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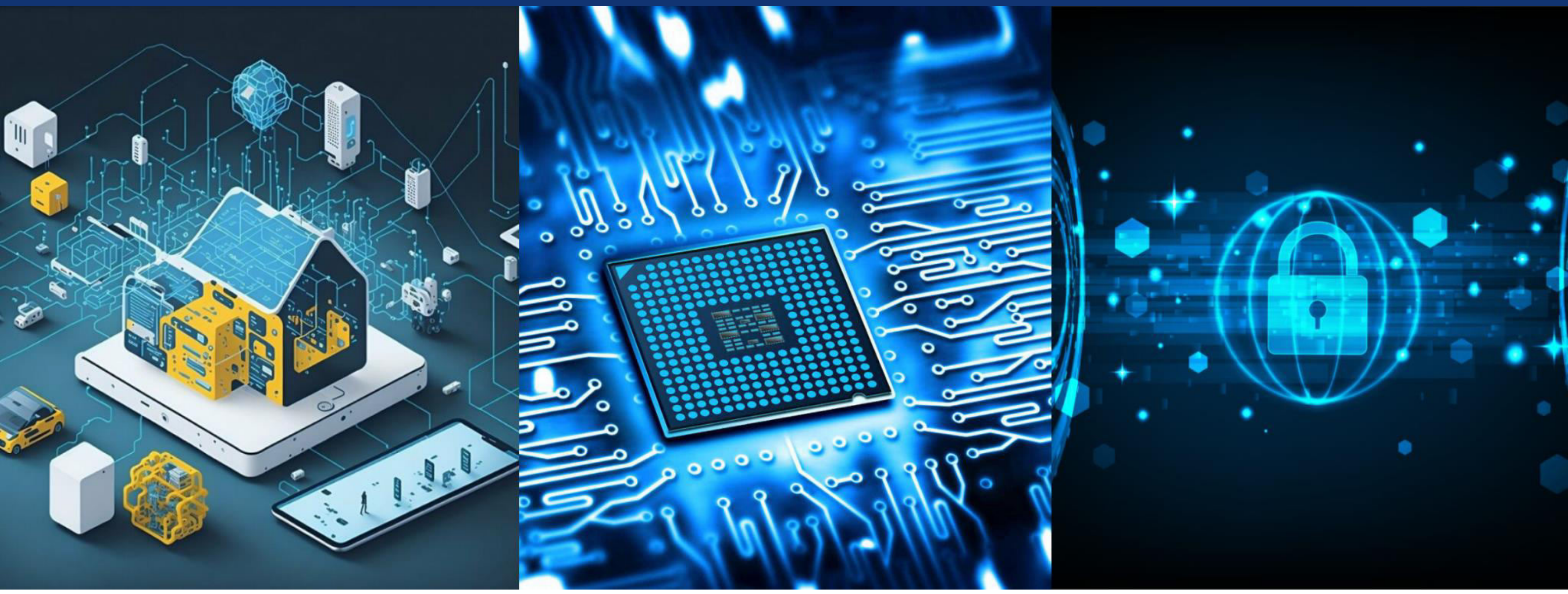

