevel alert and notification system has been included. If the Gas or Temperature sensor is within the Normal Range, data will be presented on the LCD. If the Range exceeds a Moderate Level, a short beep will be emitted. When the sensor data attains the threshold level, a prolonged beep will be emitted, accompanied by an SMS notification.
- If any of the aforementioned sensor values exceed the threshold range, the Microcontroller, using a machine learning approach for sensor value assessment, verifies the readings and then dispatches an SMS to the authorized individual.

This work is designed to improve industrial safety by continuously monitoring critical parameters such as temperature, gas leakage, flame presence, and unauthorized access. The system uses an Arduino controller to process sensor data and display the status on LCD. A NodeMCU module is used to send real-time data to a cloud server for remote monitoring through an Android application. In case of abnormal conditions such as high temperature, gas leakage, or unauthorized entry, the system activates a buzzer alert and sends an SMS notification using a GSM module. A multi-level alert system is implemented to provide early warnings based on sensor threshold levels. The system also includes RFID-based access control for restricted areas. This automated safety mechanism helps in preventing accidents, reducing human risk, and ensuring reliable industrial monitoring.

The IoT interface is established with this system via a Node MCU, which connects to a local hotspot and updates data on a cloud server. The user may access this data from any location using the Android application. The Embedded C Programming Language is used. Compose the program code and compile it using the Arduino IDE compiler. Sensors are linked to analog pins, while outputs are connected to digital pins. This technology may be used in many residential applications and industrial environments. The system's power supply configuration includes a 230/12V step-down transformer, used to reduce the voltage to 12VAC. A bridge rectifier is used to convert it to direct current (DC). A capacitive filter is used, using a 7805 voltage regulator to stabilize the output at +5V required for the functioning of the microcontroller and other components, therefore eliminating ripple.

VI. RESULTS AND DISCUSSIONS:



Figure2: Proposed KIT

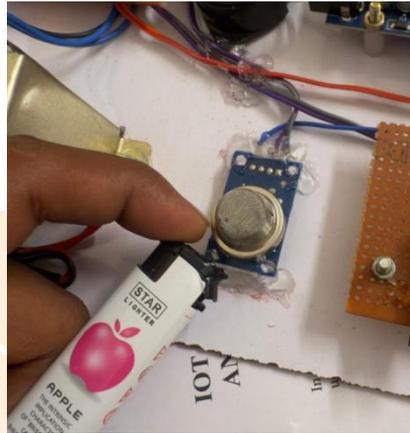


Figure3: Gas Sensor Checking

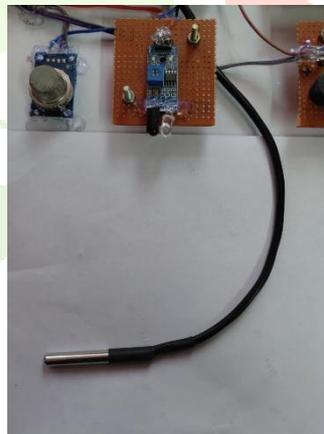


Figure4: Temperature sensor



Figure5: Restricted Area Gate



Figure6: Flame Sensor detect



Figure7: Sending Message to Mobile Number



Figure 8: Displaying Values in LCD

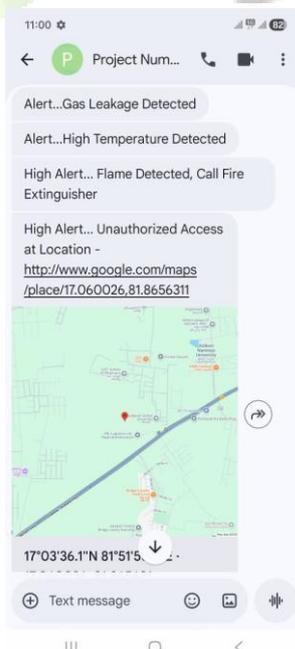


Figure9: View Message on mobile

VII. CONCLUSION

This work effectively showcases an IoT-driven Industrial Anomaly Detection and Alert System that improves safety via real-time surveillance of essential industrial metrics, including gas leaks, equipment overheating, and unauthorized area access. The system integrates IR sensors, gas sensors, and GPS tracking with a microcontroller-based machine learning architecture, therefore mitigating the constraints of human monitoring and substantially decreasing reaction time to potentially dangerous situations. Threshold-based sensor analysis, coupled with machine learning-driven alert categorization, guarantees prompt and precise anomaly identification, while automated SMS alerts provide swift response by authorized people.

Utilizing cloud storage for real-time sensor data collecting facilitates centralized oversight, historical data analysis, and predictive evaluation of industrial hazards. This capacity is especially beneficial for aged equipment, because predictive maintenance is sometimes overlooked during the design process, leading to unforeseen breakdowns that may interrupt plant operations. The suggested system effectively facilitates early defect identification and preventative measures by integrating new sensors and using machine learning on multi-level parameter data.

The system enhances worker safety, safeguards equipment, and reduces operational downtime by providing a scalable, cost-efficient, and intelligent industrial safety solution. The suggested methodology emphasizes the capability of integrating IoT, machine learning, and cloud technologies to develop proactive safety and predictive maintenance systems appropriate for contemporary industrial settings.

VIII. FUTURE SCOPE

This system may be created with many nodes of a wireless sensor network (WSN) using IoT technology to demonstrate how several sensor units can be interconnected and monitored from a single location.

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