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CABLEGUARD: SMART IOT CABLE FAULT DETECTOR

Ranjeetsingh Suryawanshi, AIDS Department, Vishwakarma Institute of Technology.
Aditi Harale, AIDS Department, Vishwakarma Institute of Technology.
Ravindra Jadhav, AIDS Department. Vishwakarma Institute of Technology.
Sahil Jadhav, AIDS Department, Vishwakarma Institute of Technology.
Shreyash Jadhav, AIDS Department, Vishwakarma Institute of Technology.
Jainivas Anandhan, AIDS Department, Vishwakarma Institute of Technology.

ABSTRACT
The need for electricity is growing daily. We are coming up with a lot of solutions to fulfill the demand, but we also need to make sure that the consumer premises are always supplied with uninterrupted electricity. Compared to underground transmission systems, there are more interruptions in overhead transmission systems. There are many problems with overhead transmission including weather conditions, lack of insulation, and weight of wire. In an Underground transmission system the main problem is fault detection as cables are buried under the ground taking out the whole wire is not convenient. The fault detection system is not able to give the precise location of the fault which causes long interruptions in repairing that fault. To overcome these problems, we have proposed our research on an IoT-based system to locate the exact location of the fault in km and also provide remote monitoring. This model consists of IoT devices for measuring the distance of fault from the system, enabling real-time monitoring and data analytics. The results demonstrate an efficient and reliable solution for fault detection, allowing for rapid response and maintenance. This research addresses a critical issue in power distribution, contributing to improved service reliability and customer satisfaction.

Keywords:
Underground cable, Internet of Things (IoT), Fault detection, Fault location, Arduino Microcontroller

I. Introduction
Electricity is the lifeblood of modern society, powering our homes, industries, and technological advancements. In today's rapidly advancing technological landscape, the need for efficient and reliable infrastructure solutions is more crucial than ever. To ensure a reliable and uninterrupted supply of electrical energy, underground power cables have become an integral component of the electrical distribution network. They are inexpensive, low maintenance, and safe for the environment. They have lowered operational and maintenance expenses, such as the cost of storm repair. Furthermore, storm damage from wind is eliminated by buried lines. They are not vulnerable to flooding-related damage, which typically ruins and disrupts electric service. They increase public safety by ensuring that there are fewer brief disruptions caused by trees falling on electrical poles or wires. There is a significant decrease in life-wire contact injuries. This results in the removal of unsightly cables and poles from the streets, improving visibility for both vehicles and pedestrians [1].
Underground high-voltage cables are being employed more often to reduce the threat that environmental effects represent to extremely sensitive distribution networks. Despite these advantages, finding issues in underground cables may be a very difficult undertaking [2]. Therefore, it is imperative to create a particularly effective approach for identifying cable defects. The consequences of cable faults are not limited to mere inconvenience; they extend to environmental concerns, economic repercussions, and the overall stability of the power grid. Detecting and locating these faults swiftly and accurately is essential to minimize downtime, reduce operational costs, and ensure the longevity of the underground cable infrastructure. When a fault arises, the supply to the neighborhood is hampered and the power flow is diverted towards the problem. It turns out that the voltages are unstable. In electrical wires, prompt problem identification is crucial. Traditional methods like time

domain reflectometry (TDR) and acoustic methods have paved the way for more sophisticated approaches such as distributed temperature sensing (DTS) and online monitoring systems. These newer techniques offer real-time data analysis, allowing for quicker fault identification and localization. Despite these advancements, difficulties still exist, such as the complexity of subterranean habitats, the requirement for ongoing observation, and the processing of enormous volumes of data. A multidisciplinary strategy that combines technical knowledge with data science and machine learning methods is needed to address these issues [3]. It is feasible to create prediction models that may foresee probable problems based on past data trends by utilizing the capabilities of big data analytics and artificial intelligence.

This research paper embarks on a comprehensive exploration of underground cable fault detection, delving into state-of-the-art techniques while examining the challenges they face and proposing potential solutions [4]. It offers an in-depth analysis of existing approaches for fault detection in underground cables, shedding light on their strengths and limitations. Moreover, the paper underscores the urgent need for innovation in this domain, highlighting the transformative potential of emerging technologies such as data analytics and artificial intelligence in revolutionizing fault detection and localization.

