IOT-Enabled Real-Time Fault Localization in Underground Cables Using Arduino

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Abstract
Underground power cables are increasingly adopted in modern electrical distribution systems due to their enhanced safety, reliability, and reduced exposure to environmental disturbances. However, detecting and localizing faults in underground cables is challenging because the cables are buried and inaccessible. This paper presents an IoT-enabled, Arduino-based real-time fault localization system for underground cables. The proposed system uses an impedance-based method to detect faults by monitoring voltage and resistance variations across three phases. Fault distance is calculated accurately, displayed locally on an LCD, and transmitted to a cloud-based IoT platform using an ESP8266 Wi-Fi module. Experimental results demonstrate the effectiveness of the proposed system in identifying faulty phases, estimating fault distance, and enabling remote monitoring.

I.Introduction

Underground cables play a critical role in modern power distribution systems, particularly in urban and industrial areas, due to their improved safety, aesthetic advantages, and reduced susceptibility to weather-related faults compared to overhead lines [1].

Despite these advantages, underground cables are prone to faults caused by insulation degradation, moisture ingress, thermal stress, manufacturing defects, and accidental mechanical damage [2]. Locating such faults is difficult because the cables are buried underground, making manual inspection and excavation expensive and time-consuming.

Traditional fault detection methods rely on time-domain reflectometry, manual testing, or sectional isolation, which often require skilled labor and prolonged outage durations [3]. With the advancement of embedded systems and Internet of Things (IoT) technologies, automated fault detection and localization systems have gained significant attention. IoT-enabled monitoring allows real-time fault reporting, faster response times, and improved reliability of power distribution networks [4]. Therefore, an integrated solution combining impedance-based fault detection with IoT-based remote monitoring is essential for modern smart grid applications.

II. Literature Survey

Several researchers have proposed techniques for underground cable fault detection and localization. Kurinjimalar et al. developed an IoT-based underground cable fault diagnosis system that enables remote monitoring and faster fault identification, but the system provides limited accuracy in fault distance estimation [5]. Ibrahim et al. investigated impedance-based incipient fault detection methods in power distribution networks, demonstrating improved sensitivity to early-stage faults, though without IoT integration [6].

Microcontroller-based systems using Arduino and PIC controllers have been widely studied due to their low cost and ease of implementation [7]. Some works focus on GSM-based alert systems for fault notification; however, such systems lack continuous data logging and visualization [8]. Recent research emphasizes the integration of IoT platforms for cloud-based monitoring, data analytics, and predictive maintenance [9]. Despite these advancements, there is a lack of unified systems that combine fault detection, localization, isolation, and IoT-based visualization in a single framework. This gap motivates the proposed work

III. Proposed Methodology

The proposed system implements an impedance-based fault localization technique integrated with an Arduino microcontroller and IoT-enabled communication for accurate underground cable fault detection. An impedance network composed of precision resistors is used to emulate the electrical characteristics and physical length of underground cables, allowing controlled simulation of faults at different distances. Voltage sensing circuits are connected to the R, Y, and B phases to continuously monitor real-time voltage variations.

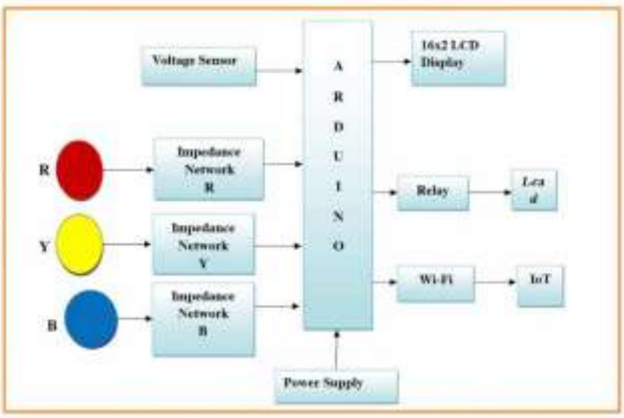

Fig. 1. Hardware prototype of the proposed underground cable fault localization system.

Under normal operating conditions, the phase voltages remain within predefined limits. When a fault occurs, a sudden impedance variation results in a measurable voltage drop proportional to the distance of the fault from the source. These analog signals are converted into digital values using the Arduino's on-chip ADC and processed using a calibrated algorithm to identify the faulty phase and estimate fault distance.

