Smart Underground Cable Fault Monitoring Over Internet Net Of Things

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***Abstract*—In recent years, the rapid expansion of urban infrastructure has significantly increased the use of underground cables for power distribution due to their safety, reliability, and aesthetic advantages. However, one of the major challenges associated with these systems is the difficulty in detecting and locating faults, as they are not visible and require extensive manual inspection. This often leads to increased maintenance time, higher costs, and delays in restoring power. To address this issue, this paper presents a smart and efficient system for underground cable fault monitoring using Internet-based communication. The proposed system employs an embedded solution built around an Arduino microcontroller, integrated with essential components such as sensors, LCD display, GSM module, LEDs, and a buzzer. The system operates on the principle of detecting voltage variations along the cable to identify faults and estimate their location accurately.**

Keywords— IoT, GSM Communication, Embedded Systems, Fault Location Identification, Power Distribution System, Smart Grid Technology, Voltage Drop Method, Arduino Microcontroller.

I. INTRODUCTION

In modern power distribution systems, underground cables have become an essential component, especially in urban and industrial environments. Compared to overhead transmission lines, underground cables offer several advantages such as improved safety, reduced exposure to environmental conditions, and better visual appeal. However, despite these benefits, maintaining underground cable networks presents a significant challenge, particularly when faults occur.

Faults in underground cables—such as short circuits, open circuits, and insulation failures—are often difficult to detect and locate due to the absence of direct visibility. Traditional fault detection methods typically involve manual inspection and trial-and-error techniques, which are time-consuming, labor-intensive, and often inaccurate. These limitations can lead to prolonged power outages, increased operational costs, and reduced reliability of the power distribution system.

With advancements in embedded systems and communication technologies, there is a growing need for intelligent solutions that can automatically detect faults and provide real-time information to operators. In this context, the integration of microcontrollers and communication modules has enabled the development of smart monitoring systems that enhance efficiency and reduce human intervention.

This paper proposes a Smart Underground Cable Fault Monitoring System using an Arduino-based embedded platform. The system continuously monitors the condition of the cable by analyzing electrical parameters, particularly voltage variations, to detect the presence of faults. Once a fault is identified, the system estimates its location and displays the information on an LCD screen for local monitoring.

To further enhance functionality, a GSM communication module is incorporated to transmit fault information to users remotely, enabling Internet-based monitoring. Additional components such as LEDs and a buzzer provide immediate visual and audible alerts, ensuring quick response to fault conditions. The system also includes switches to simulate fault scenarios for testing and demonstration purposes.

The proposed solution aims to minimize the time required for fault detection and localization, reduce maintenance costs, and improve the overall reliability of power distribution networks. By combining embedded technology with communication systems, this project contributes to the development of smarter and more efficient electrical infrastructure.

Doi:10.48047/ijiee.2026.16.2.4

II. REVIEW &LITERATURE SURVEY

The detection and localization of faults in underground cables have been widely studied due to their importance in ensuring reliable power distribution. Over the years, several techniques and systems have been proposed, ranging from traditional manual methods to modern embedded and IoT-based solutions.

Early approaches to underground cable fault detection relied heavily on manual inspection and conventional testing techniques such as Murray loop tests and Varley loop methods. Although these methods provided basic fault identification, they were time-consuming, required skilled personnel, and were not suitable for real-time monitoring.

With the advancement of embedded systems, researchers began focusing on automated solutions using microcontrollers. A study by S. R. Purohit et al. (2023) introduced an Arduino-based underground cable fault detection system that utilizes Ohm's Law to determine fault location. By measuring variations in voltage and current, the system calculates the distance of the fault and displays it, thereby reducing the time required for maintenance operations.

Similarly, another approach presented in an IJERT publication (2023) integrates Arduino with GPS and GSM modules to enhance fault detection capabilities. In this system, once a fault is detected through electrical parameter analysis, its geographical location is determined using GPS and communicated to the user via GSM. This method significantly improves accuracy and enables remote monitoring, making it suitable for large-scale power networks.

Further research published in IJSRSET (2024) emphasizes the use of voltage drop analysis for identifying fault locations. The system demonstrates how variations in voltage along the cable can be used to estimate the fault distance and display the results on an LCD interface. This approach highlights simplicity and cost-effectiveness while maintaining reasonable accuracy.

In another study from ASEJAR (2025), an Arduino Nano-based system is proposed, where fault detection is achieved by analyzing resistance changes in the cable. The system focuses on improving precision in identifying fault positions and is particularly applicable in municipal and industrial environments.