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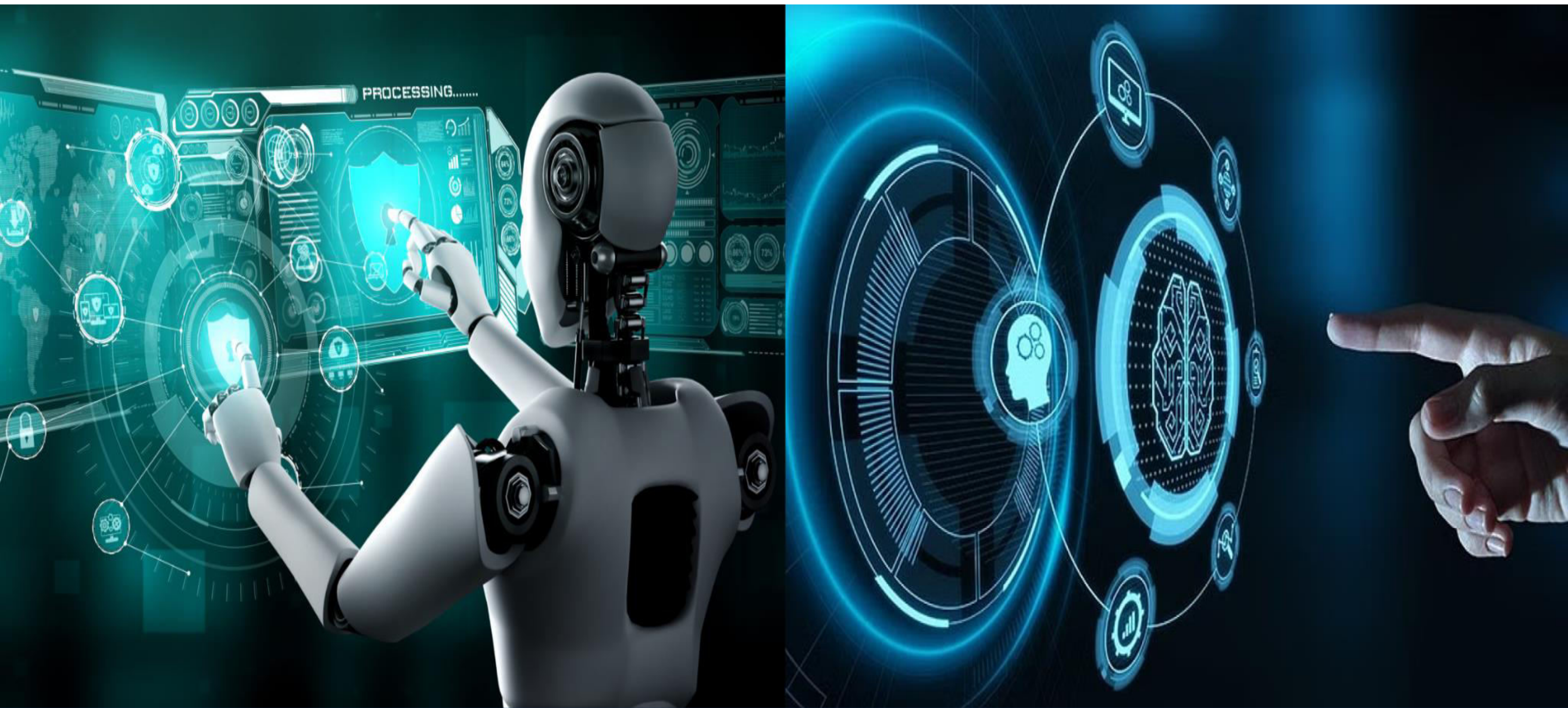

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IoT-Based Underground Tunnel Monitoring System for Safety and Fault Detection

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ABSTRACT: Underground tunnels require continuous monitoring to ensure safety and operational efficiency. This project presents an IoT-based underground tunnel monitoring system utilizing various sensors and modules to detect faults and hazardous conditions in real time. The system consists of a potential transformer (PT), current transformer (CT), temperature sensor, and fire sensor, all interfaced with an Arduino Uno. These sensors continuously measure voltage, current, temperature, and fire hazards. An LCD display provides real-time updates, while an IoT module transmits the data to a remote monitoring system. Under normal conditions, the relay remains active, allowing the tunnel operations to continue. However, if any abnormality is detected—such as high or low voltage from the PT, excessive current from the CT, high temperature, or fire detection—the system triggers an alarm, displays warnings on the IoT platform, and immediately turns off the relay to cut power, ensuring safety. This automated response minimizes the risk of accidents and electrical failures. The proposed system enhances tunnel safety, prevents damage to electrical infrastructure, and allows for remote monitoring, making it an efficient solution for underground environments.

