IOT BASED UNDERGROUND CABLE FAULT DISTANCE IDENTIFIER

A PROJECT REPORT

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BONAFIDE CERTIFICATE

This is to certify that the project report entitled **“IoT based Underground Cable Fault Distance Identifier”** is the bonafide record of project work done by SUDHAKARAN B (22EER095), SUKUMAR S (22EER099), VISHAL A M (22EER114) in partial fulfillment of the requirements for the award of the Degree of Bachelor of Engineering in Electrical and Electronics Engineering at Anna university Chennai during the year 2024 – 2025.

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EXAMINER-I **EXAMINER-II**

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DECLARATION

We affirm that the project report titled **"IoT based Underground Cable Fault Distance Identifier"** is being submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering is the original work carried out by us. It has not formed part of any other project report or dissertation based on which a degree or award was conferred on an earlier occasion on this or any other candidate.

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ABSTRACT

The IoT-based underground cable fault distance identifier is a system designed to detect faults in underground electrical cables using the principles of resistivity. This project addresses a critical need for efficient, reliable, and accurate methods of identifying cable faults, which are often hidden and difficult to locate. The system operates with an Arduino-based milliohmmeter that measures the resistance across different segments of an underground cable. Changes in resistance can indicate potential faults, as an increase in resistance suggests a fault or disruption at a specific location along the cable. Using the concept of resistivity, the system estimates the fault’s distance from the measurement point, helping maintenance teams identify the fault's exact location without extensive manual inspections.

Python is used to facilitate the IoT component of the project, handling the data acquisition from the Arduino’s serial monitor and automatically sending fault data to a designated email address. This feature enables remote monitoring, as the system immediately alerts personnel of any detected faults, reducing downtime and improving the speed of repairs. The use of IoT ensures real-time monitoring and notification, making this system especially useful for large or complex cable networks where manual fault detection would be impractical and time-consuming.

This system offers several advantages, including reduced maintenance costs, minimized power outages, and greater efficiency in power distribution networks. Its integration of IoT for remote notifications also enhances accessibility, allowing maintenance teams to respond quickly to alerts without being physically present. The simplicity and adaptability of this solution make it a valuable tool for various applications, from urban power grids to industrial power systems. Future advancements could include GPS integration for even more precise fault location and the use of machine learning algorithms for predictive fault analysis, turning this project into a comprehensive, automated maintenance system. The design can be further expanded with more advanced IoT functionalities, such as cloud-based data analytics and visualization, making it a valuable tool for power distribution companies, municipalities, and other organizations reliant on extensive underground cable infrastructure.

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INTRODUCTION

Underground power cables are vital components in modern electrical distribution systems, especially in urban and densely populated areas where overhead power lines are not practical. Unlike overhead lines, underground cables are not exposed to environmental factors like wind and storms, making them more stable and less prone to certain types of damage. These faults can lead to power outages, impacting daily life and operations, and finding the precise location of faults in underground cables is a challenging and often costly process. Traditionally, detecting and locating faults in underground cables required manual inspection and extensive physical measurements, which are not only time-consuming but also impractical for large-scale networks.

To address these challenges, this project proposes an Internet of Things (IoT)-based underground cable fault distance identifier, which utilizes the concept of resistivity to detect and locate faults. The system combines an Arduino-based milliohmmeter for precise resistance measurements with a Python-based IoT application for data handling and remote monitoring. The principle behind this system relies on resistivity, where changes in resistance indicate variations in the length of the conductive path within the cable. When a fault occurs, the effective length of the cable increases due to breaks or shorts, causing an abnormal rise in resistance. By measuring the resistance at different points, the system can identify the approximate distance to the fault location.

The Arduino microcontroller serves as the core hardware component in this system. The Arduino-based milliohmmeter is capable of measuring very low resistance values, detecting even minor changes in resistance that indicate the presence of faults. This milliohmmeter setup is calibrated to ensure high sensitivity, as underground cable faults often manifest as small resistance changes. By reading and processing the resistance data continuously, the Arduino can quickly detect when a fault occurs. Once an abnormal resistance is measured, the data is sent to a connected Python-based application for further analysis and communication.

