IOT Based Underground Cable Fault Detection

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Abstract— The Underground power cables are a vital component of modern electrical distribution systems due to their improved safety, reliability, and aesthetic advantages over overhead lines. During continuous power transmission, these cables are exposed to faults such as short circuits, open circuits, and insulation failures caused by aging, moisture, or physical damage. Such faults can interrupt power supply and lead to increased maintenance costs and safety risks. Traditional fault detection methods rely on manual testing and excavation, which are time-consuming and unsuitable for quick fault localization. The Arduino-Based Underground Cable Fault Detection System provides an efficient solution by continuously monitoring electrical parameters such as voltage, current, and resistance. The system detects abnormal conditions, identifies the type of fault, and calculates the distance to the fault location using Ohm's Law. The fault distance is displayed on an LCD, enabling faster repair and reduced downtime. This system assists power utilities and maintenance engineers in quickly locating underground cable faults, reducing outage duration, and improving operational efficiency. By minimizing manual intervention and enhancing safety, the proposed system ensures reliable power distribution and effective infrastructure management. .

Index Terms: Underground cable Fault Detection, Voltage Regulator, Relay, Resistor, Capacitor, Diode, Arduino, WI-FI Module, IC, IC Socket, Lead-Acid Battery, and LCD Display.

I. INTRODUCTION

In modern power distribution systems, ensuring the reliability and safety of electrical supply is crucial, especially in densely populated urban areas. Traditionally, power transmission has relied on overhead cables, which are relatively easy to install and maintain. One of the key advantages of overhead lines is the ease of identifying and repairing faults through visual inspection. However, in crowded cities and metropolitan areas, overhead lines are not practical due to space limitations, aesthetic concerns, and safety risks. As a result, there has been a significant shift toward the use of underground cables for power transmission and distribution. Underground cables offer several advantages, including protection from environmental factors such as rain, wind, snow, and lightning. They also provide better safety, durability, and minimal visual impact, making them ideal for modern infrastructure. However, a major drawback of underground cable systems is the difficulty in detecting and locating faults. Since these cables are buried beneath the ground, visual inspection is not possible, and identifying the fault location often requires complex equipment or extensive manual digging, leading to delays and increased maintenance costs. A fault in an underground cable refers to any condition that alters the normal path of current or disrupts the performance of the cable. These faults can be caused by various factors such as insulation failure, moisture ingress, rodent damage, aging, or accidental damage during construction activities. Detecting the precise location of such faults is essential to minimize service interruptions and repair time. The objective of this project is to develop a system that can accurately detect the location of a fault in an underground cable and display the distance from the base station in kilometers using an Arduino microcontroller. The system uses fundamental electrical principles, particularly Ohm's Law, to measure the voltage drop across known resistances to calculate the distance to the fault. Key components of the system include the Arduino board, sensors for monitoring voltage and current, and an LCD display for real-time feedback. This model simulates different cable fault scenarios using a resistor network and manually operated fault switches. The real-time detection capability greatly reduces the time and effort needed to locate faults, especially in complex underground networks. By automating the fault detection process, the system enhances the overall efficiency of cable maintenance, reduces downtime, and improves service reliability for power distribution authorities.

II. MATERIALS AND METHODS

The proposed system aims to detect and display the location of faults in underground power cables using basic electronic components and a microcontroller. The methodology is divided into several theoretical stages, explained below:

A. Fault Sensing Circuit

Fault Sensing Circuit A fault sensing circuit is developed using interconnected switches connected along a test cable. These switches are placed at known intervals and can be manually operated to simulate faults such as open circuits or short circuits. This helps to test how the system detects and responds to faults at specific distances.

B. Principle of Resistance-Based Fault Location

The system etermines the location of the fault based on the concept that the resistance of a cable increases with its length. When a fault occurs, the voltage drop across the cable changes due to the change in resistance. By measuring this change, the system can estimate how far the fault is from the base station. This principle forms the basis for fault location detection.

3. Analog to Digital Conversion

The analog voltage measured from the sensing circuit is converted into a digital signal using an Analog to Digital Converter (ADC). This step is necessary because the microcontroller (Arduino UNO) processes only digital signals.

