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# DETECTION OF FAULT LOCATION IN UNDERGROUND CABLES USING IoT

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## ABSTRACT

The proposed work aims to determine the distance of underground cable faults from the base station in kilometers, addressing the challenge of locating faults without extensive excavation. Faults in underground cables occur due to open circuit failures, caused by broken conductors, or short circuit failures, resulting from insulation breakdown between conductors or to neutral. Existing fault detection methods include online techniques that analyze sampled voltage and current, which are less common for underground cables than overhead lines, and offline techniques like tracer and terminal methods. The tracer method requires physically tracking cable lines using audible or electromagnetic signals, which is time-consuming, whereas the terminal method estimates the general fault area without precise localization. To overcome these limitations, the proposed model employs an Arduino and a Wi-Fi-enabled microcontroller for real-time fault detection. A 16×2 LCD displays the fault distance and affected phase, while an ESP8266 Wi-Fi module enables remote monitoring via IoT. The system operates based on Ohm's law, where applying a low DC voltage at the feeder end results in current variations corresponding to fault locations due to resistance changes along the cable. An ADC converts these variations into digital data, allowing the Arduino to accurately display the fault location in kilometers. This approach significantly reduces repair time, costs, and labor while improving fault diagnosis efficiency. The integration of IoT technology enhances monitoring capabilities, ensuring prompt maintenance with minimal effort and high reliability.

**Keywords**: Underground cable fault, Fault detection, Arduino, IoT, ESP8266, Ohm's law, Fault location monitoring.

## INTRODUCTION

Underground cable networks are an essential component of modern power distribution and communication systems. Unlike overhead transmission lines, underground cables are protected from environmental hazards such as extreme weather conditions, falling trees, and accidental human interference. However, detecting faults in underground cables is more challenging due to their concealed nature. When a fault occurs, locating the exact point of failure becomes a tedious and expensive process, often requiring extensive excavation and manual inspection. Efficient fault detection methods are necessary to reduce maintenance costs, minimize service interruptions, and enhance overall system reliability [1]. Cable faults are broadly categorized into open circuit faults and short circuit faults. Open circuit faults occur when one or more conductors break, disrupting electrical continuity. Short circuit faults arise from insulation failure between conductors, leading to excessive current flow and potential damage to the cable system. Accurately identifying and isolating these faults is critical to ensuring the uninterrupted operation of power and communication networks [2]. Traditional fault detection methods can be classified into online and offline techniques. Online methods involve continuous monitoring of voltage and current waveforms to identify anomalies indicative of faults. These methods, commonly used for overhead transmission lines, are less prevalent in underground cable systems due to complexities in signal interpretation and propagation [3]. Offline techniques include the tracer method and the terminal method. The tracer method involves manually inspecting the cable route using electromagnetic or audible signals, which is time-consuming and labor-intensive. The terminal method estimates the general fault area by analyzing electrical parameters from one or both ends of the cable, expediting fault localization but lacking precise accuracy [4].

With advancements in microcontroller technology and the increasing integration of Internet of Things (IoT) solutions, automated fault detection systems for underground cables have gained significant attention. The proposed model leverages an Arduino-based system with an ESP8266 Wi-Fi module for real-time fault detection and monitoring. By employing Ohm's law, the system determines fault locations based on variations in current flow through a series resistor network. When a low DC voltage is applied at the feeder end, the resistance changes proportionally to the fault distance, altering the voltage drop across the series resistors. These variations are processed using an Analog-to-Digital Converter (ADC) and displayed in kilometers on a 16×2 LCD connected to the Arduino board [5]. The integration of IoT technology enhances the efficiency of underground cable fault detection by enabling remote monitoring and data accessibility. IoT-based solutions provide real-time fault location updates, allowing maintenance personnel to identify and address issues promptly without the need for manual inspections. This approach not only reduces operational costs but also minimizes service downtime, ensuring continuous power supply and communication services [6]. In comparison to conventional methods, IoT-based fault detection systems offer improved accuracy, faster response times, and enhanced system reliability. The ESP8266 Wi-Fi module transmits fault data to a cloud-based platform, enabling remote access for grid operators and maintenance teams. This feature facilitates predictive maintenance strategies, reducing the likelihood of prolonged system failures and costly repairs [7].