Python plays a crucial role in managing the IoT aspects of the project. When the Arduino detects a fault and sends the resistance data through its serial monitor, Python reads this data and processes it to determine the fault’s significance and exact location. If the readings confirm a fault, Python uses built-in libraries to send an automated email alert to maintenance personnel, providing them with real-time information about the fault's location. This enables a quick response, as technicians receive the fault information instantly via email, reducing downtime and allowing prompt repairs. This IoT-based approach not only minimizes manual inspections but also streamlines the overall fault management process, making it faster and more cost-effective.

Another advantage of this system is its cost-effectiveness. The use of an Arduino microcontroller and Python software, both of which are affordable and widely available, makes this a practical solution for large networks.. Additionally, by integrating IoT capabilities, this system provides maintenance teams with immediate fault notifications, allowing them to plan and execute repairs efficiently.

In summary, this IoT-based underground cable fault distance identifier offers a modern solution to a longstanding problem in electrical distribution systems. By utilizing resistivity principles, an Arduino-based milliohmmeter, and a Python-powered IoT framework, this system achieves accurate fault detection and location, enabling prompt and efficient responses to faults in underground cables. This approach not only improves the reliability of power distribution networks but also presents a cost-effective alternative to traditional fault detection methods.

OBJECTIVE

- **Accurate Fault Detection**: To precisely identify and locate faults in underground cables using resistivity measurements through an Arduino-based milliohmmeter, ensuring reliable and efficient maintenance.
- **Real-Time Monitoring and Alerts**: To enable real-time data acquisition and fault notifications via Python, which sends alerts to maintenance teams through email for prompt response.
- **Cost-Effective, Scalable Solution**: To provide an affordable, scalable IoT solution using open-source technology, suitable for diverse power distribution networks with minimal manual intervention.

LITERATURE SURVEY

There is several research papers have been published about IoT based Underground Cable Fault Distance Identifier. Here are some of the papers that we have referred to the implementation of IoT based Underground Cable Fault Distance Identifier.

LITERATURE REVIEW

Mr. M. Dinesh, Mr. K. Vairaperumal, and Mr. P. Senthilkumar titled "Design and Detection of Underground Cable Fault Using Raspberry Pi & IoT System" presents a system that integrates Raspberry Pi and IoT technology for real-time underground cable fault detection. The system uses a milliohmmeter to measure resistance changes in cables, indicating fault locations. The data is processed and analyzed, with fault alerts sent to maintenance teams via email, ensuring rapid response and reducing downtime. The approach combines affordable hardware and advanced IoT functionalities to enhance the efficiency of underground cable monitoring.

M. Fonseca-Badillo and L. Negrete-Navarrete titled "Simulation and Analysis of Underground Power Cables Faults" focuses on simulating and analyzing the faults in underground power cables. The study highlights the importance of accurate fault detection techniques to minimize system downtime and improve maintenance efficiency. The authors discuss various fault types and propose methodologies for fault location estimation, which can be further enhanced by IoT-based systems like those that utilize resistivity measurements for real-time fault identification.

Manar Jaradat and Moath Jarrah titled "The Internet of Energy: Smart Sensor Networks and Big Data Management for Smart Grid" explores the integration of smart sensor networks and big data technologies in smart grid systems. It emphasizes the role of IoT and data analytics in enhancing the efficiency, reliability, and fault detection capabilities of power distribution networks. The concepts discussed can be applied to underground cable fault detection systems, where real-time monitoring and data processing, similar to those in this project, improve fault identification and maintenance planning.

The paper "Composite Milliohm-Meter for Resistance Measurement of Precision Current Shunts in Industrial Environments" discusses the development of a milliohm-meter designed for accurate resistance measurement, especially in industrial applications. It focuses on precision measurement techniques, which are critical for ensuring the reliability of electrical systems. This concept is similar to the IoT-based underground cable fault distance identifier, where an Arduino-based milliohm-meter measures small resistances in underground cables to detect faults, with real-time data processed and sent via Python for alerts, improving fault detection and maintenance efficiency.

Md. Zakaria Hossain, Md. Hasibuzzama, Alif Anjum Nion, and Sadia Mallika titled "Smart Cable Fault Location Diagnosis System" presents a smart system for diagnosing cable faults using advanced technologies. It focuses on employing sensors and real-time data analysis to detect and locate faults in cables quickly and accurately. The approach integrates IoT and data processing methods, which aligns with the principles used in the IoT-based underground cable fault distance identifier, where fault locations are determined through resistivity measurements and real-time alerts are sent to maintenance teams.