4. Arduino UNO Microcontroller
The Arduino UNO receives the digital data and uses a pre-programmed logic to determine the fault distance. The system is calibrated so that specific voltage values correspond to specific distances along the cable. Arduino processes this input and converts it into readable fault location data.
5. LCD Display Module
A LCD display is used to show the fault distance in real-time. This makes it easy for the user to see where the fault has occurred without any manual calculation or external equipment.
6. Real-Time Monitoring and Reset Functionality
The system is capable of real-time monitoring and can be reset to perform continuous or multiple tests. It is user-friendly, portable, and can be used in educational demonstrations, small-scale power systems, or experimental setups.

B. Hardware Components

Arduino UNO: The Arduino UNO is a versatile and accessible micro controller board that serves as an ideal platform for learning and prototyping electronic projects. Its combination of simplicity, functionality, and a robust community ecosystem makes it an essential tool for hobby its,educators, and professionals alike.

Micro-controller: The Arduino UNO is based on the ATmega328P micro controller, which is an8- bit AVRRISC-based micro controller. It features 32 KB of flash memory for storing code, 2 KBof SRAM, and1KB of EEPROM.

Power Supply: The board can be powered via a USB connection or an external power supply (7- 12V). Ithasabuilt-in voltage regulator to provide a stable 5V output for connected components.

Input/Output Pins: The UNO features 14 digital input/output pins, of which 6 can be used for PWM(PulseWidthModulation) output. It also has 6 analog input pins for reading varying voltage levels.

Communication: It supports various communication protocols, including UART (serial communication), I2C, andSPI. The board is equipped with a USB connection for easy programming and serial communication with a computer. Programming: The Arduino UNO is programmed using the Arduino Integrated Development Environment(IDE), which supports a simplified version of C/C++. This user-friendly interface allows users to write, compile, and upload code to the board easily.

LED Indicators: The board includes a built-in LED on pin 13 for testing and debugging purposes, aswellaspower and status indicators. The Arduino UNO is a versatile and accessible micro controller board that serves as an ideal platform for learning and prototyping electronic projects. Its combinationof simplicity, functionality, and a robust community ecosystem makes it an essential tool for hobby ists,educators, and professionals alike.

LCD Display: Liquid Crystal Display (LCD) is a type of flat-panel display technology that uses liquid crystals sandwiched between two layers of glass or plastic. LCDs are widely used in devices such as monitors, TVs, smartphones, and more. They work by applying an electric current to control the alignment of liquid crystals, determining the passage of light and thus creating images.
LCDs offer thin, energy-efficient displays with good image quality. An LCD16x2displayisacommon type of liquid crystal display module featuring 16 characters per lineand2lines.These displays are widely used in electronic projects and devices due to their simplicity, affordability, and ease of interfacing with micro-controllers. Each character position on the display can be individually controlled, allowing for the presentation of alpha numeric characters, symbols, and custom graphics.

Push Button: Push Button A Push Button switch is a type of switch which consists of a simple electric mechanism or air switch mechanism to turn something on or off. Depending on model they could operate with momentary or latching action function. The button itself is usually constructed of astrong durable material such as metal or plastic.

Relay: A relay is an electrically operated switch. Many relays use an electromagnet to mechanically operate a switch, but other operating principles are also used, such as solid-state relays. Relaysare used where it is necessary to control a 3 circuit by a separate low-power signal, orwhereseveral circuits must be controlled by one signal. The first relays were used in long distance tlegraph circuits as amplifiers: they repeated the signal coming in from one circuit and re-transmitted it on another circuit.