As the reach of underground cable networks continues to expand, playing a pivotal role in electrical energy distribution, the imperative for more effective fault detection solutions grows more pronounced [5]. To address these challenges effectively and ensure the fault is located precisely we have proposed a system that locates the exact location of the fault in km and provides remote monitoring. This paper presents a novel model designed to address the challenges associated with detecting faults in underground cables. Our model integrates IoT devices capable of measuring the distance of faults from the system, enabling real-time monitoring and data analytics. This innovative approach not only enhances the efficiency of fault detection but also contributes to the overall reliability and resilience of underground power distribution networks. By synthesizing insights from the various papers, this research seeks to propel the field forward, paving the way for a more resilient and sustainable energy infrastructure.

II. Literature

The research paper authored by Roshani Shingrut, titled “Underground cable fault detection,” published in the IJERT journal in February 2020. The project is focused on detecting faults in underground cables. The project's goal is to locate the cable defect and measure its distance from it using a liquid crystal display (LCD). The paper discusses related work using IoT, Raspberry Pi, and Arduino for fault detection. The technology offers possible benefits including less maintenance and better efficiency and can discriminate between different sorts of cable failures, such as open circuit and short circuit faults [6].

The research paper authored by Jitesh Kumar, titled “A Paper on underground cable fault detector,” published in the JETIR journal in March 2019. The project focuses on detecting faults in underground power cables, especially high-voltage ones used in distribution networks. A system based on microcontrollers is employed to ascertain the separation between a cable malfunction and the base station. This method uses voltage variations brought on by short circuits to detect problems using Ohm's law. Components like GSM modules and voltage regulators are integrated in this project to enhance functionality, by making it a comprehensive solution for underground cable fault detection [7].

The research paper authored by Ashish Shinde, titled by “Underground Cable Fault Detection,” published in the IJARSCT journal in June 2021. It presents an underground cable fault locator using a 1-channel relay module that can handle high currents. The paper suggests a future enhancement involving capacitors in AC circuits to detect open circuit faults and improve fault location accuracy. The future scope includes improving aesthetics, increasing public acceptance, and enhancing the

protection against electromagnetic field radiation. It aims to reduce maintenance costs and improve reliability, public safety, and property values [8].
The research paper authored by S. Sharmillla, titled by "Analysis of Underground Cable Fault Distance Locator," was published in the 2017 IJSSET journal. It introduces an innovative IOT-based solution for the detection of faults in underground power cables, addressing a critical need in the power distribution infrastructure. The theory underlying the suggested system is Ohm's law, which explains the relationship between resistance, voltage, and current in an electrical circuit. The fault phase, distance, and time of occurrence can be shown by the system on a webpage. Future enhancements could extend the system's capabilities to detect open circuit faults and other fault types [9].
The research paper authored by Abhishek Navale, titled by "UNDERGROUND CABLE FAULT DETECTOR AND LOCATOR," presents an innovative model for locating faults in underground power cables using a microcontroller. The paper primarily focuses on short-circuit faults and how they impact the voltage drop across the cable, which varies according to the fault's location. To represent these variations, a set of resistors simulates cable length. The data collected is then processed by microcontroller, and the resulting calculations are displayed on an LCD screen [10].
The research paper authored by Kadam Dinesh, titled by "Precise Kilometer Calculation By Underground Cable Fault Detector," was published in the IJIRSET journal in April 2020. It discusses a method for detecting faults in underground electrical cable lines. This paper presents a field study at a live fault site to investigate the existing fault detection system used by the Maharashtra State Electricity Distribution (MSEB) board. The paper also highlights the drawbacks of the MSEB system, such as its bulk size, high voltage requirements, and associated costs. It explores different fault detection techniques for underground cable lines and identifies the limitations of the current systems [11].
The research paper authored by P. Anitha, titled by "Under Ground Cable Fault Detection Using Machine Learning Algorithm," found its place in the Journal of Research and Advancement in Electrical Engineering. The project is aimed at precisely determining the distance of underground cable faults from a base station in kilometers. The paper outlines the objectives, existing methods, block diagrams, advantages, and disadvantages of underground systems, as well as the working principle. As technology continues to advance, the system's capabilities may be further refined, making it an essential tool in the maintenance of underground cable systems [12].
The research paper authored by Gilbert Cheung, Yuan Tian, and Tobias Neier, titled by "Technics of Locating Underground Cable Faults inside Conduits," was published in the 2016 International Conference on Condition Monitoring and Diagnosis. It addresses the definition and challenges associated with cable faults in underground systems, emphasizing the diverse nature of faults that can impact cable performance. Any flaw, inconsistent behavior, weakness, or non-homogeneity that impairs cable functionality is referred to as a cable fault. Underground wires are frequently installed within PVC conduits or pipes in many different nations. The report draws attention to the growing challenge of accurately locating conduit defects. Despite these difficulties, the study examines a range of tools and methods that can be used to determine the precise position of subterranean cable faults within conduits [13].
The research paper authored by Wang, and Xiangyu, titled by "A Novel Method for Underground Cable Fault Detection and Location Based on Machine Learning and Improved Travelling Wave Analysis," published in the 2023 IEEE Access. It presents a new approach based on machine learning and enhanced traveling wave analysis for the detection and localization of underground cable faults. The proposed method utilizes a combination of support vector machine (SVM) and traveling wave analysis (TWA) to identify faults and determine their location. The experimental results demonstrate that the proposed method achieves high accuracy in detecting and locating faults [14].
The research paper authored by Zhang, and Lei, titled by "A Hybrid Fault Location Method for Underground Cable Based on Deep Learning and Particle Swarm Optimization," published in the 2023 IEEE Access. It provides a hybrid approach based on particle swarm optimization (PSO) and deep