Vivek KR Verma and Mayank Kumar titled "Underground Cable Fault Detection Using IoT"discusses an IoT-based system for detecting faults in underground cables. It focuses on utilizing IoT sensors and communication technologies to monitor cable health and send real-time fault alerts to maintenance teams. This approach is similar to the IoT-based underground cable fault distance identifier, where resistance measurements are used to detect faults, and notifications are sent through Python to alert the concerned personnel.

The paper "Low Ohmic Resistance Measurement" by Manuel AguilaMuno and Manuel Torres Sabino focuses on methods for accurately measuring very low resistances, which is crucial for applications such as fault detection in underground cables. The paper discusses the techniques and technologies for precise low-resistance measurements, which are directly applicable to the IoT-based underground cable fault detection system. In this system, an Arduino-based milliohmmeter measures resistance to identify faults, with the data processed and sent via Python for real-time notifications, similar to the techniques discussed in the paper.

PROPOSED METHODOLOGY

The proposed system for underground cable fault detection operates on the concept of resistivity, leveraging an Arduino-based milliohmmeter for accurate resistance measurements. Underground cables are prone to faults due to factors like physical damage, aging, and environmental degradation. These faults often result in an increase in the resistance of the cable at the point of fault, which can be detected using precise resistance measurement techniques. By measuring the resistance across different sections of the cable, the system can pinpoint the location of the fault based on the principle that resistance is directly proportional to the length of the conductor.

At the core of this system is the Arduino microcontroller, which is programmed to act as a milliohmmeter. The Arduino is responsible for measuring the small resistances in the cable, which is necessary to detect minute changes that may indicate a fault. The microcontroller is equipped with a suitable analog-to-digital converter (ADC) that reads the resistance values with high precision. Given that underground cable faults generally manifest as an increase in resistance, the system is specifically calibrated to detect small variations, ensuring that even minor faults are detected. Once the resistance data is collected, it is passed through the Arduino’s serial monitor for further processing.

Python plays a crucial role in the system's IoT functionality. Once the Arduino captures the resistance data, Python is employed to read and process the serial data from the Arduino. Using Python’s robust libraries for serial communication, the program continuously monitors the serial output from the Arduino, parsing the resistance values. Upon detecting an abnormal increase in resistance that signifies a fault, Python calculates the approximate location of the fault by applying the resistivity formula:

$$R=\rho A/L$$

where R is resistance, ρ is resistivity, L is the length of the cable, and A is the cross-sectional area of the conductor. This formula allows the system to estimate the fault's distance from the measuring point along the cable.

Once the fault is confirmed, the Python program triggers an IoT notification. This is accomplished by sending an email to a pre-configured recipient (typically a maintenance team) with detailed information about the fault's location. Python's email libraries allow the system to seamlessly send these alerts in real-time, ensuring that the maintenance personnel is promptly informed and can take the necessary action to repair the fault. This IoT-based remote monitoring feature minimizes downtime and allows for quicker fault identification and resolution without requiring manual inspections.

The fault detection methodology is both cost-effective and accurate. The Arduino-based milliohmmeter provides a reliable and affordable solution for measuring small resistances, making it a practical choice for detecting underground cable faults in various environments. The integration of Python for data analysis and email alerts makes the system more efficient by automating the fault detection process and providing real-time alerts. This is especially beneficial in large-scale networks where manual fault detection would be time-consuming and inefficient.

In conclusion, the IoT-based underground cable fault distance identifier provides an efficient solution for locating faults in underground cables. By combining the precision of an Arduino-based milliohmmeter with the processing power of Python for IoT communication, the system can quickly detect faults and notify maintenance personnel, significantly reducing downtime and repair costs. Furthermore, the system can be expanded in the future to incorporate advanced features, such as predictive fault detection using machine learning and integration with GPS for more accurate fault location tracking, making it a valuable tool for modern power distribution systems.