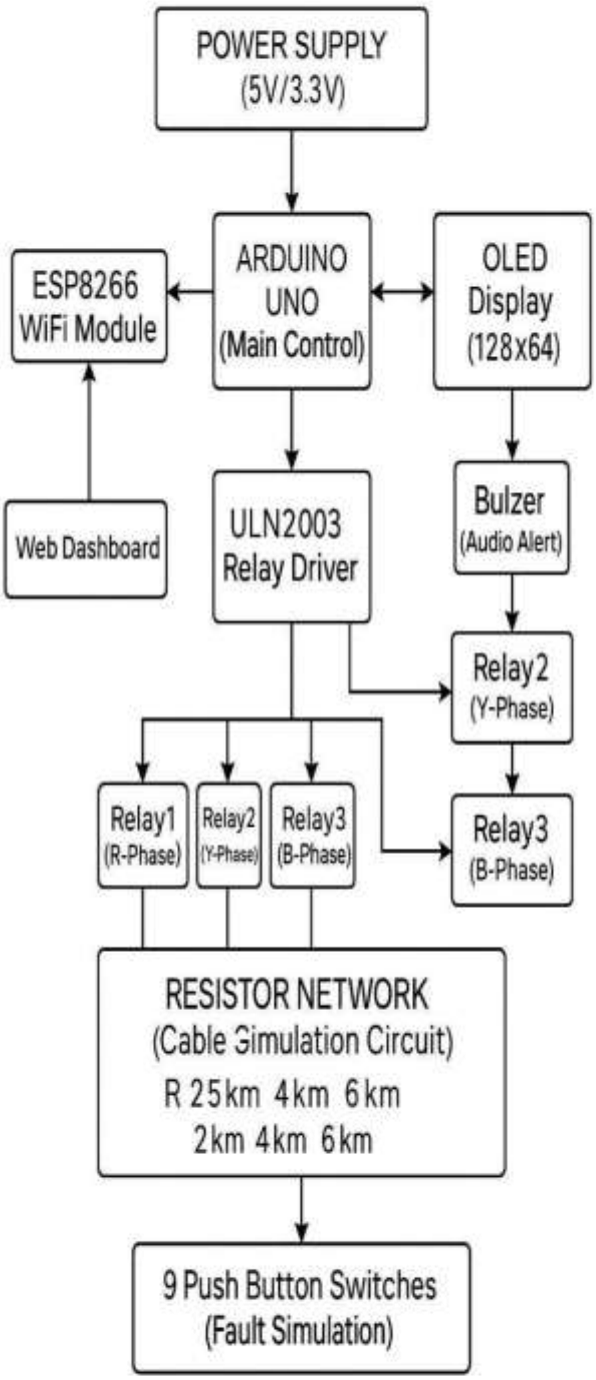
10k Variable Resistor
Potentiometer A variable resistor is a resistor of which the electric resistance value can be adjusted. A variable resistor is in essence an electro-mechanical transducer and normally works by sliding acontact(wiper) over a resistive element.

Power Supply: Power Supply A 12V adapter, also known as a 12V power supply or 12V DC adapter, is a device that converts AC (alternating current) voltage from a mains power outlet into DC (direct current) voltageof12 volts. These adapters are commonly used to power electronic devices and equipment that require a 12V power source, such as routers, LED lights, CCTV cameras, and small appliances.The adapter typically consists of a transformer, rectifier, and voltage regulator circuitry enclosed in a plastic or metal housing.

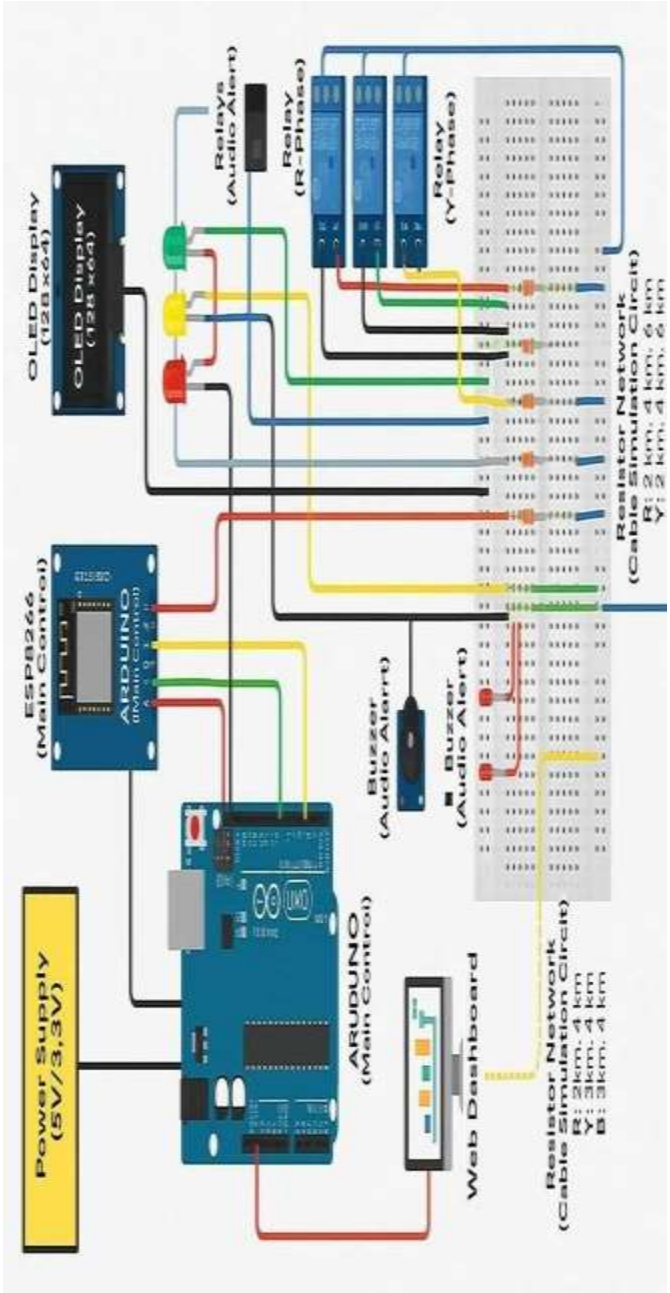
100R Resistor :16A 100R resistor is a fundamental component in electronics that provides the exact resistance needed for circuits to work smoothly. It controls the flow of electricity, makes voltage division easier, and helps weaken signal.