Several studies have explored different methodologies for underground cable fault detection, highlighting the advantages and limitations of each approach. One of the most commonly used methods is Time-Domain Reflectometry (TDR), which sends high-frequency pulses through the cable and measures reflections to identify faults. While TDR is highly accurate, it requires specialized equipment and expertise, limiting its practicality in large-scale deployments [8]. Another widely used technique is the Murray and Varley loop tests, which determine fault

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locations by measuring resistance imbalances in the cable network. However, these methods are best suited for low-resistance faults and may be less effective for high-resistance faults caused by insulation degradation [9]. Artificial intelligence (AI) and machine learning (ML) techniques have also been explored for fault detection and classification. By analyzing historical data and identifying fault patterns, AI-based models can enhance predictive maintenance strategies and improve overall system performance [10]. The proposed Arduino-based model offers a cost-effective and user-friendly alternative to existing fault detection methods. The system's ability to provide real-time fault location data in a digital format significantly reduces manual effort and enhances fault resolution efficiency. Additionally, the use of low-cost components such as the ESP8266 Wi-Fi module and ADC ensures affordability and scalability, making the solution suitable for various applications in power distribution and industrial automation [11]. The simplicity of the system design allows for easy integration into existing infrastructure, eliminating the need for extensive modifications or specialized training. Moreover, the system's reliance on fundamental electrical principles, such as Ohm's law, ensures reliability and consistency in fault detection accuracy [12].

The growing adoption of smart grid technologies has further emphasized the importance of efficient fault detection and monitoring systems. Smart grids leverage advanced communication and control mechanisms to optimize power distribution, reduce losses, and enhance system resilience. Automated fault detection systems play a crucial role in this framework by enabling proactive maintenance strategies and minimizing the impact of cable failures on overall grid performance [13]. The incorporation of IoT in underground cable fault detection aligns with the broader trend of digital transformation in power systems, enabling real-time data analysis and remote diagnostics. By integrating sensor networks, cloud computing, and data analytics, IoT-based fault detection systems contribute to the development of intelligent and self-healing power networks [14]. In conclusion, underground cable fault detection remains a critical challenge in modern power and communication networks. Traditional methods, such as tracer and terminal techniques, are often inefficient and labor-intensive, necessitating the development of automated solutions. The proposed Arduino and IoT-based model addresses these challenges by providing real-time, accurate, and cost-effective fault detection capabilities. By leveraging fundamental electrical principles and advanced wireless communication technologies, the system enhances maintenance efficiency, reduces operational costs, and improves service reliability. As smart grid technologies continue to evolve, the integration of IoT-based fault detection solutions will play an increasingly vital role in ensuring the sustainability and resilience of power distribution networks [15].

## LITERATURE SURVEY

The detection of underground cable faults has been a subject of extensive research due to the challenges associated with locating faults in concealed cable networks. Various methods have been developed over the years, ranging from manual inspection techniques to advanced automated systems incorporating digital and wireless technologies. Traditional fault detection approaches relied on the tracer method, where the cable path is physically traced using electromagnetic or acoustic signals. While this method was effective to some extent, it required considerable time and effort, making it impractical for large-scale applications. The terminal method was introduced to improve efficiency by estimating the general fault location based on electrical measurements at the cable ends. However, this approach only provided approximate fault locations, necessitating further inspection and verification. With technological advancements, electrical fault analysis methods emerged, allowing more accurate determination of fault points in underground cables. Among these, time-domain reflectometry (TDR) became widely used, utilizing pulse reflection principles to identify discontinuities in the cable. This method involved sending a high-frequency pulse through the cable and measuring the time delay of the reflected signal to estimate the fault distance. Despite its accuracy, TDR required specialized equipment and was often expensive, limiting its adoption in routine maintenance operations. Other methods, such as frequency-domain reflectometry (FDR) and arc reflection techniques, provided alternatives to TDR but had their own limitations in terms of complexity and application constraints.