HARDWARE IMPLEMENTATION

COMPONENTS USED:

S.no	Name of the component	Specification
1.	Arduino UNO	
2	LM317 voltage regulator	
3	Conductor	
4	Test Resistor	
5	Python	

1. Arduino UNO

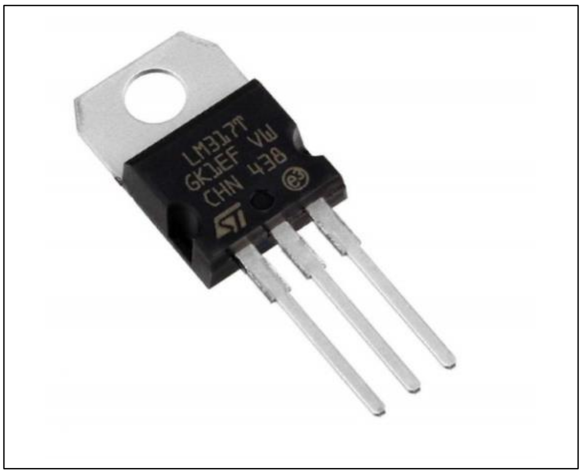
- Description:
  - The Arduino Uno is an open-source microcontroller board based on the ATmega328P, widely used in electronics projects for its ease of programming and flexibility. It provides multiple input and output pins for interfacing with sensors, actuators, and other devices. Its compatibility with various sensors and modules makes it ideal for developing real-time monitoring systems.
- Role in the Project:
  - In this project, the Arduino Uno functions as the core data acquisition unit, measuring the resistance along underground cable segments to detect faults.
  - It is programmed to act as a milliohmmeter, taking periodic resistance readings and sending this data to a computer or Raspberry Pi via a serial connection.
  - The Arduino's role is crucial for real-time monitoring, as it collects the raw data needed for fault detection.

- Technical Specifications:
  - Microcontroller**:**ATmega328P
  - Operating Voltage**:** 5V
  - Digital I/O Pins**:** 14 (6 PWM outputs)
  - Analog Input Pins**:** 6

2. LM317 voltage regulator

- Description:
  - The LM317 is an adjustable three-terminal voltage regulator capable of supplying a variable output voltage between 1.25V and 37V with a current capacity of up to 1.5A. It is widely used in electronics to provide a stable DC output from an unregulated input, offering high versatility due to its adjustable output range. The LM317 is also equipped with overload and thermal protection, making it a reliable choice for various applications.

- Role in the Project:
  - In this project, the LM317 voltage regulator is used to ensure a stable and adjustable voltage supply for the Arduino-based milliohmmeter and any connected sensors or circuitry.
  - Consistent voltage is crucial for obtaining accurate resistance measurements, as fluctuations in power can cause variations in readings.
  - By regulating the input voltage, the LM317 helps maintain the precision needed for accurate fault detection in the underground cable monitoring system.
- Technical Specifications:
  - Input Voltage Range: 3V to 40V
  - Output Voltage Range: 1.25V to 37V (adjustable)
  - Maximum Output Current: 1.5A
  - Voltage Regulation: 0.01% per load current change
  - Protection features: Overload protection, thermal shutdown, safe area compensation.



3. Conductor

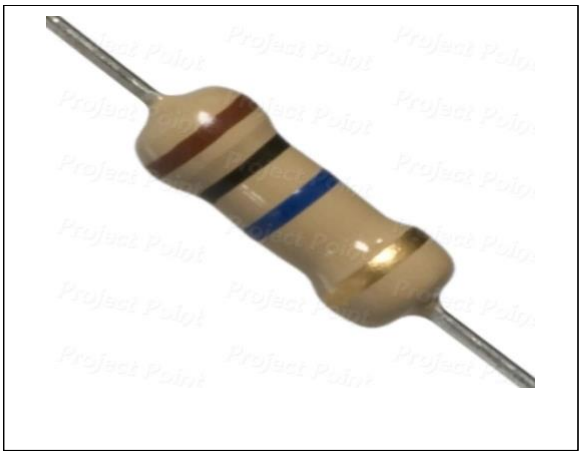
- Description:
  - A steel conductor is a high-strength metallic conductor typically used in electrical and structural applications due to its durability and conductive properties.
  - Steel is often coated or combined with other metals to improve its conductivity and corrosion resistance.
  - In power systems, steel conductors are chosen for their robustness and long-lasting performance, especially in underground installations where physical strength and resistance to environmental factors are essential.
- Role in the Project:
  - In this project, the steel conductor serves as the primary material of the underground cable whose resistivity is monitored to detect faults. The conductor's resistance changes along its length in response to faults such as breaks or insulation damage, allowing the system to use resistivity measurements to identify the fault's location. Steel's stable resistance properties and mechanical strength make it suitable for providing accurate and consistent resistance values in the fault detection system.
- Technical Specifications:
  - Resistivity: Approximately $1.43\times10{-7}$ Ωm at 20°C
  - Tensile Strength: High tensile strength (up to 200-250 MPa) for durability in underground conditions.
  - Thermal Conductivity**:** Moderate, sufficient for maintaining stable electrical characteristics under load.