LED An LED (light-emitting diode) is a semiconductor device that emits light when an electrical current passes through an LED, electrons in the semiconductor recombine with electron holes, releasing energy in the form of photons. The color of the light depends on the energy required for electrons to cross the band gap of the semiconductor.

System Architecture



SIMULATION MODEL(CERCUIT DIAGRAM)

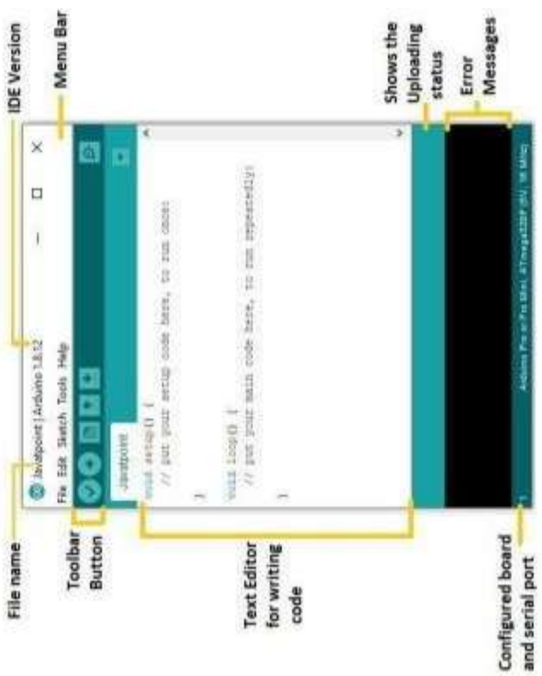


The Arduino code that is supplied is intended for a project that detects faults in underground cables. The code establishes pin connections for three relays (relay1, relay2, relay3), a buzzer, and an analog sensor (A0). It also uses the Liquid- Crystal library to drive a 16×2LCDdisplay.The analog sensor reading and the computed distance are stored in two global variables, read ADC and distance, respectively. An arrow-like custom symbol is made for the LCD display. Pin modes are configured and a custom LCD character is formed in the set up function. An introductory message appears on the LCD. The primary logic is continually carried out via the loop function.

Sequential relay activation is done, and an LCD with arrows indicating the direction of the cable defect are displayed. The software computes the distance, reads data from the analog sensor, and shows the result on the LCD. In the event that a defect is found, the buzzer sounds momentarily. Three simulated cable portions are cycled through while the pattern repeats. The data function is in charge of reading the analog sensor, figuring out how far something is, and sounding the buzzer when a problem is found. Through the LCD and buzzer, the software simulates the identification of problems in various parts of an underground wire, offering both visible and aural feedback. The entire dependability of subterranean cable systems is increased by this approach, which makes it possible to evaluate cable sections for any problems in a methodical and sequential manner.

SOFTWARE COMPONENTS DESCRIPTION

Arduino IDE
Program in c embedded system
Software = Arduino IDE
The Arduino Integrated Development Environment - or Arduino Software (IDE) – contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino hardware to upload programs and communicate with them. The Arduino IDE is an open-source software, which is used to write and upload code to the Arduino boards. The IDE application is suitable for different operating systems such as Windows, Mac OS X, and Linux. It supports the programming languages C and C++. Here, IDE stands for Integrated Development Environment. The program or code written in the Arduino IDE is often called as sketching. We need to connect the Arduino board with the IDE to upload the sketch written in the Arduino IDEsoftware. The sketch is saved with the extension '.ino.'



Objective: The goal is to locate faults in underground electrical cables accurately. Traditional fault detection methods can be challenging due to the lack of visibility in underground systems.