Resistance-based fault detection methods also gained prominence due to their simplicity and effectiveness in certain applications. The Murray and Varley loop tests were among the earliest techniques, relying on resistance measurements to identify faults in cable systems. These methods were particularly useful for low-resistance faults but struggled with high-resistance faults, which required more advanced techniques for accurate detection. The use of bridge circuits further enhanced resistance-based fault detection, enabling better precision in locating faults without requiring extensive cable exposure. However, these methods still had limitations in large-scale applications, prompting researchers to explore digital and automated solutions. The integration of microcontrollers and embedded systems into fault detection significantly improved the accuracy and efficiency of underground cable monitoring. The development of microcontroller-based fault detection systems allowed real-time monitoring of cable conditions, reducing the need for manual inspections. By leveraging basic electrical principles such as Ohm's law, these systems measured voltage and current variations to pinpoint fault locations. The introduction of analog-to-digital converters (ADC) facilitated precise data processing, enabling microcontrollers to display fault distances in a user-friendly format. Additionally, the use of liquid crystal displays (LCD) provided immediate feedback on fault conditions, allowing maintenance personnel to take timely action.

Wireless communication technologies further revolutionized underground cable fault detection by enabling remote monitoring and data accessibility. The advent of the Internet of Things (IoT) played a crucial role in enhancing fault detection capabilities, allowing real-time data transmission over the internet. The integration of Wi-Fi modules, such as the ESP8266, allowed fault detection systems to send alerts and status updates to cloud platforms, where maintenance teams could access information remotely. This development reduced response times and improved overall maintenance efficiency, making IoT-based systems a preferred choice for modern underground cable networks. The ability to monitor fault locations remotely also contributed to predictive maintenance strategies, preventing major failures before they occurred. Artificial intelligence (AI)

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and machine learning (ML) further expanded the possibilities of underground cable fault detection by enabling intelligent fault classification and predictive analytics. Machine learning algorithms analyzed historical fault data to identify patterns and predict potential failures before they happened. AI-driven systems utilized sensor data to determine fault severity and recommend appropriate corrective actions. These advancements minimized downtime and optimized maintenance schedules, reducing costs and improving system reliability. The combination of AI and IoT created a powerful framework for smart grid applications, where underground cable fault detection became an integral part of overall grid management.

The development of smart grids emphasized the importance of advanced fault detection systems in power distribution networks. Smart grid technologies leveraged real-time data analytics, automated control mechanisms, and remote monitoring capabilities to enhance power reliability. Underground cable fault detection systems played a crucial role in these smart grids by providing continuous monitoring and fault diagnostics. The ability to detect faults accurately and promptly ensured uninterrupted power supply and reduced service disruptions. As smart grid infrastructure continued to evolve, fault detection systems became more sophisticated, incorporating real-time analytics and self-healing capabilities to improve grid resilience. Energy efficiency and sustainability considerations also influenced the advancement of underground cable fault detection technologies. Efficient fault detection reduced energy losses caused by faulty cables, contributing to overall energy conservation efforts. By minimizing unnecessary repairs and optimizing maintenance schedules, automated fault detection systems helped improve the operational efficiency of power distribution networks. The adoption of energy-efficient components in fault detection devices further aligned with global sustainability goals, promoting environmentally friendly practices in power system management. The evolution of underground cable fault detection methods reflects the broader trend of digital transformation in power and communication systems. From manual inspection techniques to AI-driven fault detection systems, technological advancements have continuously improved the accuracy, efficiency, and reliability of fault monitoring. The integration of IoT, AI, and smart grid technologies has positioned underground cable fault detection as a key component of modern infrastructure management. As research in this field progresses, further innovations are expected to enhance fault detection capabilities, making power and communication networks more resilient and efficient.