learning for underground cable fault identification. The suggested approach uses a convolutional neural network (CNN) and particle swarm optimization (PSO) combination to identify errors and extract features from the time-series data. The experimental findings demonstrate that the suggested approach may accurately and efficiently discover flaws [15].
The research paper authored by Hu, and Jun, titled by "An Improved Fault Detection and Location Method for Underground Cables Based on Multi-Channel Time Domain Reflectometry," published in the 2023 IEEE Transactions on Power Delivery. It proposes an improved fault detection and location method for underground cables based on multi-channel time domain reflectometry (MTDR). The proposed method utilizes a combination of multi-channel sensors and an improved signal processing algorithm to enhance the accuracy of fault detection and location. The experimental findings show that the suggested approach finds and detects flaws in complex underground wire environments with excellent accuracy [16].
The research paper authored by Li, and Guoliang, titled by "A Fault Diagnosis and Location Method for Underground Cables Based on Improved Artificial Neural Network and Multi-Source Information Fusion," published in the 2023 IEEE Transactions on Smart Grid. It proposes an enhanced artificial neural network (ANN) and multi-source information fusion for the fault diagnosis and locating technique for subterranean cables presented in this research. To improve the accuracy of defect detection and location, the suggested solution combines particle swarm optimization (PSO), multi-source information fusion, and an upgraded artificial neural network (ANN). The outcomes of the experiment demonstrate that the suggested technique may accurately and successfully identify problems in subterranean cables [17].
The research paper authored by Ma, and Xiaodong, titled "A Research on Fault Detection and Location Technology for Underground Cables Based on Improved Pulse Current Method," published in the 2022 IEEE Transactions on Power Delivery. proposes an improved pulse current method for identifying and locating the fault in underground cables. The proposed method utilizes an improved pulse current signal and an enhanced signal processing algorithm to enhance the accuracy of fault detection and location. The results of the experiment show that the suggested technique finds and detects problems in underground cables with a high degree of precision [18].
The research paper authored by Emmanuel Gbenga Dada, Abdulkadir Hamidu Alkali, Stephen Bassi Joseph, and Umar Abba Sanda, titled “Design and Implementation of Underground Cable Fault Detector,” International Journal of Science and Engineering Investigations. It introduces a brand-new subterranean cable failure detection technology designed to overcome shortcomings in existing approaches. It describes the effects of electrical faults on cable resistance and voltage transmission, analyzes the shortcomings of current detection methods, and describes the steps involved in the proposed system's methodology, which includes resistance measurement and fault type identification. Tests showed good results in identifying flaws within a 2-kilometer range, but more investigation is required to confirm its practicality, scalability, and long-term durability [19].

