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Automated Underground Cable Fault Detection and Location System using Arduino and Ultrasonic Sensors

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Abstract: *This project presents a smart and cost-effective underground cable fault detection system using an Arduino microcontroller and a potential divider network to accurately locate faults in underground power lines. By measuring voltage drops along the cable, the system calculates the distance to the fault, significantly reducing excavation time and repair costs. It detects both line-to-line and line-to-ground faults, improving fault identification and system response. The integration of ultrasonic sensors enhances accuracy and adaptability in real-world environments. The system displays real-time fault data on an LCD and can be expanded with communication modules such as GSM or Wi-Fi for remote monitoring and instant alerts to maintenance teams. Designed to be user-friendly and highly efficient, the system reduces human effort and minimizes disruption in power distribution. Additionally, it supports proactive maintenance strategies by enabling early fault detection before severe damage occurs. This automated solution is ideal for use in urban infrastructure, industrial complexes, and smart city applications, where reliable and uninterrupted power supply is critical. Overall, the project not only strengthens the reliability of electrical networks but also contributes to the development of intelligent grid systems by offering a scalable, precise, and technologically advanced fault detection mechanism*

Keywords: Underground Cable Fault Detection, Arduino Microcontroller, Voltage Divider Network, Real-Time Monitoring, Line-to-Line and Line-to-Ground Faults

I. INTRODUCTION

Underground power cables form the backbone of modern electrical distribution systems, offering numerous advantages such as safety, reduced maintenance, aesthetic appeal, and resilience against weather-related disruptions compared to traditional overhead lines. As cities grow and infrastructure demands increase, the reliance on underground cabling continues to rise, particularly in urban, industrial, and sensitive zones where space and safety are paramount. However, these cables are not immune to faults; they are prone to damage from environmental factors like moisture, soil erosion, chemical corrosion, rodent activity, and mechanical wear over time, as well as accidental impacts during construction or digging. Faults in underground cables can lead to severe consequences such as power outages, voltage fluctuations, equipment damage, and service disruption, affecting households, businesses, and critical facilities like hospitals and data centers. Detecting these faults using conventional methods often involves physically tracing the cable, performing resistance measurements, and excavating large areas, which is labor-intensive, time-consuming, expensive, and disruptive to public spaces and traffic. This project addresses these limitations by developing an efficient, automated underground cable fault detection system based on Arduino microcontroller technology, which uses a potential divider network to detect voltage variations along the cable that indicate the presence and location of a fault. The system calculates the distance to the fault with high accuracy, enabling targeted excavation and faster repair. It is capable of detecting both line-to-line and line-to-ground faults, thus improving diagnosis and reducing downtime. To increase precision and operational efficiency, the system integrates ultrasonic sensors that help in environmental scanning and

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object detection. Real-time fault data is displayed on an LCD screen and can be transmitted to remote operators via communication modules like GSM or Wi-Fi, facilitating immediate response by maintenance teams. This compact and scalable system is easy to implement and requires minimal human intervention, making it suitable for a variety of real-world applications. It supports early fault detection, thereby preventing major breakdowns and enabling proactive maintenance strategies. Additionally, the use of low-cost components and simple circuit design ensures affordability without compromising on functionality. This solution is ideal for implementation in smart cities, industrial zones, large residential areas, and any power distribution network where consistent, uninterrupted power is crucial. Ultimately, the project significantly enhances the reliability, efficiency, and intelligence of power distribution systems, contributing to the vision of modern, automated, and resilient electrical infrastructure that aligns with the future of smart grid technolo

II. LITERATURE REVIEW

Bangle He; Jialiang Yuan; Chenyuan Wang; Yunjie Zhou; Runtian Chen; Ting Ye "High-Voltage Cable Fault Detection Technology Based on Broadband Impedance Spectroscopy "-IEEE 2022

Firstly, the relationship between the wave impedance and the distribute parameters is deduced from the distributed parameter model theory of the cable, so as to obtain the key factors affecting the impedance. Then, the broadband impedance spectroscopy of the cable is measured by the linear resonance technique, and the characteristic data is analyzed and extracted from the impedance spectroscopy to obtain the relevant unknowns of the fault defect, so as to realize the cable fault detection. A 220kV cable fault is detected, and the analysis results show that the broadband impedance spectroscopy analysis can detect the cable Insulation defects,and the fault location accuracy meets the engineering requirements .

Bangle He; Yunjie Zhou; Hai Li; Ting Ye; Shifeng Fan; Xiaodi Wang "Fault Identification of High-voltage Cable Sheath Grounding System Based on Ground Current Analysis "-2022.