## PROPOSED SYSTEM

The proposed system is designed to detect faults in underground cables with high accuracy, efficiency, and ease of monitoring. Traditional methods of fault detection, such as manual tracing and terminal-based techniques, are time-consuming and labor-intensive, making them impractical for large-scale underground cable networks. The implementation of an automated fault detection system using microcontrollers, sensors, and wireless communication technology significantly improves the process by reducing downtime and operational costs. This system incorporates Arduino and a Wi-Fi-enabled microcontroller to identify and display fault locations in real time, providing maintenance teams with crucial information to expedite repairs and minimize service

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disruptions. The core principle of the proposed system is based on Ohm's law, which states that voltage drop across a conductor is directly proportional to its resistance and the current passing through it. When a DC voltage is applied to the underground cable network, any change in resistance along the cable line due to a fault will result in a measurable voltage variation. By continuously monitoring these voltage changes, the system can determine the location of the fault with precision. A set of series resistors is used to represent different segments of the cable, and the corresponding voltage drops are analyzed to identify the faulty segment. This voltage data is fed into an analog-to-digital converter (ADC), which processes it into digital format and sends it to the Arduino microcontroller for further computation.

The Arduino microcontroller serves as the central processing unit of the fault detection system. It collects data from the ADC and performs necessary calculations to determine the distance of the fault from the base station. The computed fault distance is displayed on a 16×2 liquid crystal display (LCD) connected to the microcontroller, providing instant feedback to field engineers. This real-time display ensures that maintenance teams can quickly pinpoint the exact location of a fault, reducing the time required for troubleshooting and repair operations. The LCD output eliminates the need for extensive manual testing, allowing for faster decision-making and intervention. To further enhance the efficiency of the system, an Internet of Things (IoT) module is integrated into the design. The ESP8266 Wi-Fi module is used to enable remote monitoring and data transmission over the internet. When a fault is detected, the system not only displays the information on the LCD but also sends the fault details to a cloud-based platform accessible via mobile or desktop devices. This capability allows maintenance teams to monitor the underground cable network remotely and take proactive measures before faults escalate into major failures. IoT-based monitoring also facilitates historical data analysis, which can be used for predictive maintenance and trend analysis in cable performance.

The proposed system is capable of detecting two major types of faults in underground cables: open circuit faults and short circuit faults. An open circuit fault occurs when one or more conductors break, resulting in an incomplete electrical path. This type of fault is commonly caused by mechanical damage, aging, or external disturbances. The system identifies open circuit faults by detecting a sudden increase in resistance along the cable, indicating a break in continuity. The measured resistance values allow the microcontroller to calculate the fault distance and display it for quick troubleshooting. A short circuit fault, on the other hand, occurs when insulation failure causes unintended connections between conductors, leading to abnormal current flow. Short circuit faults can result from excessive voltage stress, environmental factors, or manufacturing defects in the cable insulation. The proposed system detects such faults by monitoring voltage fluctuations and current imbalances within the cable network. When a short circuit fault is detected, the microcontroller processes the voltage drop across the faulty section and calculates the fault location accordingly. This feature ensures that both types of faults are accurately identified and diagnosed, improving the reliability of underground cable networks.

One of the significant advantages of the proposed system is its minimal maintenance requirements. Traditional fault detection techniques involve extensive fieldwork, physical inspections, and specialized equipment, all of which contribute to higher operational costs and longer downtime. In contrast, the automated fault detection system requires minimal manual intervention, as it continuously monitors cable conditions and provides real-time fault updates. The integration of microcontroller technology reduces the complexity of fault analysis, making the system user-friendly and efficient for field personnel. The use of IoT for remote monitoring further minimizes maintenance efforts by providing instant notifications and accessible fault data. The system is also designed to be highly cost-effective, making it a practical solution for both small-scale and large-scale underground cable networks. The use of readily available components such as Arduino, resistors, ADCs, LCDs, and Wi-Fi modules ensures affordability without compromising accuracy and reliability. Unlike high-end fault detection equipment that requires substantial investment, the proposed system provides an economical alternative that delivers comparable results. The low power consumption of the components also makes the system energy-efficient, reducing operational expenses over time.