KEYWORDS: Micro-controller, Wi-fi, Real time Monitoring

I. INTRODUCTION

Underground tunnels play a crucial role in transportation, utilities, and industrial operations. However, ensuring their safety is a major challenge due to risks such as electrical failures, overheating, and fire hazards. This project focuses on developing an IoT-based Underground Tunnel Monitoring System to detect and prevent potential hazards in real-time. By incorporating potential transformers (PT), current transformers (CT), temperature sensors, and fire sensors with an Arduino Uno, this system enables real-time monitoring of both electrical and environmental conditions inside the tunnel. The PT and CT monitor voltage and current levels, detecting abnormalities such as overvoltage, undervoltage, or excessive current flow. The temperature sensor ensures that the heat levels remain within safe limits, while the fire sensor detects any fire incidents. All sensor data is displayed on an LCD screen and transmitted to an IoT platform for remote monitoring. Under normal conditions, the system operates without interruption. However, if any sensor detects an anomaly, the relay is immediately turned off, cutting power to prevent further damage, and an alarm is triggered to alert authorities. This automated system improves safety, reliability, and efficiency in underground tunnels by offering early alerts and minimizing the risk of disasters, making it an essential solution for managing tunnel infrastructure.

II. EXISTING SYSTEM

The current methods for underground tunnel monitoring primarily rely on manual inspections and conventional monitoring systems. Maintenance personnel conduct routine checks to assess electrical conditions, temperature levels, and fire risks. These methods are inefficient, time-consuming, and prone to human error, leading to delayed responses in emergencies. Some tunnels use basic alarm systems that detect fire and overheating, but these systems often lack real-time monitoring and remote accessibility. In case of an electrical fault, such as overvoltage, undervoltage, or overcurrent, the detection process is delayed, increasing the risk of severe damage to equipment and infrastructure. Additionally, most existing systems do not have an automated response mechanism, meaning faults must be manually addressed, which can be hazardous in critical situations. Another limitation of the existing systems is the lack of integration with IoT platforms, preventing remote monitoring and instant notifications. Without real-time data transmission, operators must rely on periodic inspections, which can miss sudden faults and lead to catastrophic