3. Methodology

The implementation of the "CableGuard: Smart IoT Cable Fault Detection System" is a comprehensive solution that combines a range of hardware devices to address problems in fault detection and precise localization. The integration of sophisticated sensors and microcontrollers, backed by an IoT architecture, is the core of this system [20]. Key hardware components include the Arduino UNO microcontroller, 12 V Relay, 4007 Diode, ULN 2003, Slide Switch, and an LCD. The relay is used to control the power supply to the underground cable. The Arduino can trigger the relay to cut off power to the faulty portion of the cable when a fault is identified while, the 4007 Diode can be used in the circuitry of the power supply or signal processing unit to guarantee appropriate voltage levels and signal integrity.

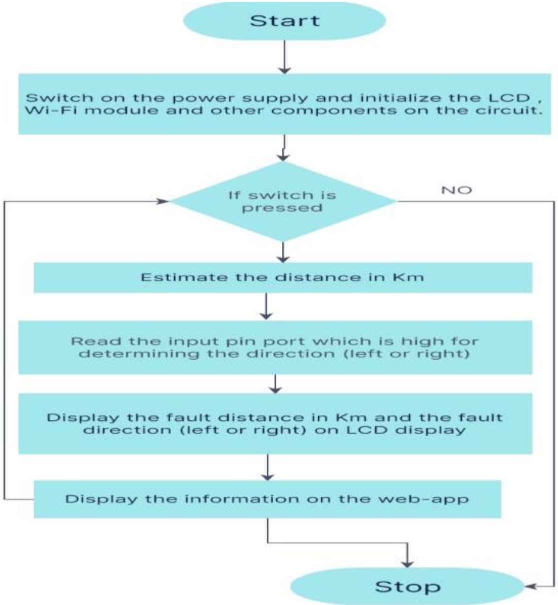

Fig. 1: Smart IoT Cable Fault Detector System Architecture

The architecture for a smart IoT cable fault detector represents a powerful tool for enhancing the reliability, safety, and efficiency of electrical systems. Its ability to detect, report, and analyze cable faults empowers businesses and organizations to minimize downtime, optimize maintenance procedures, and ensure a safe and uninterrupted flow of electricity.

The ability of this device to continually monitor the cable's voltage and current levels is its fundamental component. The system collects real-time data using advanced sensors and data-collecting systems, enabling accurate and proactive defect identification. The Arduino microcontroller instantly starts a notification procedure when a malfunction is found, whether it is a short circuit, deteriorating insulation, or another problem. The alert is quickly sent across secure channels and strong communication protocols to a distant server [21]. This smooth communication channel guarantees that maintenance staff members are quickly informed when a problem arises, allowing them to respond appropriately and quickly. The system efficiently minimizes the impact of problems, lowering downtime and associated costs, by permitting quick response and intervention.

A. Components used:

Arduino Uno: A prominent open-source microcontroller board for electronic project creation and prototyping, built around the ATmega328P.

16*2 LCD display: This type of liquid crystal display, which can show 16 characters in two lines, is frequently used in electronic projects to display text-based data.

12V 5-pin Relay: Electromagnetic switches that can control high-power devices using a low-power input, featuring five pins for various connections.

4007 Diode: General-purpose diodes are often used for rectification in electronic circuits to allow current flow in one direction.

ULN2003: A Darlington transistor array with high voltage and high current that is commonly used to power inductive loads like stepper motors and relays.

Slide Switch: A small switch that can be toggled by sliding a lever, used to control the flow of electric current in a circuit.

B. Ohm’s Law:

This system employs Ohm’s Law to identify short circuits. It is a fundamental principle in electrical engineering and physics that describes the relationship between voltage, current, and resistance in an electrical circuit.