A comprehensive review by Shweta Gajbhiye and S. P. Karmore (2013) discusses various cable fault monitoring techniques, including computational and signal-processing-based methods. The study highlights the importance of accurate fault detection in minimizing power outages and economic losses, and it emphasizes the need for modern, automated systems.

Additionally, a review paper published in ISCA (2021) explores different Arduino-based fault detection techniques, categorizing faults into open-circuit and short-circuit types. The study concludes that microcontroller-based systems are highly effective due to their low cost, flexibility, and ability to provide real-time monitoring.

From the surveyed literature, it is evident that recent research trends are shifting toward smart, automated, and communication-enabled systems. While many existing solutions successfully detect faults and estimate their locations, there is still a need for systems that combine accuracy, real-time monitoring, ease of implementation, and cost-effectiveness.

The proposed system builds upon these existing approaches by integrating Arduino-based fault detection with GSM-enabled Internet communication and real-time alert mechanisms. This combination aims to provide a more efficient, user-friendly, and scalable solution for underground cable fault monitoring.

III. RESEARCH METHODOLOGY

The proposed Smart Underground Cable Fault Monitoring System is developed using a systematic approach that combines embedded system design, fault detection principles, and communication technologies. The methodology focuses on designing a reliable system capable of detecting, locating, and reporting faults in underground cables in real time.

Initially, a detailed study of underground cable faults and their characteristics was carried out. Faults such as short circuits and open circuits were analyzed based on their impact on electrical parameters, particularly voltage and resistance. The system design is based on the principle that the distance of a fault in a cable can be estimated by measuring variations in voltage along the cable, which is derived from fundamental electrical laws.

The hardware design forms the core of the system. An Arduino microcontroller is used as the central processing unit to control all operations. The underground cable is represented using a series of resistors to simulate different cable lengths. Switches are incorporated to artificially create fault conditions at

Doi:10.48047/ijiee.2026.16.2.4

various points, enabling testing and validation of the system.

The sensing mechanism continuously monitors voltage levels across different sections of the cable. When a fault occurs, there is a change in voltage distribution, which is detected by the Arduino through its analog input pins. Based on predefined calibration values, the system calculates the approximate distance of the fault from the source.

For user interaction and indication, an LCD display is used to show the fault location in real time. LEDs are included to provide visual status indications, while a buzzer is used to generate an audible alert whenever a fault is detected. These features ensure immediate awareness of abnormal conditions.

To enable remote monitoring, a GSM communication module is integrated into the system. Once a fault is identified, the system automatically sends a notification message containing the fault details to a predefined mobile number. This allows users to monitor the system over the Internet without the need for physical presence at the site.

The software implementation is carried out using the Arduino IDE, where the program is developed in embedded C. The code includes modules for data acquisition, fault detection logic, distance calculation, display handling, and GSM communication. Proper testing and debugging are performed to ensure accurate operation under different simulated fault conditions.

Finally, the system is tested under various scenarios by introducing faults at different locations using switches. The results are observed through the LCD display and GSM alerts to verify the accuracy and reliability of the system.

This methodology ensures a cost-effective, efficient, and scalable solution for underground cable fault monitoring, combining real-time detection with remote communication capabilities.

IV. EXISTING SYSTEM

The existing methods for detecting faults in underground cables are largely based on traditional techniques and manual inspection processes. These methods have been widely used in power distribution systems for many years but come with several limitations in terms of efficiency, accuracy, and response time.

Conventional fault detection techniques such as the Murray loop test and Varley loop test are commonly employed to locate faults in underground cables. These methods rely on measuring resistance and require skilled personnel to interpret the results. Although they can provide approximate fault locations, they are time-consuming and not suitable for real-time applications.

In many practical scenarios, fault detection is performed manually by inspecting cable routes or using basic electrical testing equipment. This process is labor-intensive and often involves digging at multiple locations to identify the exact fault point. As a result, it leads to increased maintenance costs, longer downtime, and inconvenience to consumers due to delayed power restoration.

Some modern systems have introduced microcontroller-based approaches for fault detection. These systems utilize basic sensing techniques to identify faults and display the results locally, typically on an LCD. While they improve accuracy compared to traditional methods, many of them lack advanced features such as remote monitoring, real-time alerts, and Internet connectivity.

Additionally, existing systems often do not provide continuous monitoring of cable conditions. Faults are usually detected only after a failure occurs, rather than being predicted or identified in real time. This reactive approach reduces the overall reliability of the power distribution system.

Another limitation of current systems is their dependency on manual supervision. Even when faults are detected, the information is not automatically communicated to the concerned personnel, leading to delays in response and repair.