4. Test Resistor

Description:

- A test resistor is a precision resistor used to simulate specific resistance values within an electrical circuit for testing and calibration purposes.
- Test resistors are commonly used in fault detection systems to verify measurement accuracy and calibrate devices like milliohmmeters.

- Role in the Project:
  - In this project, the test resistor serves as a reference or baseline resistance for the Arduino-based milliohmmeter.
  - By comparing measurements against known resistance values, the system can be calibrated to accurately detect even small resistance changes in the steel conductor.
  - This calibration is essential for ensuring reliable fault detection, as it enables the system to differentiate between normal resistance variations and those indicative of faults.
- Technical Specifications:
  - Resistance Values: Typically low resistance values (e.g., 0.1Ω to 10Ω), chosen based on the expected range of faults,
  - Material:Often constructed from alloys like manganin or constantan, known for their stability in low-resistance application.



5. Python

- Description:
    - Python is a high-level, interpreted programming language known for its readability, ease of use, and extensive libraries. It is widely used in data processing, automation, IoT, and web applications due to its versatility and strong community support. Python's rich set of libraries allows rapid development of complex systems, including real-time monitoring and communication for IoT projects.
- Role in the Project:
    - In this project, Python serves as the interface between the Arduino-based milliohmmeter and the IoT network, enabling data acquisition, processing, and remote fault notification.
    - It reads real-time resistance data from the Arduino via serial communication, analyzes it, and identifies potential faults. Once a fault is detected, Python sends an alert email with details of the fault location, allowing maintenance personnel to respond quickly.
    - Python's role is critical for data handling, processing, and enabling IoT-based notifications.
- Technical Specifications:
    - Data Handling Capabilities**:** Python enables smooth handling of real-time data from the Arduino, allowing filtering, logging, and processing.
    - Network and IoT Integration**:** Python's networking libraries, like smtplib, allow integration with email servers or cloud platforms for IoT alerts.
    - Ease of Development**:** Python's simplicity and readability make it suitable for rapid IoT prototyping and integration with hardware.

APPENDIX

```
void setup() {
 // Initialize serial communication at 9600 bits per second:
Serial.begin(9600); Serial.println("MiliOhm Meter"); }
// The loop routine runs over and over again forever:
void loop() {
// Read the input on analog pin 0:
 int sensorValue = analogRead(A0);
// Convert the analog reading (which goes from 0 - 1023) to a voltage (0 - 5V):
float voltage = sensorValue * (5.0 / 1024.0);
// Calculate resistance
float Rx = voltage / 0.104;
// Define constants for resistivity and area
float resistivity = 1.675514667e-5; // in ohm meters
float area = 3.14159e-6; // in square meters
// Calculate length using L = (rho * A) / R
float length = (Rx * area) / resistivity;
if (Rx > 41) {
Serial.println("Out of Range");
delay(1000);
} else {
Serial.print("Resistance: ");
Serial.print(Rx);
Serial.println(" Ohm");
Serial.print("Length: ");
Serial.print(length);
Serial.println(" m");
delay(1000);
}
}
```

1.Analog Reading:

- analogRead(A0) reads the analog input value from pin A0. This value (sensorValue) is a digital representation of the analog voltage input, ranging from 0 to 1023, where 0 corresponds to 0V and 1023 corresponds to 5V.

2.Voltage Calculation:

- The analog reading is converted to voltage using the formula:

```
float voltage = sensorValue * (5.0 / 1024.0);
```

Here, 5.0 represents the reference voltage (5V), and 1024.0 is the resolution of the ADC (Analog-to-Digital Converter). This gives the actual voltage in the circuit.

