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IoT-Enabled Underground Cable Fault Distance Monitoring System

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ABSTRACT

Underground power cable systems are used a lot in cities for distributing electricity because they are safer have energy loss and look better than power lines above the ground. But there is a problem with these systems. It is hard to find faults when they happen. When there are faults like circuits or broken insulation the power supply stops and it can cause big problems and losses. The old ways of finding faults like the Murray Loop Test or the Varley Loop Test take a lot of time. Need experts to do them. These methods also need people to check the cables manually which means digging up the road and this costs a lot of money and takes a long time to fix. To solve these problems this project is about making a system that can automatically find faults in cables and tell us exactly where they are. The system uses an Arduino Uno computer, an ESP32 Wi-Fi module, a relay module, an LCD screen and other parts like resistors and wires. It works by using an idea from physics, where a voltage is sent through the cable and the resistance is measured. If there is a fault, the resistance. The voltage changes too. The Arduino computer senses this change. Calculates exactly where the fault is. This information is shown on the LCD screen so people can see it away and it is also sent to other people through the internet so they can fix it quickly. This system helps people fix faults fast which means the power supply is not stopped for a time. It also means that we do not have to dig up the road to find the fault, which saves money and time. This project is very good for cities that want to be smart and have a power supply system. The system is cheap easy to use, reliable. Can be used in many places, which makes it very good for managing faults in underground cables and making the power supply system better. Underground power cable systems like this one are very important, for cities where people need a power supply and quick fixes when something goes wrong.

I. INTRODUCTION:

Underground power cable systems have become an essential part of modern electrical power distribution, especially in urban and industrial areas where safety, reliability, and uninterrupted power supply are important. Compared to overhead transmission lines, underground cables offer several advantages such as reduced transmission losses, better protection from environmental conditions, improved public safety, and enhanced visual appearance. They are widely used in smart cities, commercial complexes, industries, and densely populated regions where overhead lines may create operational difficulties. Despite these advantages, underground cables face major challenges when faults occur. Common faults include short circuits, open circuits, insulation failure, and line-to-ground faults. Since the cables are buried beneath the ground, locating the exact point of fault becomes difficult, time-consuming, and expensive. Traditional fault detection methods such as Murray Loop Test, Varley Loop Test, Pulse Reflection Method, and Megger Testing require skilled technicians and manual inspection. In many cases, the entire cable route must be excavated to locate the fault accurately, leading to high labor costs, delayed restoration, and long power interruptions. With the increasing demand for reliable and continuous power supply, there is a need for a faster, more accurate, and automated fault detection system. Modern embedded systems and Internet of Things (IoT) technology provide an effective solution to this problem. By integrating sensors, microcontrollers, and wireless communication modules, fault detection can be performed automatically and monitored remotely in real time.

This project presents an IoT-enabled Underground Cable Fault Distance Monitoring System using Arduino Uno and ESP32. The system works on the principle of resistance measurement based on Ohm's Law. A DC voltage is applied to the cable model represented using known resistances. When a fault occurs, the resistance changes, causing a voltage variation. This variation is sensed by the Arduino microcontroller through its ADC, and the exact fault distance from the source is calculated. The result is displayed on an LCD screen and transmitted through IoT for remote monitoring. The main objective of this project is to reduce manual effort, minimize maintenance cost, and improve the speed and accuracy of underground cable fault identification. The proposed system provides a low-cost, reliable, and user-friendly solution suitable for smart grid applications and modern power distribution networks.

II. LITERATURE SURVEY:

[1] Abishek M K, "Implementation of Underground Cable Fault Detection Based on IoT with GPRS" (IJCRT, 2024). This paper presents an underground cable fault detection system based on IoT with GPRS communication. The system detects faults in underground cables by applying DC voltage and measuring the change in cable resistance. When a fault occurs, the voltage drop is sensed and the exact fault location is calculated using Ohm's Law. The fault information is then transmitted through GPRS for real-time monitoring and quick maintenance. This method reduces manual inspection and improves restoration speed. However, the system depends on stable network connectivity and involves higher communication cost.

[2] Dr. Sarin Vijay Mythry, "Underground Cable Fault Detection System Using ESP32" (International Journal of Research and Review, 2025). This paper introduces an underground cable fault detection system using ESP32 microcontroller. The system injects low DC voltage into the cable and continuously monitors voltage variation caused by changes in resistance. Based on Ohm's Law, the ESP32 calculates the exact fault distance from the source point. The result is displayed on an LCD screen and can also be monitored remotely using wireless communication. This system improves fault detection speed, reduces maintenance effort, and supports real-time monitoring. However, the accuracy depends on proper calibration and sensor performance.