Overall, the existing systems for underground cable fault detection are either manual, time-consuming, or lack integration with modern communication technologies. These limitations highlight the need for a smart, automated, and Internet-enabled solution that can provide accurate fault detection, real-time monitoring, and instant communication.

Doi:10.48047/ijiee.2026.16.2.4

V. PROPOSED METHODOLOGY

The proposed system introduces a smart and automated approach for detecting and monitoring underground cable faults using embedded technology and Internet-based communication. The methodology focuses on achieving accurate fault detection, real-time monitoring, and instant notification to the user with minimal human intervention.

At the core of the system is an Arduino microcontroller, which acts as the central processing unit. The underground cable is modeled using a network of resistors to represent different distances. Fault conditions are simulated using switches placed at various points along the cable model, enabling controlled testing and analysis.

The system operates based on the principle of voltage drop across the cable. Under normal conditions, the voltage distribution remains uniform. However, when a fault occurs—such as a short circuit or open circuit—the voltage level changes at a specific point. The Arduino continuously monitors these voltage variations through its analog input pins.

Once a fault is detected, the system processes the voltage data and calculates the approximate distance of the fault from the source. This is achieved by comparing the measured values with predefined reference values corresponding to different cable lengths. The calculated fault location is then displayed on a 16×2 LCD screen, providing immediate local feedback.

To enhance the system's functionality, a GSM module is integrated for remote communication. When a fault is identified, the system automatically sends a message to a predefined mobile number containing details of the fault, including the affected phase and its location. This enables real-time monitoring over the Internet and ensures that maintenance personnel are informed instantly.

In addition to communication features, the system incorporates LEDs and a buzzer for alert mechanisms. LEDs indicate the status of different phases, while the buzzer provides an audible warning when a fault occurs. These features help in quick identification and response.

The software implementation is carried out using the Arduino IDE, where the program is structured to perform continuous monitoring, fault detection, distance calculation, display control, and GSM communication. The system is designed to operate efficiently with low power consumption and minimal hardware complexity.

Overall, the proposed methodology offers a reliable, cost-effective, and scalable solution for underground cable fault monitoring. By integrating sensing, processing, and communication technologies, the system significantly reduces fault detection time, minimizes manual effort, and improves the efficiency of power distribution systems.

VI. BLOCK DIAGRAM

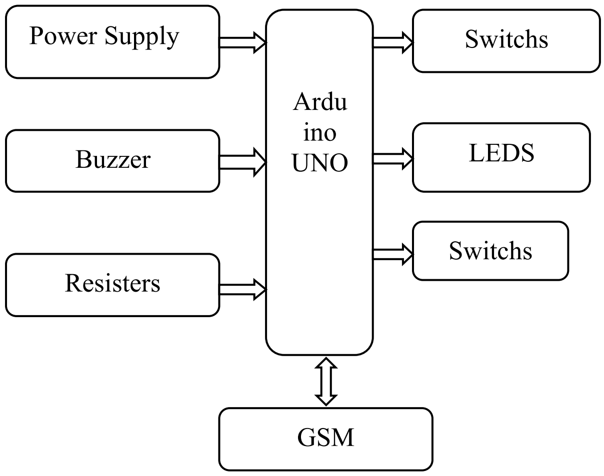

Fig. 6.2. Block Diagram

VII. RESULTS AND OUTCOMES

The proposed Smart Underground Cable Fault Monitoring System was successfully designed, implemented, and tested under various simulated fault conditions. The system demonstrated reliable performance in detecting faults, estimating their locations, and providing real-time alerts to the user.

Doi:10.48047/ijiee.2026.16.2.4

Fig:7.1:Output1

During testing, faults were intentionally introduced at different points in the cable model using switches. The system accurately detected the occurrence of faults in different phases and calculated their approximate distances based on voltage variations. The results were displayed clearly on the 16×2 LCD screen, enabling easy interpretation of the fault location.

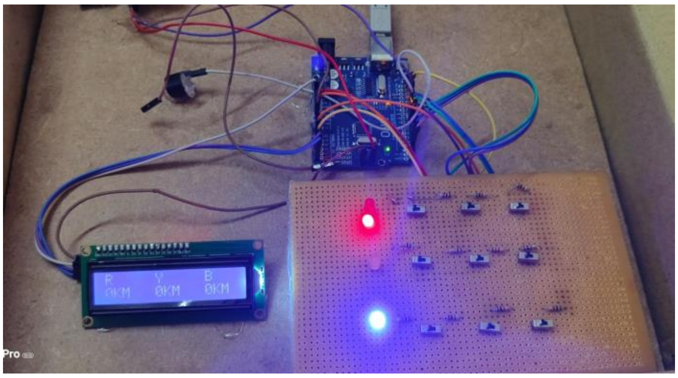

Fig:7.2: Output2

The integration of the GSM module proved effective in achieving remote monitoring. Whenever a fault was detected, the system successfully transmitted alert messages containing fault details to the predefined mobile number. This ensured that users were informed instantly without the need for physical inspection.