3.Resistance Calculation (Rx):

- The resistance is calculated using the formula:

```
float Rx = voltage / 0.104;
```

0.104 is assumed to be the current in the circuit (in amperes), derived from the voltage applied and the known characteristics of the circuit. Using **Ohm's Law**:

$$R=V/I$$

where V is the measured voltage and I is the known current, the code calculates Rx as the resistance.

4.Calculation of Cable Length:

- To determine the length of the faulty cable section, the code uses the resistivity formula:

$$L=R\times A/\rho$$

where:

  - R (or Rx in the code) is the calculated resistance,
  - A is the cross-sectional area of the cable (given as 3.14159e-6 m^2),
  - ρ is the resistivity of the material (given as 1.675514667e-5 ohm meters).

- The result (length) represents the estimated distance to the fault point in meters.

CONCLUSION

The IoT-based underground cable fault distance identifier using the concept of resistivity offers a robust and efficient solution for detecting faults in underground power cables. By utilizing an Arduino-based milliohmmeter, the system is capable of measuring small resistances with high precision, which is crucial for identifying even minor faults that may otherwise go undetected. As underground cables are often exposed to physical damage, aging, and environmental factors, early detection of faults is essential to ensure uninterrupted power supply and prevent costly damage. This system significantly enhances fault detection and location accuracy, enabling quick responses and minimizing downtime.The integration of Python for data acquisition and IoT functionality further improves the system's capabilities. Python processes the resistance data from the Arduino’s serial monitor, analyzes it for abnormal resistance spikes, and calculates the fault's approximate distance from the source using the resistivity formula. The use of Python also enables the system to automatically send email notifications whenever a fault is detected, providing real-time alerts to maintenance personnel. This reduces the need for manual inspections and streamlines the process of fault identification, leading to faster resolution times and more efficient maintenance operations.One of the key advantages of this system is its cost-effectiveness. The use of readily available and affordable components such as Arduino, milliohmmeters, and Python libraries makes it accessible for large-scale deployment across power distribution networks. This low-cost solution provides high accuracy in fault detection, making it an ideal choice for monitoring underground cables in various industrial, residential, and commercial settings. Moreover, the ability to remotely monitor and receive alerts through IoT enhances the operational efficiency of maintenance teams, reducing the need for on-site inspections and allowing for proactive maintenance.In conclusion, the IoT-based underground cable fault distance identifier using resistivity measurement, Arduino, and Python for data analysis and IoT communication presents a highly effective, cost-efficient, and scalable solution for underground cable fault detection. By automating the fault detection process and providing real-time alerts, this system contributes significantly to the reliability and efficiency of power distribution networks, ensuring that faults are detected and addressed promptly. The potential for further improvements makes this system a promising tool for future advancements in smart grid and infrastructure monitoring technologies.

FUTURE SCOPE

The future scope of the IoT-based underground cable fault distance identifier, resistivity concepts with Arduino and Python, holds great potential for further advancements in fault detection and power distribution network management. As the technology continues to evolve, several improvements and additional features can be integrated to enhance the system's capabilities. One promising area of development is the integration of machine learning algorithms to predict potential faults before they occur. By analyzing historical data and patterns in resistance measurements, machine learning models could forecast likely fault locations and times, enabling proactive maintenance and reducing the risk of unplanned outages.

Additionally, the system could be enhanced by incorporating more precise localization techniques, such as Global Positioning System (GPS) technology. This would allow the system to pinpoint fault locations with greater accuracy, which is particularly beneficial for large-scale networks with numerous cable sections. The integration of GPS could also help in mapping faults in real-time, facilitating faster intervention by maintenance teams. Another area for future enhancement is scalability, enabling the system to monitor and manage multiple cables simultaneously. This would be crucial for expanding the system's applicability to large power grids, industrial complexes, and urban infrastructure, where multiple underground cables are in operation.

The future scope of this system also extends to the adoption of IoT-enabled smart grids, where this fault detection system could become an integral part of a larger automated network. With the ability to monitor cable health in real time, the system could be part of a self-healing grid, where faults are automatically detected, isolated, and rerouted to minimize disruptions in power supply.In conclusion, the IoT-based underground cable fault distance identifier has a promising future, with potential for integration into more sophisticated systems, machine learning, real-time localization, wireless communication, and smart grid infrastructure. As these technologies continue to advance, the system will become even more efficient, reducing maintenance costs, minimizing downtime, and ensuring more reliable power distribution.

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