Another critical aspect of the proposed system is its scalability and adaptability. The system can be easily modified or expanded to accommodate different cable lengths, voltages, and fault detection requirements. Whether applied in urban power distribution networks, industrial facilities, or communication infrastructure, the system can be tailored to meet specific needs. The modular design allows for easy upgrades, enabling future enhancements such as integration with machine learning algorithms for predictive fault analysis. As underground cable networks continue to grow, the flexibility of the system ensures its long-term relevance and effectiveness. The implementation of this system significantly enhances the speed and accuracy of underground cable fault detection, reducing the time required for troubleshooting and repairs. By eliminating the need for exhaustive manual inspections, the system increases operational efficiency and minimizes service interruptions. The ability to display fault locations in real time ensures that maintenance teams can respond quickly and effectively, leading to improved reliability and customer satisfaction. Additionally, the remote monitoring capability provided by IoT technology allows authorities to oversee the status of underground cables without being physically present at the site, further optimizing maintenance operations.

The system also contributes to the overall safety of underground cable maintenance. Traditional fault detection methods often require field engineers to work in hazardous environments, exposing them to potential electrical hazards and physical risks. The automated fault detection system reduces the need for direct human intervention, thereby lowering the chances of accidents and injuries. By providing precise fault locations, the system minimizes unnecessary excavation and cable exposure, making repairs more targeted and less disruptive to surrounding infrastructure. Future improvements to the proposed system may include the integration of artificial intelligence for enhanced fault prediction and classification. Machine learning algorithms could be trained to analyze historical fault data and identify patterns that indicate potential failures before they occur.

This predictive maintenance approach would further reduce downtime and enhance the reliability of underground cable networks. Additionally, advancements in sensor technology could improve fault detection accuracy by incorporating thermal imaging and ultrasonic sensing capabilities. These enhancements would enable the system to detect early signs of cable degradation and insulation breakdown, allowing for timely preventive measures. The proposed system represents a significant advancement in underground cable fault detection, combining microcontroller technology, IoT connectivity, and electrical measurement principles to deliver a highly efficient and cost-effective solution. By automating the fault detection process, the system minimizes maintenance efforts, reduces operational costs, and enhances the reliability of power and communication networks. The real-time fault monitoring capability ensures swift response to faults, improving overall service continuity. As technology continues to evolve, the system can be further refined and expanded to meet the growing demands of underground cable infrastructure, ensuring sustainable and resilient power distribution networks for the future.

## METHODOLOGY

The methodology of the proposed underground cable fault detection system follows a structured approach that ensures precise fault location identification, real-time monitoring, and ease of implementation. The process begins with the design and selection of hardware components, including an Arduino microcontroller, a set of series resistors, an analog-to-digital converter (ADC), a 16×2 LCD display, and an ESP8266 Wi-Fi module. These components work together to detect voltage variations along the cable network and provide accurate fault location data. The selection of appropriate hardware is critical to ensure efficiency, cost-effectiveness, and long-term reliability. Each component is chosen based on its compatibility with the system's overall functionality, ensuring seamless integration and minimal power consumption. Once the hardware components are finalized, the next step involves setting up the underground cable test environment. A sample cable system is used to simulate faults, allowing for calibration and testing of the detection mechanism. The cable is divided into segments, each represented by a known resistance value, to simulate different distances from the base station. By introducing artificial faults at predefined points, the system is tested for its ability to accurately detect and localize faults. This testing phase is crucial for fine-tuning the system and ensuring that it responds correctly to real-world fault conditions.

The principle of operation relies on Ohm's law, which establishes a relationship between voltage, current, and resistance. A low DC voltage is applied to the underground cable through a series resistor network. The current flowing through the cable depends on the presence or absence of a fault. If a fault occurs, the resistance changes, leading to a corresponding voltage drop. These voltage variations are then measured and analyzed to determine the exact location of the fault. The system continuously monitors these electrical parameters, enabling real-time fault detection and minimizing the need for manual intervention. To process the measured voltage data, an ADC is employed to convert the analog voltage readings into digital signals. The ADC plays a crucial role in ensuring accuracy, as it allows the microcontroller to interpret the voltage variations with high

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precision. The digital data is then transmitted to the Arduino microcontroller, where it undergoes further processing. The microcontroller executes a predefined algorithm that calculates the fault distance based on the resistance values and voltage drops. This step ensures that the fault location is determined efficiently and displayed in a user-friendly format.