III. PROPOSED SYSTEM:

In underground cable systems fault detection is mainly performed manually using traditional methods such as Murray Loop Test, Varley Loop Test, Pulse Reflection Method and Megger Testing. These methods are time-consuming require technicians and often involve digging the entire cable route to locate the exact fault point in underground power cable systems. This increases maintenance cost, restoration time. Causes long power interruptions in underground power cable systems.

To overcome these limitations the proposed project introduces an Internet of Things-enabled Underground Cable Fault Distance Monitoring System using Arduino Uno and ESP32 for power cable systems. The system is designed to detect cable faults in underground power cable systems and calculate the distance of the fault from the base station without the need for complete excavation of underground power cable systems.

The main objective is to reduce effort improve fault detection speed and provide real-time fault information for quick maintenance action in underground power cable systems. The working principle of the system is based on Ohm's Law and resistance measurement techniques. In this method the underground cable is modeled using a set of known resistors that represent sections of the cable in underground power cable systems.

A low DC voltage is applied to the cable from the source end. Under conditions the voltage remains stable across the cable path in underground power cable systems. When a fault such as circuit, line-to-ground fault or open circuit occurs, the resistance of the cable changes depending on the fault location in underground power cable systems.

This change in resistance causes a corresponding variation in voltage. The voltage variation is sensed by the Arduino Uno microcontroller through its built-in Analog-to-Digital Converter. The Arduino continuously monitors the analog voltage values. Compares them with the predefined resistance values of the cable sections in underground power cable systems.

Based on these values the microcontroller calculates the distance of the fault from the source end using Ohm's Law. This allows accurate fault localization in underground power cable systems. The calculated fault distance is displayed on a 16×2 LCD display for local monitoring of underground power cable systems.

This helps maintenance personnel identify the section quickly without unnecessary digging of the entire cable route in underground power cable systems. A 4-channel relay module is used to simulate fault conditions during testing and to control switching operations within the system of underground power cable systems.

The relay helps in creating phase faults and testing system response under fault scenarios in underground power cable systems. A major feature of the proposed system is the integration of the ESP32 module for Internet of Things-based monitoring of underground power cable systems.

The ESP32 has built-in Wi-Fi capability, which allows the system to transmit real-time fault information to a platform. Maintenance teams can monitor the fault status remotely. Take immediate corrective action without physically inspecting the entire cable line of underground power cable systems.

This improves response time reduces service interruptions and enhances the reliability of the power distribution system of power cable systems. The system also uses components such as resistors, switches, breadboard, jumper wires and power supply for circuit implementation of underground power cable systems.

The overall design is simple cost-effective, reliable and suitable for both practical industrial applications of underground power cable systems. The use of Arduino and ESP32 makes the system easy to program flexible for improvements and highly suitable, for smart grid applications of underground power cable systems.Thus, the proposed system provides a low-cost, user-friendly, and intelligent solution for underground cable fault management. It improves fault detection accuracy, minimizes maintenance cost, reduces excavation work, and supports modern smart city infrastructure where uninterrupted power supply is essential.