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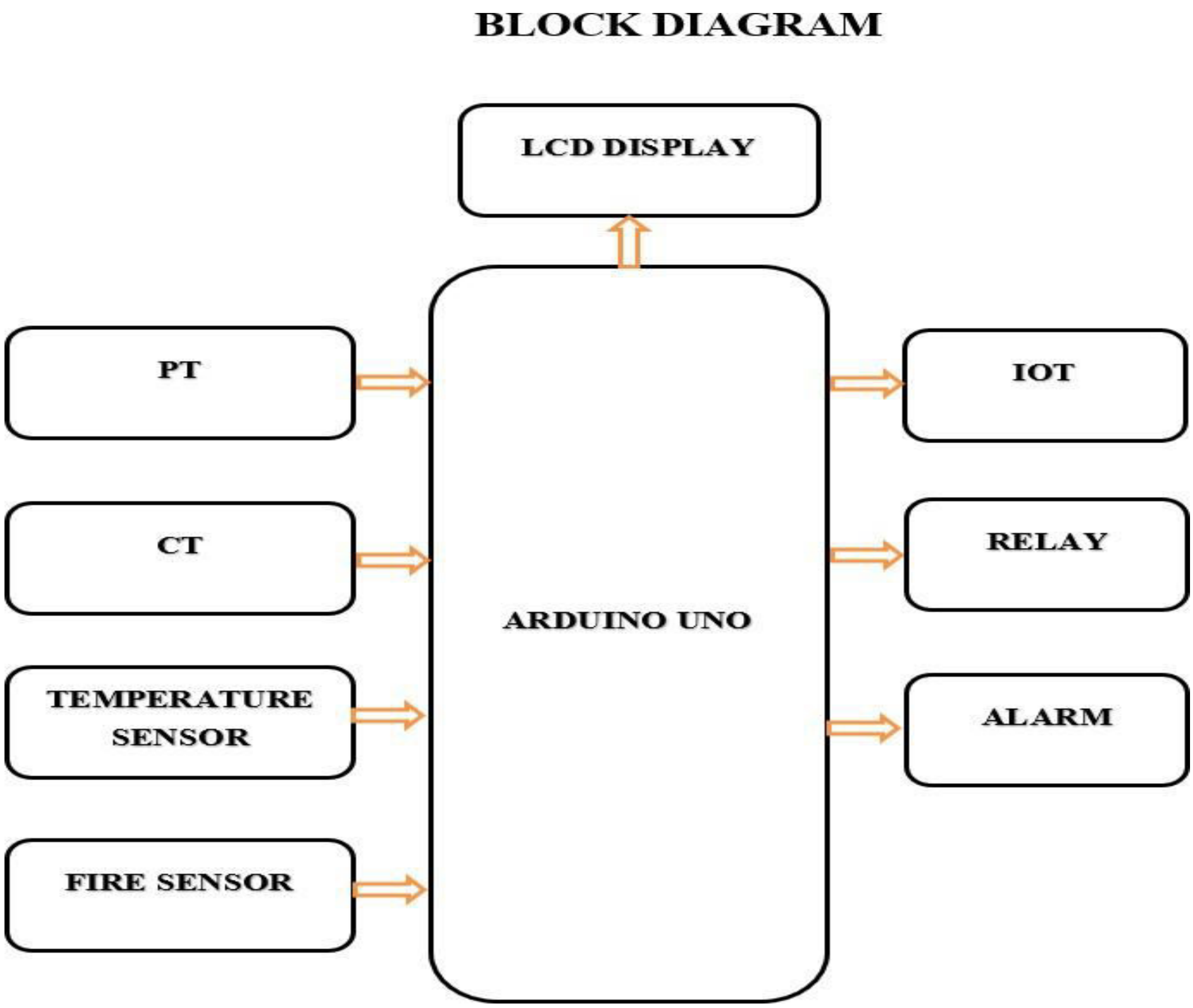
failures. Due to these limitations, there is a growing need for an automated, IoT-driven monitoring system that can quickly detect anomalies, trigger alarms, cut off power through a relay, and provide real-time alerts to enhance safety and efficiency in underground tunnels.

III. PROPOSED SYSTEM

The proposed IoT-based Underground Tunnel Monitoring System is designed to provide real-time monitoring and automated fault detection to enhance tunnel safety and efficiency. This system integrates potential transformers (PT), current transformers (CT), temperature sensors, fire sensors, an Arduino Uno, an LCD display, an IoT module, a relay, and an alarm to continuously monitor critical parameters within the tunnel. The PT and CT measure voltage and current levels, detecting overvoltage, undervoltage, and overcurrent conditions. The temperature sensor monitors heat levels to prevent overheating, while the fire sensor detects fire hazards. Under normal conditions, the system runs smoothly. However, if any abnormality is detected, the system automatically turns off the relay, cutting power to prevent damage or hazardous situations. Simultaneously, an alarm is triggered, and real-time alerts are sent to the IoT platform, allowing remote monitoring. The LCD display provides instant updates within the tunnel, while the IoT module ensures that alerts reach operators promptly. This automated response system significantly reduces human intervention, reaction time, and potential damage compared to traditional monitoring methods. By integrating IoT technology, this solution enables proactive maintenance, enhances tunnel safety, and minimizes operational risks, making it an efficient alternative to conventional systems.



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IV. VOLTAGE ADJUSTMENT TIPS

The power supply should deliver +5V with a maximum transient tolerance of 10mV. To achieve optimal display contrast, the voltage (VL) at pin 3 must be precisely adjusted. Modules should not be inserted or removed while the circuit is powered. The ground terminal of the power supply must be properly isolated to prevent voltage induction. Furthermore, the module should be isolated from other circuits to avoid stray voltages that may lead to display flickering.