A relay module is activated to isolate the faulty section, preventing further damage to the system. Simultaneously, fault information is displayed on a 16×2 LCD module for local monitoring. To enable remote supervision, an ESP8266 Wi-Fi module transmits fault data to a cloud server in real time, improving fault response time and maintenance efficiency.

IV. Hardware Implementation

The experimental setup consists of an Arduino Uno microcontroller, impedance network, voltag sensing modules, relay modules, ESP8266 Wi-Fi module, 16×2 LCD display, buzzer, and regulated power supply. The impedance network represents different cable lengths and fault locations. The Arduino serves as the central processing unit, interfacing with sensors, relays, display, and IoT module.

Fig. 2. Hardware prototype of the proposed underground cable fault localization system.

Fig. 2 illustrates the complete hardware prototype of the proposed underground cable fault localization system. The setup consists of an Arduino microcontroller, impedance network for cable simulation, voltage sensing circuits, relay modules, and an ESP8266 Wi-Fi module. The impedance network emulates different fault distances across R, Y, and B phases, while the Arduino processes voltage variations to detect faults. A 16×2 LCD displays real-time fault information, and the relay module isolates the faulty section. The integrated IoT module enables remote monitoring of fault data through a cloud server

V. Results and Discussion

The system was experimentally tested by deliberately introducing faults at multiple locations across different phases using a controlled impedance network. During each test scenario, the LCD module accurately displayed the affected phase along with the corresponding fault distance, demonstrating precise fault localization capability. The relay module responded promptly by isolating the faulty phase, thereby preventing fault propagation and ensuring overall system protection.

In addition, real-time fault data—including phase identification and distance information—was successfully transmitted to the IoT platform, allowing continuous remote monitoring, visualization, and logging of fault events. This feature enhances operational awareness and supports timely maintenance decisions. The consistent and repeatable experimental outcomes validate the accuracy, reliability, and practical applicability of the proposed underground cable fault localization system for real-world power distribution environments.

Fig. 3. LCD output and system response during fault condition.

Fig. 3 shows the LCD output and system response when a fault is detected in the underground cable model. The display indicates the identified faulty phase along with the estimated distance of the fault from the source. This real-time visual feedback confirms the accuracy of the impedance-based fault localization algorithm implemented in the Arduino. Simultaneously, the detected fault information is prepared for transmission to the IoT cloud platform for remote monitoring.

Fig. 4. LCD output and system response during fault condition.

Fig. 4 illustrates the system response during an active fault condition in the underground cable model. The LCD displays the detected faulty phase and the corresponding fault distance calculated using the impedance-based method. The illuminated indicator LEDs and activated relay confirm successful fault detection and isolation. This demonstrates the real-time operation and reliability of the proposed hardware system under fault conditions.

Fig. 5. LCD output and system response during fault condition.

Fig. 5 shows the experimental validation of the proposed system during a fault condition at a different location along the underground cable model. The LCD displays the identified faulty phase along with the updated fault distance, indicating accurate localization based on impedance variation. The glowing status LEDs and relay activation confirm successful fault detection and isolation. This result demonstrates the consistency and repeatability of the proposed fault localization approach under varying fault scenarios

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VI. Conclusion and Future Scope

This paper presented an IoT-enabled, Arduino-based real-time underground cable fault localization system designed to improve fault detection accuracy and response time in power distribution networks. The proposed system successfully employs an impedance-based method to detect faults, identify the faulty phase (R, Y, or B), and accurately estimate the fault distance from the source. Experimental results obtained from the hardware prototype demonstrate reliable system performance under various fault conditions. The integration of relay-based isolation enhances operational safety, while the ESP8266 IoT module enables real-time remote monitoring through a cloud platform, significantly reducing maintenance response time and manual inspection efforts.

Future enhancements of this work may focus on incorporating machine learning and data analytics techniques to enable predictive fault analysis and early fault warning systems. The system can be further extended by integrating GSM or LTE-based communication modules to provide fault alerts in locations with limited internet connectivity. Additionally, scaling the proposed approach for high-voltage and long-distance distribution networks, along with the use of advanced sensors and robust communication protocols, can make the system suitable for real-world utility applications and smart grid environments.

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