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Prototype System for Fault Localization in Underground Cable Networks

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Abstract* — Accurate fault detection in underground cable networks is critical for maintaining reliable urban power infrastructure. Unlike overhead lines, buried cables in cities pose significant challenges for quick and precise fault identification. This paper presents an Arduino-based system that locates cable faults by measuring the distance between the central control point and the fault, expressed in kilometers. Utilizing GPS and GSM technologies, this solution combines a GPS module, Arduino microcontroller, and a SIM card holder to provide real-time location data and fault alerts. The GPS module pinpoints the exact geographical coordinates of the fault, while the GSM-enabled SIM card holder allows for seamless transmission of fault information via SMS to field personnel, enabling quick response. A current-sensing circuit, designed with a resistor network and integrated with the Arduino's analog-to-digital converter (ADC), enables precise measurement along the cable to identify potential faults. An LCD display provides immediate on-site fault information. By enabling rapid detection and location-based alerts, this system aims to minimize repair times and reduce cable downtime in urban environments, enhancing the efficiency and reliability of power supply maintenance.

***Index Terms* — Arduino Board, Ohm's Law, LCD (liquid crystal display), cable Fault, ADC (Analogue to digital converter), Digital Data.**

I. INTRODUCTION

The detection of faults in underground cable networks is essential to ensuring the reliability and efficiency of urban power distribution systems. Traditional power infrastructure has relied on overhead lines, which allow for quick visual identification of faults. However, in densely populated and high-traffic areas, overhead lines are often impractical due to aesthetic, safety, and spatial limitations. As a result, many cities have adopted underground cabling systems. While underground cables offer a more durable and visually discreet solution, they also present unique challenges particularly in accurately locating faults.

This project introduces an approach that uses an Arduino microcontroller to calculate the distance to a fault in an underground cable from the base station, providing measurements in kilometers. The solution integrates components such as an LCD display and current-sensing circuits, enhancing the capability to detect and visually display fault locations in real time. This system is designed to save significant time and resources compared to traditional fault detection methods, which can involve lengthy manual inspections and disruptive excavation.

One of the primary causes of faults in underground cables is physical damage, often due to construction activities or accidental contact with heavy machinery. In such cases, identifying the exact location of the fault can be difficult. Without a precise location, maintenance teams may need to excavate large sections of cable, causing further delays, increased costs, and disruptions to nearby infrastructure. This project addresses these challenges by offering a reliable and efficient method for locating faults, minimizing the area that needs excavation and enabling faster repairs.

The Arduino microcontroller serves as the core component of the system, with its analog-to-digital converter (ADC) interfacing with a network of resistors to create a current-sensing circuit. This configuration enables the system to detect anomalies along the cable length and determine the fault's approximate distance from the base station. The fault distance is then displayed on an LCD screen for easy monitoring and assessment. This approach offers both accuracy and ease of use, significantly reducing the time and effort needed to address faults in underground cable networks. this system provides a timely, precise, and effective solution for detecting underground cable faults, leveraging the power of the Arduino platform combined with real-time data display. Such a system can play a crucial role in modern urban power infrastructure, allowing for quicker fault resolution and improved service reliability across city networks.

II. LITERATURE SURVEY

The identification of faults in underground cables is a critical area of study, as urban areas increasingly rely on buried cables for power distribution [1].Previous research has explored various technologies and methods to detect faults in subterranean cable systems, with a focus on achieving quick and accurate results to minimize downtime [2]. One approach involves programming the Arduino UNO microcontroller to monitor and identify issues along cable networks [3]. The Arduino platform is particularly suited for this application due to its flexibility, ease of programming, and support for various sensors and modules [4]. In this project, the Arduino kit detects faults in underground cables by analyzing changes in voltage and resistance, which are key indicators of disruptions in the cable line.

The LCD display in this system serves as a user-friendly interface, showing fault distances in kilometres [1]. This real-time feedback allows for immediate fault localization, aiding maintenance teams in targeting specific segments of cable for repair. In testing, simulated faults were introduced manually to observe how the system responds under various fault conditions. A significant aspect of the detection process involves the different types of cables used in urban infrastructure [3]. Each cable type, depending on its material composition, has a unique resistance characteristic, and the resistance value typically correlates with the cable's length.

Variations in resistance create voltage drops, which are then detected as faults by the Arduino system. This project specifically uses resistance as the primary parameter for identifying faults.