Where,

V = Voltage (V)
I = Current Required (A)
R = Resistance (Ohm)

The feeder side receives a direct current (DC) voltage applied through a series resistor, and the cable problem is identified by measuring the difference in current caused by the distance. This method uses a variety of resistors to indicate the cable's length in kilometers. To ensure accuracy, fault modeling is accomplished by combining switches at predefined kilometer intervals [22]. An ADC converter receives the voltage drop across the feeding resistor and uses it to produce exact data. After interpreting this data, a specialized microcontroller interfaces with a 16*2 LCD to display the appropriate problem location in kilometers along with division and phase details. The low-level computing component or Embedded C program is baked into the microcontroller's ROM which is converted to DC with the use of a bridge rectifier. Waves are removed via a capacitive channel, and they are then brought to +5V by means of a voltage controller, which is necessary for the microcontroller and other components to function. When a fault occurs, the voltage drop will change based on how long the fault is in the line since current fluctuates.

C. Algorithm:

1. Include the library for LCD and initialize it. Define pin configuration for LDR sensor.
2. Define the setup() function to set up the Arduino board. Configure the digital output pins for the data pins of the LCD. Initialize the LCD and print a startup message on it. Initialize the serial monitor.
3. Define the loop() function. The code runs in a continuous loop to read sensor values and display messages on the LCD based on the readings. Check the resistor value and print corresponding messages on the LCD and serial monitor.
4. It checks the sensor value and prints messages on the LCD and serial monitor based on predefined ranges of resistor value using if-else conditional statements for each of the Red, Yellow, and Blue.

III. Conclusion

The "CableGuard: Underground Cable Fault Detection" System project marked a significant leap forward in the realm of electrical infrastructure management. Through rigorous testing and evaluation, the system has demonstrated remarkable efficiency in accurately identifying and localizing faults within the underground cable network. Comparative analysis with existing systems underscored substantial improvements, particularly in terms of fault detection accuracy and system versatility. However, challenges and limitations, including specific fault types and environmental conditions, were acknowledged. In conclusion, the project showcased a robust underground cable fault detection system with promising results, laying the groundwork for upcoming developments in the area.

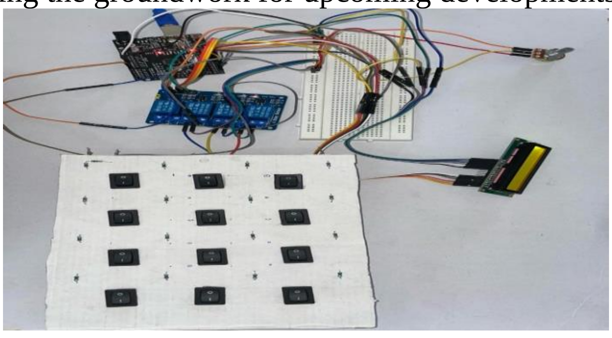

Fig. 2: Fault display with its location

Sr. No.	Features-> Papers	Localization	LCD Display	Short Circuit Fault Detection	Open Circuit
1.	Our Paper	✓	✓	✓	✓
2.	Intelligent Home Automation Using IOT	×	×	×	✓
3.	IOT based Home Automation	×	×	×	✓
4.	An internet of things based voice automated system for home appliances	×	×	✓	✓
5.	IOT based smart office Room automation using Wi fi technology	×	×	✓	✓
6.	Bluetooth Controlled Electronic Home Appliances System	✓	×	×	✓
7.	Internet of Things (IOT) based Home Automation System (HAS) Implementation of Real-Time Experiment	×	×	✓	✓
8.	IOT Big Data Techniques for Smart Home: A Study for Applicable in Small City at India	×	×	✓	✓

Fig. 3: Comparison of various Papers with our

proposed system

The project proves to be a significant breakthrough in the realm of electrical infrastructure management. Using extensive testing and comparison with current systems, the project demonstrated notable enhancements in fault detection precision and system adaptability. The subterranean cable network's faults may be precisely identified and localized thanks to the system's integration of state-of-the-art sensors and sophisticated fault detection algorithms. Although there were difficulties with particular fault kinds and environmental circumstances, the project's conclusions offer insightful information for improving the system's performance and resilience. The quick discovery of faults made possible by the system reduces downtime while simultaneously enhancing the general dependability and effectiveness of electrical networks. In the future, more research and development will be done to expand the capabilities of the system. This entails investigating developments in sensor technology, including predictive maintenance features, and refining fault detection algorithms. These developments will keep spurring innovation in the identification of faults in subterranean cables, guaranteeing a steady, secure, and uninterrupted supply of energy.

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