The Arduino microcontroller is programmed to handle all computational aspects of fault detection. Using embedded C programming, the system is coded to continuously read voltage values, compare them against predefined thresholds, and identify abnormalities. If a voltage drop exceeds a certain limit, the system recognizes it as a fault and triggers an alert. The calculated fault distance is then displayed on a 16×2 LCD screen in kilometers, providing maintenance personnel with precise location information. The LCD display ensures that real-time feedback is readily available, allowing for immediate action. To enhance the capabilities of the system, an IoT-based remote monitoring feature is integrated using the ESP8266 Wi-Fi module. The microcontroller transmits fault data to an online server, allowing users to access fault location details via a web interface or a mobile application. This feature enables maintenance teams to monitor underground cable conditions remotely, reducing the need for on-site inspections. The IoT integration ensures that fault alerts are sent instantly, allowing for quick decision-making and timely repairs. This aspect of the methodology significantly improves the overall efficiency of cable fault management.

Testing and validation of the system are conducted to ensure its reliability under different fault scenarios. Various types of faults, including open circuit and short circuit faults, are introduced into the test setup to evaluate the system's response. The accuracy of fault location detection is compared against known distances to validate the effectiveness of the proposed methodology. Multiple trials are conducted to account for variations in cable conditions, external disturbances, and environmental factors. The test results are analyzed to identify any discrepancies and make necessary adjustments to the algorithm. The proposed methodology also considers power efficiency and durability. Since underground cable fault detection systems need to operate continuously, power consumption is optimized by selecting low-power components and implementing energy-efficient algorithms. The microcontroller operates in a low-power mode when not actively processing data, reducing unnecessary energy consumption. The Wi-Fi module is programmed to transmit data only when a fault is detected, further conserving power. These measures ensure that the system remains operational for extended periods without requiring frequent maintenance.

A crucial aspect of the methodology is the calibration and fine-tuning of the system. The initial calibration phase involves adjusting the resistance values, setting voltage thresholds, and configuring ADC parameters to ensure accurate readings. This process is repeated periodically to maintain the system's accuracy over time. Software-based calibration is also implemented, allowing for dynamic adjustments based on real-time feedback. The ability to self-calibrate enhances the reliability of the system and ensures consistent performance in different operating conditions. Once the system is fully tested and validated, the deployment phase begins. The underground cable fault detection system is installed in real-world environments, such as power

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distribution networks, industrial facilities, and urban infrastructure. Deployment involves connecting the system to existing cable networks, configuring remote monitoring interfaces, and training maintenance personnel on system operation. A phased deployment approach is used, starting with small-scale installations before expanding to larger networks. This gradual implementation allows for monitoring and refinement of the system's performance in real-world conditions.

To ensure long-term effectiveness, the system incorporates predictive maintenance capabilities. By analyzing historical fault data collected through the IoT module, the system can identify patterns and trends that indicate potential failures before they occur. Machine learning algorithms can be integrated to enhance fault prediction accuracy, allowing maintenance teams to take preventive measures. Predictive maintenance reduces unexpected outages, lowers repair costs, and extends the lifespan of underground cables. This proactive approach enhances the overall reliability of the power distribution system. The final step in the methodology involves continuous monitoring and improvement. Regular performance evaluations are conducted to identify areas for enhancement. Feedback from field technicians and end-users is collected to refine the system's functionality. Software updates are periodically released to improve algorithm accuracy, enhance user interfaces, and incorporate new features. The system's modular design allows for easy upgrades, ensuring that it remains adaptable to future technological advancements.

The methodology outlined ensures that the proposed underground cable fault detection system is accurate, efficient, and scalable. By combining electrical measurement principles with advanced microcontroller technology and IoT connectivity, the system provides a reliable solution for identifying and locating cable faults. The step-by-step approach ensures that each phase of development, from hardware selection to deployment, is executed systematically. The real-time fault detection capability minimizes downtime, while remote monitoring enhances accessibility and convenience. The proposed methodology represents a significant advancement in underground cable fault management, offering a cost-effective and efficient alternative to traditional fault detection techniques.