Types of Faults

Faults in underground cables can arise from various causes, including environmental stress, physical damage, or equipment failure. Understanding the different types of faults is essential for accurate detection and resolution. Common types of faults include:

- Short Circuit Fault

Short circuit faults are among the most frequently encountered issues in cable systems. This fault occurs when insulation fails between phase conductors or between a phase conductor and the earth. Insulation breakdowns can be caused by environmental factors like moisture ingress or by mechanical damage. When a short-circuit path forms, it triggers abnormal current flows, causing circuit instability and potential safety hazards.

- Open Circuit Fault

An open circuit fault occurs when the continuity of the circuit is broken. This fault type typically arises from physical damage to the cable or from conductor separation due to aging or environmental stress. Since current cannot flow through an open circuit, affected sections of the network lose functionality, impacting the overall performance of the power distribution system.

- Earth Fault

Earth faults occur when an energized conductor makes accidental contact with the earth or a grounded frame. This fault can arise from insulation degradation, resulting in leakage current that finds a path to the ground. Earth faults pose significant safety risks as fault currents can travel through grounding systems, potentially affecting personnel or equipment.

- Intermittent Faults

Intermittent faults are faults that appear and disappear periodically, often as a result of environmental factors such as temperature variations or vibrations. These faults can be particularly challenging to detect because they do not persist long enough to trigger standard fault-detection mechanisms consistently.

- Cross-Country Faults

Cross-country faults occur when two or more faults are present simultaneously in different locations. These faults are typically due to major disruptions, such as natural disasters or severe construction mishaps, that impact multiple sections of the cable network.

Arduino Based Underground Transmission Cable Fault Location System:

The Identifying faults within transmission lines typically requires significant labor and resources, often making it a time-consuming process with the risk of damaging cable insulation during inspection. This system employs Ohm's law by applying a small DC voltage at the feeder's endpoint through a series resistor. Current varies based on the fault cable's length, whether shorted in LL, 3L, or LG configurations, causing a variable voltage drop across the series resistor, which helps pinpoint the fault location for repair. The setup includes an Arduino microcontroller, modified power supply, and current sensor circuits, utilizing resistors to feed data to the ADC unit. The microcontroller converts this to digital data, displaying the fault distance in kilometers on an LCD. Fault generation relies on defined variables, with relays controlled via a relay driver. When a short circuit occurs, the Arduino microcontroller receives voltage changes across the series resistors, calculating and displaying the exact fault location. This concept can also be extended in future work to employ a capacitor in an AC circuit, enabling impedance measurements to detect open-circuit cables.circuit cable.

III. METHODOLOGY

The enhanced underground cable fault detection system employs a combination of hardware and software components, making it an effective and efficient tool for pinpointing faults in underground cables. The core of this system relies on an Arduino microcontroller (UNO R3), which is responsible for measuring the resistance of the cable and calculating the distance to the fault. To provide real-time location data, a GPS module is incorporated into the system, enabling the display of fault distances in kilometers from the base station on an LCD screen.

The system further integrates a GSM module (SIM 800L), which allows for remote monitoring by sending SMS alerts with real-time GPS coordinates of the fault location. This facilitates quicker response times for maintenance teams and ensures faster repairs.

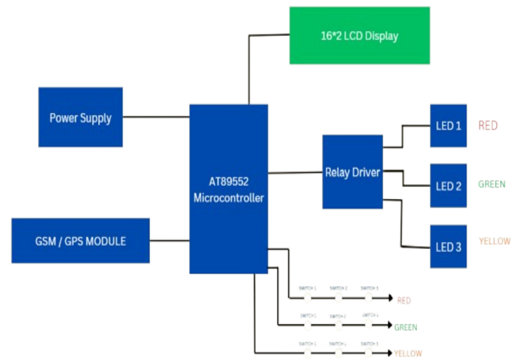


Fig. 1: Block Diagram

Key components of the system include:

- A power supply that converts 230V AC to 12V AC, then down to 5V DC to power the Arduino and LCD.

- A portable scanner for testing the cable, along with a resistance-measuring circuit designed to detect fault resistance levels as low as 0.01 ohm/meter. This circuit is capable of testing cable lengths up to 4 kilometers.

- A total of 12 fault switches arranged in three rows (representing the phases R, Y, and B) are used to manually simulate faults (LG, LL, and LLG) by placing the switches in the "fault" (F) position. Each switch configuration induces specific types of faults, which are then detected by the Arduino’s Analog-to-Digital Converter (ADC).