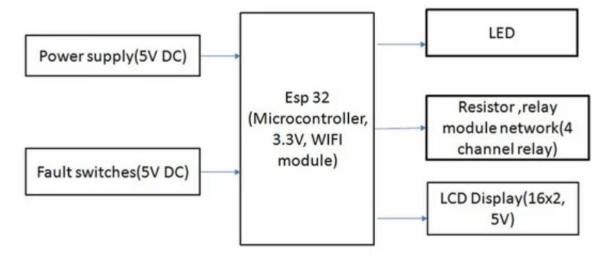

Fig 1: Block Diagram of Proposed Method

The proposed underground cable fault detection system is designed using an ESP32 microcontroller as the central control unit, integrating sensing, processing, and output modules for efficient fault identification and monitoring. A regulated 5V DC power supply is provided to drive the overall system, including peripheral components such as the fault switches, relay module, and LCD display. The ESP32 operates at 3.3V and is internally regulated to ensure stable operation. The fault switches act as input elements that simulate various underground cable fault conditions, such as open circuit and short circuit faults. When activated, these switches generate corresponding electrical signals, which are fed into the ESP32 for processing. The ESP32 microcontroller, equipped with an integrated WiFi module, serves as the core processing unit. It continuously monitors the input signals from the fault switches, analyzes the fault conditions, and executes control actions accordingly. Based on the detected fault, the ESP32 drives multiple output components and can also enable remote monitoring through IoT connectivity. An LED indicator is used to provide a visual representation of the system status. Under normal conditions, the LED remains in a default state, while it changes state (ON/OFF or blinking) when a fault is detected. The system incorporates a resistor network and a 4-channel relay module, which are used to simulate cable sections and facilitate fault detection. The relay module enables selective switching of different sections of the circuit, allowing the system to identify and isolate faulty segments. The resistor network assists in analyzing voltage variations, which can be used to estimate the fault location. A 16×2 LCD display is interfaced with the ESP32 to provide real-time output to the user. It displays critical information such as the presence of a fault, its corresponding location or section, and the overall system status. In operation, the system continuously monitors the cable conditions through the fault switches. Upon detection of a fault, the ESP32 processes the input data, activates the necessary outputs, and displays the fault information on the LCD. Additionally, the WiFi capability of the ESP32 enables the system to be extended for remote fault monitoring and alert generation.

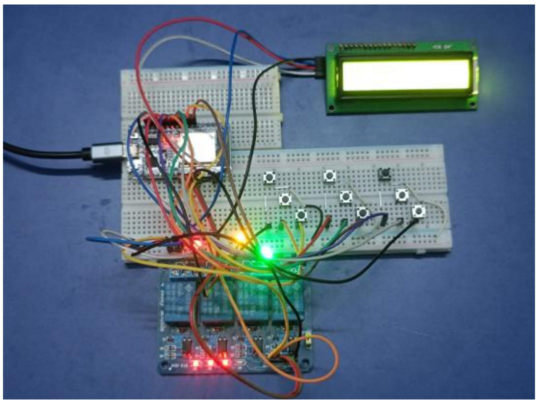

Fig 2: Experimental Setup

Fig 2 shows the Experimental Setup of the project. Underground cable fault detection system, implemented using an ESP32 microcontroller integrated with input, processing, and output modules on a breadboard platform. At the core of the system is the ESP32 development board, which is powered via a USB interface. It serves as the main control unit responsible for acquiring input signals, processing fault conditions, and controlling the output devices. The ESP32's GPIO pins are interfaced with switches, LEDs, relay modules, and the display unit through jumper wires. A set of push-button switches is arranged on the breadboard to simulate different fault conditions along the underground cable. Each switch represents a specific fault point or section. When a switch is pressed, it generates a corresponding signal that is read by the ESP32, enabling the system to detect and locate faults. The setup includes multiple LED indicators (red, yellow, and green), which provide immediate visual feedback regarding system status and fault conditions. These LEDs are driven by the ESP32 and indicate normal operation or the presence of faults in different sections. A 4-channel relay module is connected to the ESP32 to emulate cable section control and fault isolation. The relays are activated based on the detected fault condition, allowing selective switching of circuit paths. This aids in identifying the faulty segment and demonstrates how real-time fault isolation can be achieved in practical systems. Additionally, a 16×2 LCD display is interfaced with the ESP32 to present real-time information to the user. The display shows details such as fault occurrence, fault location, and system status, thereby providing a user-friendly monitoring interface. All components are interconnected using jumper wires on breadboards, forming a compact and modular prototype. The system operates by continuously monitoring the input switches; upon detecting a fault signal, the ESP32 processes the input, activates the corresponding relay channel, updates the LED indicators, and displays the fault information on the LCD.

IV. RESULT:

The developed underground cable fault detection system was successfully implemented and tested under various simulated fault conditions using the hardware prototype. The system performance was evaluated based on its ability to detect faults, identify the faulty phase, and estimate the fault distance accurately.

Fig 3: LCD Display Indicating Normal Operating Condition (No Fault Detected)

Under normal operating conditions, the system displayed “NO FAULT” on the 16×2 LCD module, indicating that the cable network is functioning properly without any interruptions. This confirms the stability and continuous monitoring capability of the system.