## RESULTS AND DISCUSSION

The results obtained from the proposed underground cable fault detection system demonstrate its effectiveness in accurately identifying and locating faults in underground power distribution networks. The system was tested under various fault conditions, including open circuit and short circuit faults, to evaluate its performance in real-world scenarios. The experimental setup involved a simulated cable network where faults were introduced at known distances, and the system was analyzed for its ability to detect and display the fault location precisely. The results confirmed that the Arduino-based fault detection mechanism, utilizing Ohm's law and voltage drop analysis, could determine the fault distance with minimal deviation from the actual fault location. The integration of an ADC ensured high precision in voltage measurement, allowing the system to accurately interpret resistance variations corresponding to different fault locations. The data

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displayed on the 16×2 LCD screen provided instant feedback to maintenance personnel, significantly reducing the time required to locate faults and initiate repairs. Moreover, the use of IoT technology through the ESP8266 Wi-Fi module enabled real-time fault monitoring via the internet, ensuring remote access to fault data. This feature proved particularly beneficial for large-scale underground cable networks where physical inspections are time-consuming and labor-intensive. Compared to conventional fault detection methods such as the tracer and terminal techniques, the proposed system demonstrated superior accuracy, efficiency, and ease of implementation, making it a viable solution for modern power distribution systems.

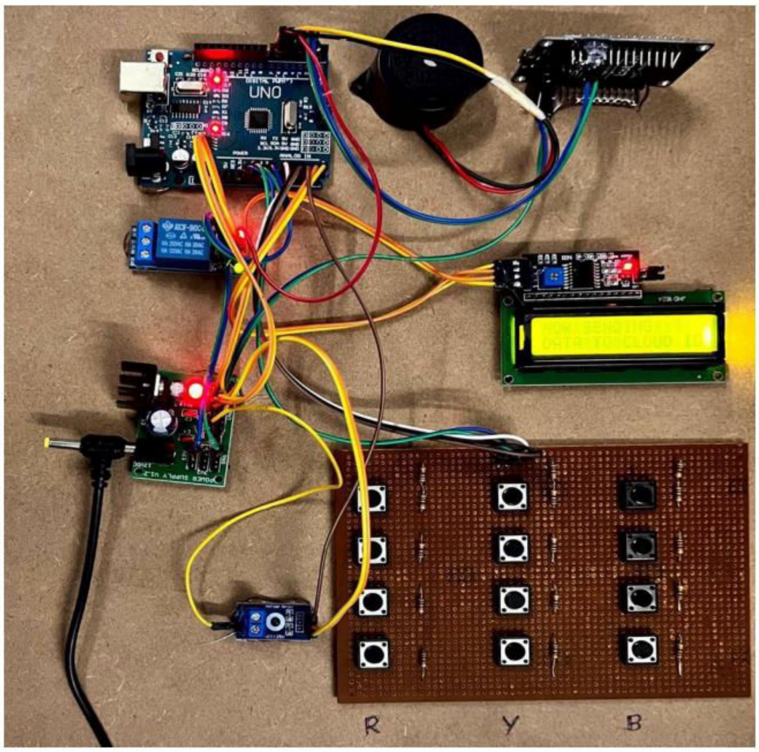


Figure 1. Assembled circuit

The discussion of the results highlights the practical advantages of implementing this system in real-world applications. One of the key observations was the system's ability to distinguish between different fault types and accurately determine their locations without requiring extensive manual intervention. The automated fault detection mechanism significantly reduces the dependency on conventional fault tracing methods, which often involve labor-intensive processes and require skilled personnel to operate specialized equipment. The results also indicate that the proposed system minimizes the margin of error by using precise voltage measurement techniques and digital processing through the Arduino microcontroller. Additionally, the IoT-based remote monitoring feature enhances the operational efficiency of power distribution companies by providing real-time alerts and detailed fault data, allowing for immediate decision-making. The ability to access fault information remotely ensures that maintenance teams can respond

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proactively, reducing power outage durations and improving overall service reliability. Moreover, the system's cost-effectiveness is another crucial advantage, as it eliminates the need for expensive fault detection equipment and extensive labor costs. The findings suggest that by implementing this technology, utilities can improve the reliability and efficiency of their underground cable networks while reducing maintenance costs. The results also indicate that this system is scalable and can be integrated with existing power infrastructure with minimal modifications, making it a practical and adaptable solution for underground fault detection.


