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"AI-BASED INDUSTRIAL FAULT DETECTION AND DIAGNOSIS"

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ABSTRACT :

This design proposes a smart, AI- AI-supported system designed to identify and respond to faults in artificial surroundings. erected around the ESP32 microcontroller, the system continuously monitors crucial parameters including temperature, bank situations, fire presence, and mortal stir through dedicated detectors. Upon detecting abnormal conditions, it triggers applicable conduct similar as cranking admonitions, suckers, or decoupling outfit via relays. Detector readings are transmitted in real time to Google Cloud, enabling easy data visualization and remote supervision. The platform also opens the possibility for integrating machine literacy algorithms to enhance fault vaticination and reduce time-out. This result is low-cost, easy to apply, and adaptable for a wide range of artificial safety and monitoring operations.

INTRODUCTION:

In industrial environments, even small faults in equipment can cause major problems such as production delays, costly repairs, and safety risks. As industries become more automated, there is a growing need for smart systems that can identify problems early and respond quickly. This project focuses on developing a low-cost, reliable fault detection and alert system using the ESP32 microcontroller, various environmental sensors, and cloud-based data monitoring. Unlike traditional fault detection methods that rely on manual checking or basic warning systems, this design uses real-time data collection and intelligent control to handle issues as they happen.

The system keeps track of key conditions such as temperature, smoke, fire, and human motion using sensors like LM35, smoke and fire detectors, and a PIR motion sensor. The ESP32 gathers input from each connected sensor and processes the collected information, and decides what actions to take based on predefined limits or patterns. If an unusual or dangerous condition is detected, the system immediately responds by activating connected devices, such as a fan, buzzer, or LED indicators, through relays. This allows the system to alert workers or even prevent damage by controlling the environment automatically. A key feature of this system is its ability to transmit sensor readings to Google Sheets over Wi-Fi. This allows users to monitor readings remotely and store data for future review.

Overall, this project demonstrates how simple, affordable technology enables the construction of an effective monitoring and fault response system for industrial settings. It supports both safety and efficiency, making it useful for factories, workshops, and other automated environments. analysis. With this data stored, future enhancements enable the system to include integrating machine learning models that learn from historical patterns to predict potential failures before they happen — a concept known as predictive maintenance. Such intelligent decision-making capabilities can significantly reduce unplanned downtimes and extend the operational lifespan of industrial equipment.

LITERATURE SURVEY:

To improve the efficiency and reliability of industrial fault detection systems, a range of methodologies incorporating Artificial Intelligence (AI), Internet of Things (IoT), and Edge Computing have been adopted. Lightweight machine learning models are developed and trained using sensor data, including temperature, gas, flame, and vibration readings, to accurately classify and predict fault conditions. These models are deployed on edge devices such as the ESP32 microcontroller, enabling real-time, low-power fault detection with immediate alerts through buzzers, LCD screens, and cloud-based dashboards. Another common strategy involves IoT-driven monitoring frameworks where various sensors collect equipment data and transmit it to cloud platforms like ThingSpeak and Blynk via Wi-Fi-enabled microcontrollers. This setup facilitates remote monitoring, real-time fault detection, maintenance scheduling, and data visualization through graphical interfaces. Additionally, wireless sensor networks have been integrated, combining temperature, gas, and vibration sensors with microcontrollers to ensure seamless, continuous data collection and immediate anomaly detection through cloud systems. Edge AI methods further strengthen these systems by processing sensor data locally on devices such as ESP32 and Raspberry Pi. This minimizes reliance on cloud infrastructure, resulting in faster fault prediction and response times. These methodologies underline the advantages of smart sensor networks, cloud integration, and embedded machine learning models, significantly enhancing industrial maintenance practices, reducing operational downtime, and promoting early fault identification.

METHODOLOGY:

- ESP32 Microcontroller Role: Serves as the central processing unit, managing sensor data and controlling output devices. Features: Dual-core processor with integrated Wi-Fi and Bluetooth; supports multiple sensor connections; handles logic processing and communicates data to cloud services like Google Sheets.
- LM35 Temperature Sensor Role: Continuously monitors ambient or machine temperature. Features: Linear analog output corresponding to temperature in Celsius; low power consumption; simple integration with ESP32's analog inputs; crucial for thermal safety monitoring.
- MQ2 Smoke Sensor Role: Detects the presence of smoke or gas to identify fire risks or air quality issues.Features: Sensitive to gases like methane, LPG, and smoke; provides fast response and recovery; supports both analog and digital outputs; essential for early warning systems.
- Flame Sensor Role: Senses visible flames within the monitored area.Features: Detects specific wavelengths associated with fire; rapid reaction time; complements smoke sensors; sends digital output to the ESP32.
- PIR (Passive Infrared) Sensor Role: Detects human movement in restricted or sensitive areas.Features: Measures changes in infrared radiation; consumes very low power; ideal for intrusion detection; connects easily through a digital output.
- Relay Module Role: Controls switching of high-voltage devices based on ESP32 instructions.Features: Electrically isolates the microcontroller from high-power circuits; operates fans, alarms, and lights; supports both AC and DC loads; enables automated responses.
- Buzzer Role: Emits audio alerts during fault or hazardous events.Features: Loud, attention-catching sound for emergency notifications; easily driven by a digital pin; enhances on-site safety awareness.
- FanRole: Activates to cool down equipment or environments upon high-temperature detection.Features: Triggered via relay module; helps prevent overheating; prolongs equipment lifespan; operates automatically based on sensor inputs.
- LED Indicators Role: Provide visual feedback regarding system status.Features: Displays different statuses through color codes; very low energy usage; offers quick, at-a-glance understanding of system health.
- 16x2 LCD Display Role: Shows real-time data and alerts directly on-site. Features: Two-line display for clear, concise information; easily interfaces with the ESP32; crucial for local monitoring of temperature, fault alerts, and system states.