V. TEMPERATURE

A thermistor is a special type of resistor whose resistance changes with temperature. The name comes from "thermal" and "resistor." Thermistors are often used to limit current when it starts, measure temperature, protect against overcurrent, and control heating. Unlike RTDs, which are made from metals, thermistors are usually made from ceramic or plastic materials. RTDs can work over a wide temperature range, but thermistors are more accurate within a smaller range, typically between −90 °C and 130 °C. In simple terms, thermistors follow this formula:

Where:
ΔR = change in resistance
ΔT = change in temperature
k = temperature coefficient of resistance There are two types of thermistors:
- PTC (Positive Temperature Coefficient): Resistance increases as temperature increases.
- NTC (Negative Temperature Coefficient): Resistance decreases as temperature increases.

Regular resistors try to keep their resistance constant over a wide range of temperatures, while thermistors are designed to change with temperature. The temperature coefficient is sometimes written as α (alpha), which is another way of expressing how the resistance changes with temperature. For example, the PT100 sensor has an α of 0.00385 or 0.385% per °C.

VI. FIRE SENSOR

Fire alarm systems and fire detectors play a crucial role in fire safety by ensuring early detection and warning. The described fire alarm system connects multiple fire sensors to sensor lines and detects fire by analyzing current modulation. It maintains a predetermined current during a fire event and modulates it based on the fire sensor's address. The system includes an address specification section that identifies the sensor issuing the fire alert based on the modulated current. A fire detector with a heatable gas sensor enhances fire detection accuracy. By cycling through different temperature ranges and collecting sensor outputs, it uses pattern recognition circuitry to analyze data and determine fire presence. The ability to evaluate multiple outputs at various temperatures improves detection reliability. Fire detection has long been a priority, with smoke detectors (ionization and photoelectric) significantly reducing fire-related losses. However, issues persist, particularly with battery-operated detectors, as many fail due to neglected battery replacements. Despite progress, there is still a demand for enhanced reliability and innovative detection technologies. The integration of gas sensors and pattern recognition offers a promising advancement, ensuring faster and more accurate fire detection while addressing shortcomings of conventional smoke detectors.

VII. DESIGN OF WEB APPLICATION

MPLAB IDE is a development environment that provides engineers with the tools to create and debug firmware for a range of Microchip devices. This Windows-based IDE from Microchip Technology allows users to:

1. Write source code using the built-in editor.
2. Assemble, compile, and link source code with a range of language tools, including an assembler, linker, and librarian, all included in MPLAB IDE. C compilers are available from both Microchip and third-party vendors.
3. Debug executable logic by tracking program flow using a simulator like MPLAB SIM or in real-time with an emulator such as MPLAB ICE. Third-party emulators are also compatible with MPLAB IDE.
4. Measure timing.