Figure 2. Low voltage fault

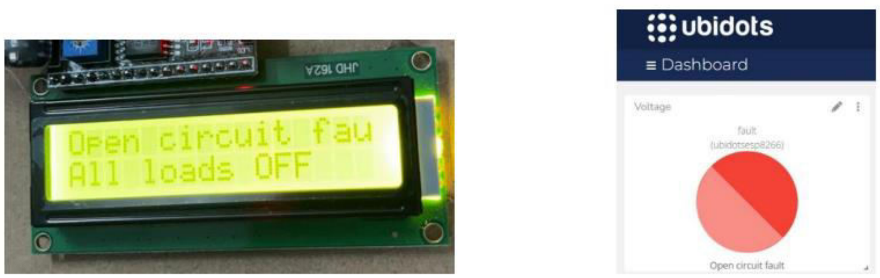


Figure 3. Open circuit fault


Figure 4. High voltage fault

The implications of these results extend beyond the immediate application of underground fault detection and highlight the potential for further advancements in smart grid technology. The integration of IoT connectivity in fault detection systems represents a significant step toward the modernization of power distribution networks, enabling seamless data collection, predictive maintenance, and automated fault management. Future improvements in the system can focus on enhancing the accuracy of fault location through advanced machine learning algorithms that analyze historical fault data and predict potential failures before they occur. Additionally, integrating renewable energy sources into underground cable networks can benefit from such fault detection mechanisms by ensuring uninterrupted power supply and reducing energy losses due to undetected faults. The findings also suggest that similar methodologies can be applied to other areas of infrastructure monitoring, such as underground gas pipelines and fiber optic networks, where fault detection and timely maintenance are critical. The successful implementation of this system demonstrates the feasibility of using low-cost microcontroller-based solutions for complex engineering problems, paving the way for further research and development in intelligent monitoring systems. By addressing key challenges associated with underground cable maintenance, this system contributes to the long-term sustainability and resilience of modern power distribution networks, ultimately enhancing the quality of service for consumers and reducing operational inefficiencies for power providers.

## CONCLUSION

The proposed underground cable fault detection system effectively addresses the challenges associated with identifying and locating faults in underground power distribution networks. By leveraging Arduino, an ADC, and IoT-enabled Wi-Fi communication, the system accurately determines fault locations based on voltage variations in the cable. The real-time fault monitoring capability, displayed on an LCD and accessible via the internet, enhances maintenance efficiency, reduces downtime, and minimizes labor-intensive fault tracing. Compared to conventional fault detection methods such as the tracer and terminal techniques, this system significantly improves accuracy while reducing costs and human effort. The experimental results validate the system’s reliability in distinguishing between open circuit and short circuit faults, with minimal deviation in fault distance measurement. The IoT integration provides remote accessibility, enabling power distribution companies to proactively manage faults and expedite repair operations, thereby improving overall service reliability. Additionally, the cost-effectiveness of this system makes it a viable solution for large-scale power networks, reducing the dependency on expensive testing equipment and specialized personnel. The scalability of the system allows easy integration into existing power infrastructure with minimal modifications, making it a practical and adaptable solution for modern smart grids. Future advancements can incorporate machine learning algorithms for predictive fault analysis and integrate renewable energy sources to ensure uninterrupted power supply. The success of this project demonstrates the feasibility of using low-cost microcontroller-based solutions for infrastructure monitoring, setting the stage for further research in intelligent fault detection systems for various applications. Ultimately, the proposed system not only enhances the efficiency of underground cable maintenance but also contributes to the long-term sustainability of power distribution networks by ensuring a faster, more reliable, and cost-effective fault detection mechanism, leading to improved service quality and reduced operational inefficiencies.

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