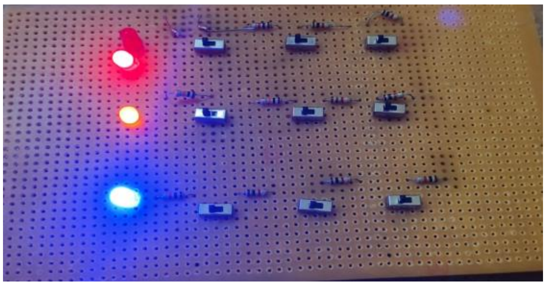

Fig:7.3:Output3

The visual and audible alert mechanisms also functioned as expected. LEDs provided clear indication of the affected phase, while the buzzer generated immediate alerts, enhancing the responsiveness of the system. These features contribute to faster fault identification and reduced downtime.

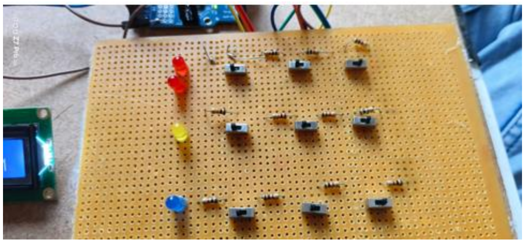

Fig:7.4:Output4

The system showed good consistency and repeatability in its performance across multiple test cases. It was able to distinguish between different fault locations with reasonable accuracy, making it suitable for practical applications in small- to medium-scale power distribution systems.

Overall, the outcomes of the project indicate that the proposed system is:

- **Efficient**, as it reduces the time required for fault detection
- **Reliable**, due to consistent and accurate results
- **Cost-effective**, using simple and easily available components
- **User-friendly**, with clear display and alert mechanisms
- **Scalable**, with potential for integration into larger smart grid systems

The successful implementation of this system demonstrates its potential to improve maintenance

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efficiency and enhance the reliability of underground power cable networks.

VIII.CONCLUSION

The development of a Smart Underground Cable Fault Monitoring System represents a significant step toward improving the efficiency and reliability of modern power distribution networks. As underground cabling becomes increasingly common in urban and industrial environments, the need for fast, accurate, and automated fault detection systems has become more critical than ever. Traditional fault detection methods, which rely heavily on manual inspection and conventional testing techniques, are no longer sufficient to meet the demands of today's dynamic and large-scale electrical infrastructure.

In this project, an intelligent system has been successfully designed and implemented using an Arduino-based embedded platform integrated with sensing, display, and communication modules. The system effectively detects faults in underground cables by analyzing voltage variations and determines their approximate location using a simple yet efficient methodology. The ability to continuously monitor the cable condition and instantly identify faults ensures a proactive approach rather than a reactive one.

One of the key strengths of the proposed system is its capability to provide real-time information. The integration of an LCD display allows local monitoring, while the GSM module enables remote communication by sending fault alerts directly to the user. This dual-mode notification system ensures that faults are not only detected quickly but also communicated efficiently, reducing response time and minimizing service interruptions.

Furthermore, the inclusion of visual indicators such as LEDs and an audible buzzer enhances the system's usability by providing immediate alerts. These features make the system highly practical for real-world applications where quick decision-making is essential. The use of switches for fault simulation also demonstrates the flexibility of the design, allowing easy testing and validation under different conditions.

From an economic perspective, the system is highly cost-effective as it utilizes readily available and low-cost components. This makes it suitable for deployment not only in large-scale power systems but also in smaller or resource-constrained environments. Additionally, the simplicity of the design ensures ease of installation, operation, and maintenance.

The results obtained from testing confirm that the system is reliable, consistent, and capable of accurately identifying fault locations with minimal error. By reducing the dependency on manual inspection and enabling faster fault localization, the proposed system significantly decreases maintenance time and operational costs. It also contributes to improving the overall stability and efficiency of power distribution networks.

In conclusion, this project successfully demonstrates how embedded systems and communication technologies can be combined to develop a smart, automated, and efficient solution for underground cable fault monitoring. The proposed system not only addresses the limitations of existing methods but also lays the foundation for future advancements in smart grid technologies and intelligent infrastructure management.

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