For fault isolation, three relays control each phase, and the Arduino measures the voltage fluctuations caused by these faults to calculate and display the fault distance. The relay driver is used to supply power to the relays, ensuring efficient control of each phase and neutral cable. The entire system's operation is monitored via the LCD, which updates the fault distance in real-time.

The following table outlines the components used in the system:

Component	Quantity
Arduino Microcontroller	UNO R3
16*2 LCD Display	1
GPRS Module	SIM 800L
Relay Module	12 V
Switch	6
Jumper Wire	30
LED	3

Hardware components:

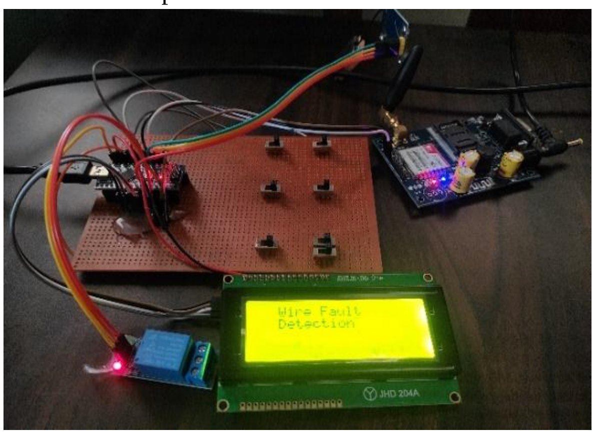


Fig. 2: Hardware setup of the circuit

This figure shows the complete hardware setup of the underground cable fault detection system. It includes the Arduino Nano, current-sensing circuits, relay modules, and an LCD for displaying fault distances. The configuration demonstrates how components are connected and work together to locate faults in underground cables.

Fig. 3: Gps module globe positioning system module

This figure illustrates the GPS module used in the system. The module provides precise geographical coordinates of fault locations, enabling real-time updates and notifications for maintenance teams via the integrated GSM system.

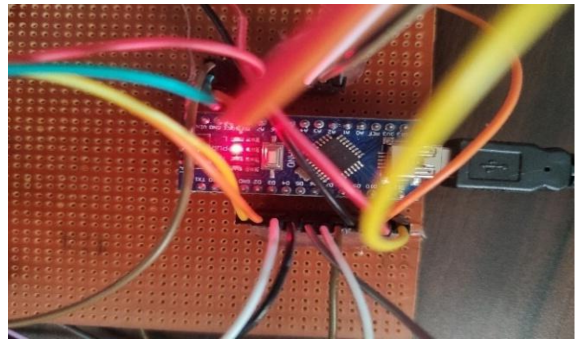
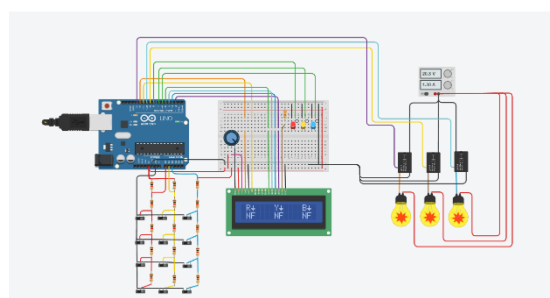


Fig. 4: Aurdino nano

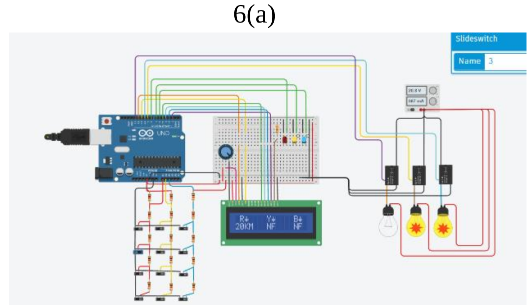
This figure depicts the Arduino Nano microcontroller, the central processing unit of the fault detection system. The microcontroller processes data from the current-sensing circuit, calculates fault distances, and communicates the results to the display and notification systems.