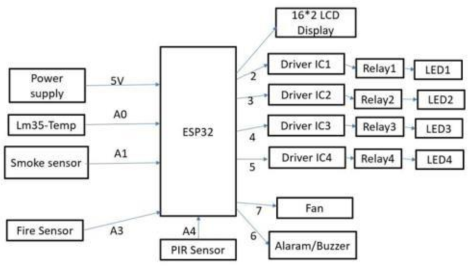

Figure 1: Block diagram of AI-Based Industrial Fault Detection and Diagnosis

The project operates by using a network of sensors connected to an ESP32 microcontroller to monitor critical industrial parameters. These sensors measure temperature, detect smoke or gas leaks, identify visible flames, and sense human presence or motion. Each sensor feeds data into the ESP32, which processes the inputs and evaluates them against predefined safety thresholds. When any sensor reading indicates abnormal behavior, such as a rise in temperature, presence of gas, or unauthorized motion, the microcontroller takes immediate action. It activates specific output components like a buzzer for sound alerts, LEDs for visual signals, and a fan for cooling. These responses are automated to ensure quick handling of potential hazards without requiring manual intervention. At the same time, the ESP32 uses its built-in Wi-Fi to transmit the collected data to an online Google Sheet. This enables real-time remote access to the system's readings, which can be useful for monitoring and later analysis. A 16x2 LCD is also used on-site to provide a local display of key sensor values and system status, offering a complete and user-friendly interface for fault detection and response.

APPLICATIONS:

- ***Industrial Safety Monitoring:***

The system can continuously monitor critical parameters like temperature, gas leaks, and fire hazards to ensure a safer working environment in factories and industrial plants.

- ***Predictive Maintenance:***

By analyzing vibration, temperature, and gas levels, the system can predict equipment failures early, allowing maintenance activities to be scheduled before a breakdown occurs, reducing downtime.

- ***Smart Manufacturing Units:***

Integration of real-time fault detection helps automate manufacturing lines, ensuring smooth operations by quickly identifying and addressing any abnormalities.

- ***Remote Industrial Supervision:***

Using cloud dashboards and IoT connectivity, plant managers can monitor equipment status and environmental conditions from remote locations without the need for physical inspections.

- ***Energy Management Systems:***

The system can detect overheating or abnormal equipment behavior, helping optimize energy usage and preventing energy wastage in industrial facilities.

- ***Fire and Gas Leak Detection Systems:***

Early detection of fire or gas leaks helps in triggering alarms and automatic safety measures, minimizing damage to assets and ensuring worker safety.

- ***Automated Emergency Response:***

On detection of critical faults, the system can automatically activate alarms, shut down machinery, or initiate cooling or ventilation systems to control the situation without human intervention.

- ***DESIGN***

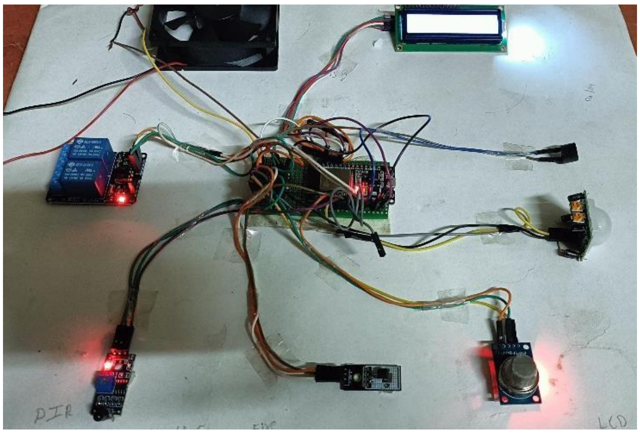

Figure2: Project Design

CONCLUSION:

This project successfully demonstrates a smart and affordable approach to fault detection in industrial environments using embedded systems and IoT technologies. By combining the ESP32 microcontroller with multiple environmental sensors, the system effectively identifies potential hazards such as heat, smoke, fire, and unauthorized movement. The automatic activation of safety responses—like alerts, fans, and lights—ensures rapid reaction to dangerous conditions, reducing the need for manual supervision. Real-time data logging to Google Sheets enhances monitoring capabilities by providing a cloud-based record of system activity. This supports both on-site and remote supervision and helps with analyzing fault trends. The solution is scalable, low-cost, and energy- efficient, making it ideal for small to medium industrial setups. Overall, the project proves that simple components, when integrated intelligently, can build powerful safety tools that enhance workplace security, reduce downtime, and support better maintenance practices.

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