System Overview: The proposed system uses an Arduino micro controller kit. It also requires a rectified power supply. Key components include current sensing circuits, switches, relays, and a 16x2 LCD display.

How It Works: These circuits use a combination of-resistors to sense current flow. The voltage across these resistors changes when a fault occurs (e.g., a short circuit). The altered voltage is fed to an analog-to-digital converter (ADC).

Arduino Micro-controller: The Arduino reads the analog voltage from the current sensing circuits. It processes this data to determine the cable length (in kilometers) from the base station tot he fault location. The microcontroller then displays this information on the 16x2 LCD screen.

Fault Creation and Detection: Faults (e.g., short circuits) are simulated using a set of switches. When a fault occurs, the system detects the change in voltage and calculates the fault distance.

ADVANTAGES

Based on your design, the advantages would be:

Real-time monitoring: Voltage and current sensors continuously track parameters, allowing immediate detection of faults such as over- voltage, under-voltage, or overloading. **Automation:** The system reduces reliance on manual inspection and periodic checks, saving time and effort. **Reduced downtime:** Quick fault detection enables faster maintenance response, minimizing service interruptions. **Improved safety**: Early identification of abnormal electrical conditions helps prevent hazards for equipment and personnel. **Efficiency in management:** Streamlined monitoring and detection improve overall reliability of the electrical network.

APPLICATIONS

Power Distribution Networks Used in low- voltage and medium-voltage underground cables to quickly detect faults and maintain uninterrupted electricity supply.

Industrial Plants & Automation Factories and manufacturing units rely on underground cables for power and control signals. Early fault detection minimizes downtime and ensures worker safety.

Smart Cities Infrastructure Supports underground cabling for smart lighting, traffic systems, and IoT devices. Fault detection ensures smooth operation of city services.

Telecommunication Networks Fiber optic and copper cables run underground for internet and phone services. Detecting faults early reduces service disruptions.

Transportation Systems Railway signaling, metro networks, and traffic control systems often depend on underground cables. Fault detection keeps these systems reliable and safe.

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Oil & Gas / Utility Pipelines (if integrated with sensors) Can be adapted to monitor underground utility lines, preventing hazards and ensuring continuous operation.

Future Scope:

- Detection of more fault types Current systems mainly focus on short-circuit faults. Future versions could identify partial discharge, insulation degradation, and overheating, enabling preventive maintenance before major failures occur.
- Predictive maintenance By analyzing historical data with machine learning, the system could predict potential faults and optimize resource allocation, preventing outages before they happen.
- Cybersecurity enhancements As IoT systems expand, future designs will likely include advanced encryption and access control to protect sensitive data from cyber-attacks.
- Integration with renewable energy and smart grids Future systems may combine fault detection with IoT-based grid management and renewable energy sources, creating a more sustainable and resilient power infrastructure.
- Scalability and modularity Design the system to be easily expandable, so it can cover larger cable networks or integrate with other monitoring systems.

CONCLUSION:

Online monitoring systems improve the reliability of power distribution by enabling real-time fault detection and analysis. This proactive approach minimizes downtime and enhances the overall stability of electrical networks.
Continuous data collection and analysis facilitate decision-making informed regarding maintenance schedules and cable replacements. This predictive maintenance approach optimizes resource allocation and extends the life span of the infrastructure.
By identifying faults quickly, online monitoring enhances safety for both personnel and the public, reducing the risk of hazardous situations caused by cable failures.
While the initial investment in monitoring technology may be significant, the long-term savings achieved through reduced outages, lower maintenance costs, and improved asset management make it a cost-effective solution.
Ongoing advancements in sensor technology and data analytic's promise to further enhance the effectiveness of online monitoring systems, making the mevenmoreintegral to modern electrical infrastructure management.
In conclusion, online monitoring and fault detection in UG cables represent acritical advancement in ensuring the reliability, safety, and efficiency of power distribution systems. As technology evolves, these systems will continue to play a vital role in addressing the challenges associated with aging infrastructure and increasin genergy demands.

system analyzes and classifies the user's cardiac status into normal or abnormal categories. The developed system offers a reliable method for monitoring heart health, especially for sports professionals who undergo high-intensity physical activities. Athletes are often at risk of unnoticed cardiac abnormalities, which can escalate if not detected early. The implemented model provides an early warning mechanism that helps in preventing severe health issues during training sessions. With its simple user interface, the system ensures smooth operation and encourages frequent usage. The integration of AI algorithms enhances the accuracy of predictions, making it a useful tool for proactive health management.

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