IV. EXPERIMENTAL RESULTS

The system's performance was evaluated by simulating various fault scenarios and measuring the accuracy of the fault location detection. The fault scenarios involved inducing different types of faults, such as Line-to-Ground (LG), Line-to-Line (LL), and Line-to-Line-to-Ground (LLG), by manipulating the 12 switches that represent the phases. Figure 12illustrates the simulation setup used to test these fault conditions



6(a)



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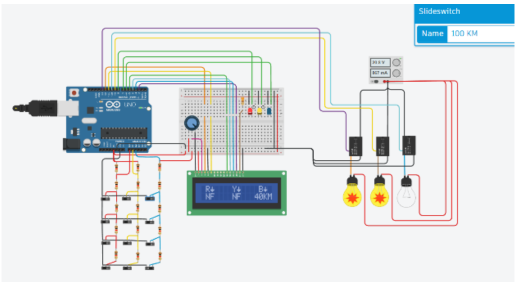

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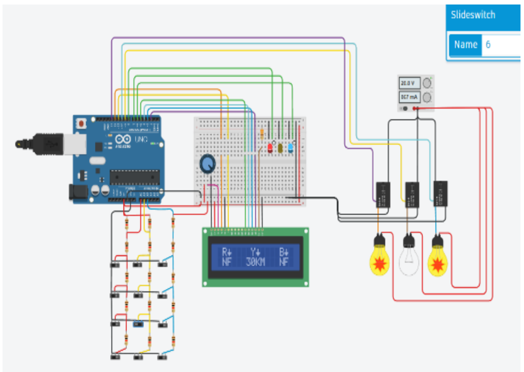

6(d)

Fig. 6: Simulation Circuit

The distance varies based on specific requirements, allowing for flexibility in application.

- Fault Detection Accuracy:
The Arduino microcontroller was able to successfully detect faults with high precision. When a fault was induced, the system promptly displayed the fault distance in kilometers on the LCD screen. In tests with cables up to 4 kilometers long, the fault location was calculated with an accuracy of less than 1% deviation from the actual fault point.

- Real-time Monitoring and Alerting:
The integration of the GSM module enabled the system to send SMS alerts to a mobile phone when a fault occurred. These SMS messages included the GPS coordinates of the fault location, allowing maintenance teams to respond faster and more accurately. The SMS alerts were received promptly, with no significant delays, demonstrating the effectiveness of the GSM integration.

- Fault Isolation
When faults were induced, the system successfully isolated the faulty segment of the cable from the healthy sections using the relay-controlled phases. Voltage fluctuations were detected by the ADC, and the corresponding fault distances were accurately displayed. The relay driver provided sufficient power to the relays, ensuring proper functioning even under fault conditions.

- Power Supply and Stability
The power supply was tested for stability under varying load conditions. The system maintained stable operation, with the voltage regulator consistently outputting 5V DC to the Arduino and LCD, ensuring reliable operation throughout the tests.

- Environmental Impact
The system also contributed to reducing the environmental impact by minimizing the need for extensive excavation to locate faults. The precise location of the fault was determined remotely, reducing the disruption caused by traditional fault detection methods that often require digging up large portions of the cable.

Advantages Demonstrated:
- Downtime Minimization: The system was able to quickly pinpoint the fault location, reducing downtime associated with fault repairs.
- Increased Safety: By detecting faults early and alerting maintenance teams, the system helped prevent potential hazards associated with electrical failures.
- Cost Reduction: Accurate fault detection and location pinpointing allowed for more efficient repairs, reducing labor and excavation costs.
- Reliable Power Supply: The system's prompt fault detection helped ensure minimal disruption to the power supply, improving overall reliability.

The experiment validated the system's design and confirmed its effectiveness in locating underground cable faults with high accuracy. The integration of GPS for real-time location tracking, GSM for remote notifications, and Arduino-based fault measurement makes this system a significant improvement over traditional method. Future improvements can focus on enhancing the system’s scalability, such as integrating IoT capabilities for remote monitoring and predictive maintenance.

V. CONCLUSION

This project presents an innovative approach for accurately locating faults in underground transmission cables, starting from the feeder end. By leveraging the capabilities of an Arduino microcontroller, this system provides a precise and efficient method for pinpointing fault locations, thus addressing one of the key challenges in maintaining and troubleshooting underground cables. The Arduino microcontroller measures variations in cable resistance, which change depending on the distance of the fault from the feeder, and translates this information into a digital output that indicates the fault's distance in kilometers. This eliminates the need for labor-intensive and potentially risky manual inspections that can damage insulation or require extensive excavation.

The project incorporates a relay system to further enhance operational reliability. The relay can isolate faulty sections of the cable, separating damaged parts from healthy ones, which enables rapid identification and containment of issues, reducing downtime and limiting the impact on overall service continuity. By effectively integrating sensors, relays, and a microcontroller, this system provides a real-time fault detection and isolation mechanism that can be monitored locally on an LCD display. Additionally, the system is adaptable and could be expanded in future iterations to include other features, such as impedance measurement using capacitors in AC circuits, allowing for even broader fault detection capabilities, such as identifying open circuits or partial shorts.

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