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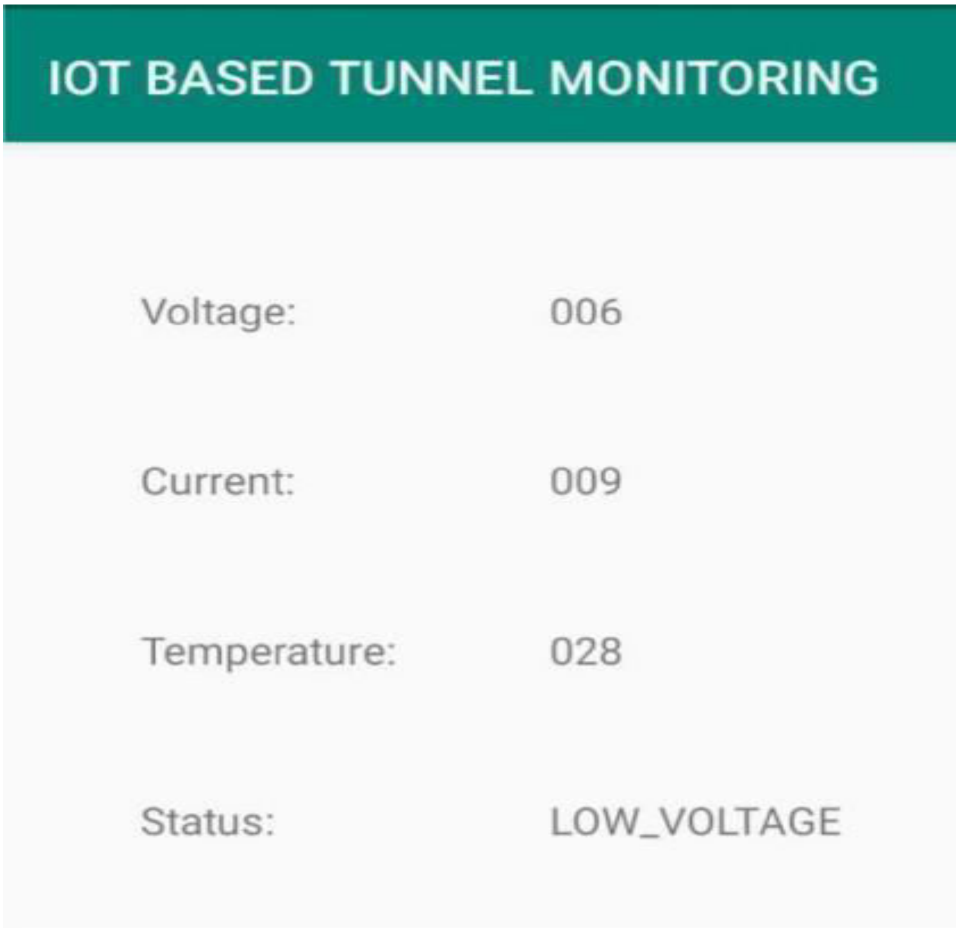
5. View variables through Watch windows.
6. Program firmware into devices using programmers like PICSTART Plus or PRO MATE II.
7. Access quick solutions via the MPLAB IDE online Help.

VIII. RESULT AND DISCUSSION

The project aims to detect the location of faults in underground cable lines using a Microcontroller and IoT technology. The monitoring system includes a potential transformer, a current transformer, and temperature sensors to monitor various parameters such as voltage level, current level, and temperature level of the underground tunnel. The values are transmitted to an IoT server, which can be accessed via an Android app. The project aims to tackle the challenges of identifying fault sources in underground cables and seeks to monitor and detect faults like low and high voltage, high current, and temperature fluctuations. The microcontroller or gateway device acts as the system's central processing unit, handling data collection from sensors, processing and analyzing the data, and enabling communication with the central monitoring system. Common microcontroller options include Arduino boards, Raspberry Pi, or specialized IoT gateway devices.



IX. CONCLUSION

The IoT-based Underground Tunnel Monitoring System provides a real-time, automated solution for ensuring safety and preventing electrical hazards in underground environments. By integrating potential transformers (PT), current transformers (CT), temperature sensors, fire sensors, an Arduino Uno, an LCD display, an IoT module, a relay, and an alarm, the system effectively detects voltage fluctuations, overcurrent, overheating, and fire risks. In contrast to conventional monitoring methods that depend on manual inspections and delayed reactions, this system provides real-time fault detection and automatic power shutdown, greatly minimizing the risk of accidents and damage to

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infrastructure. A major benefit of this system is its IoT-enabled remote monitoring feature, which enables operators to receive instant alerts and respond quickly when a fault occurs. The automated relay control ensures that power is cut off whenever dangerous conditions arise, preventing further damage. Additionally, the alarm system alerts on-site personnel, enabling a quick response to emergencies. This project is highly applicable in railway tunnels, underground metro systems, mining operations, underground parking areas, and power cable tunnels, making it a versatile and effective safety solution. Overall, this system enhances safety, reliability, and efficiency, reducing human intervention while ensuring proactive maintenance and hazard prevention.

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