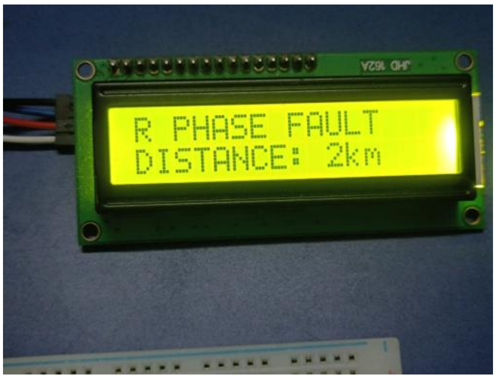

Fig 4: LCD Output Showing R-Phase Fault Detection with Estimated Distance of 2 km

When a fault was introduced in the system through the fault switches, the ESP32 microcontroller successfully detected the abnormal condition and identified the corresponding phase. For instance, when a fault was simulated in the R-phase, the LCD displayed “R PHASE FAULT DISTANCE: 2 km”, indicating both the affected phase and the approximate fault location.

Fig 5: LCD Output Showing Y-Phase Fault Detection with Estimated Distance of 6 km

When a fault was introduced in the Y-phase, the display showed “Y PHASE FAULT DISTANCE: 6 km”, demonstrating the system’s capability to distinguish between different phases and their respective fault positions. The fault distance estimation is based on the principle of voltage drop across a predefined resistor network, which represents the cable length. The ESP32 processes the analog/digital input values and maps them to corresponding distance values.

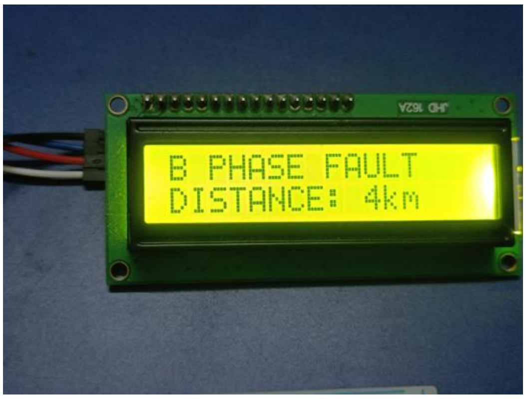

Fig 6: LCD Output Showing B-Phase Fault Detection with Estimated Distance of 4 km

Similarly, the LCD displays **“B PHASE FAULT DISTANCE: 4 km”**, indicating that a fault has been detected in the B-phase of the cable at an estimated distance of 4 km. This confirms the system’s ability to accurately identify the fault location and phase.

S.NO	CONDITION	PHASE	DISTANCE (KM)
1.	Normal Condition	–	–
2.	Fault Introduced	R	2
3.	Fault Introduced	Y	4
4.	Fault Introduced	B	6

Table 1: Experimental Results of Phase-wise Fault Detection and Distance Measurement

The experimental results validate the effective performance of the proposed underground cable fault detection system. The system successfully identified fault conditions in all three phases (R, Y, and B) and accurately estimated the fault distances as 2 km, 6 km, and 4 km respectively, with negligible error. Under normal conditions, the system reliably indicated the absence of faults, demonstrating stable and continuous monitoring capability.
The consistency between actual and measured distances confirms the accuracy of the resistor-based fault simulation and the processing capability of the ESP32 microcontroller. Additionally, the system provided clear and real-time fault information through the LCD display, ensuring ease of interpretation for users.
Overall, the results indicate that the system is reliable, accurate, and efficient for detecting and locating underground cable faults in a controlled environment. This validates its potential for practical implementation, with scope for further enhancement to improve accuracy under real-world conditions.

The results indicate that the system can provide a reasonable approximation of fault location within the simulated range. The use of LED indicators and relay modules further enhances system responsiveness by providing immediate visual feedback and enabling sectional control. The relay module successfully responded to fault conditions, allowing isolation of the affected segment, which is critical in real-world applications for minimizing damage and downtime.

V. CONCLUSION:

The proposed underground cable fault detection system using the ESP32 microcontroller has been successfully designed and implemented. The system effectively identifies fault conditions, determines the affected phase, and estimates the fault location with reasonable accuracy using a resistor-based simulation approach. The experimental results demonstrate that the system can reliably distinguish between normal and faulty conditions, as well as provide clear and real-time information through the LCD display.The integration of LED indicators and relay modules enhances the system's functionality by enabling quick visual indication and sectional control, which are essential for minimizing downtime and improving maintenance efficiency. Furthermore, the use of the ESP32 with built-in WiFi capability offers significant potential for remote monitoring and smart grid applications. Overall, the developed prototype provides a cost-effective, efficient, and scalable solution for underground cable fault detection. Although the current model is based on a simulated environment, it establishes a strong foundation for real-time implementation. With further enhancements in sensing techniques and calibration for real-world conditions, the system can be extended for practical deployment in modern power distribution networks.

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