In the process of reconnecting the cable line, the transposition is easy to be connected backwards, or even wrong. In addition, there will be many situations such as moisture, water intrusion, external force damage, resulting in cross interconnection failures in the metal sheath of the high-voltage cable. Cross connect faults need to be dealt with in time. The paper analyzes the cross-connect faults of 110kV XLPE high-voltage cables, and uses PSCAD electromagnetic transient software to model and simulate. Simulation results summarize the characteristics of grounding current changes under different sheath faults.

Yiliang He; Ning Li; Chong Zhang; Jianhui Zhao; Liqiang Wei; Guoqiang Wu "Power Cable Fault Location Method Based on Pulse Current Method "-2022.

The fault location of power cables plays an important role in quickly finding fault points. In this paper, the location method of cable high resistance faults is studied by using the pulse current method, and the breakdown reflection waveforms with and without time delay are measured respectively, which verify the effectiveness of this method for cable fault location

MinalYadavrao Barhate; Sarthak Sujitkumar Deshmukh; Anup Dnyaneshwar Deshmukh; Madhura Vilas Deshmukh; Sanjay Jeetendra Deshmukh; Vinay Prabhakar Deshmukh "Enhancing Power Distribution Network : An Advanced Underground Cable Fault Monitoring System using IoT"-2023

The system incorporates a distributed sensor network, wireless communication modules, and advanced algorithms to provide a prompt and precise assessment of underground cable health, thereby minimizing fault detection time. By identifying fault patterns, the system facilitates informed decision-making, while location estimation algorithms accurately pinpoint fault locations for swift responses. Through extensive simulation studies and practical experiments, the system showcases its potential to significantly enhance power distribution network

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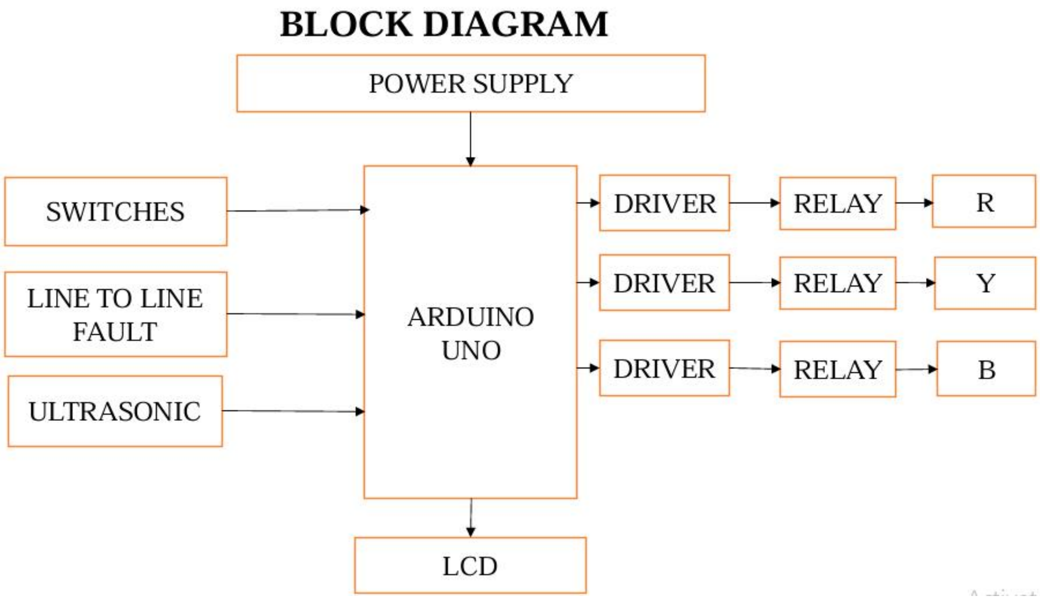
III. BLOCK DIAGRAM



IV. HARDWARE COMPONENTS

1. **Arduino UNO**

• **Type**: Microcontroller board based on ATmega328P

• **Role**: Acts as the brain of the system. It reads inputs from switches and the ultrasonic sensor, processes them, and controls

FEATURE

- **Microcontroller**: ATmega328P
- **Operating voltage**: 5V
- **Input voltage**: 7-12V
- **Flash memory**: 32KB
- **SRAM**: 2KB
- **EEPROM**: 1KB

Fig 1 Arduino.

2. Ultrasonic Sensor (HC-SR04)

• **Type**: Distance measuring sensor using sound waves

• **Role**:Sends and receives ultrasonic waves to measure the distance to the fault. It calculates how far the fault is based on the time taken for the echo to return.

• **Pins**: Vcc, GND, Trig, Echo

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Fig 2 Ultrasonic sensor.

FEATURES

- **Working Voltage:** 5VDC
- **Quiescent Current :** <2mA
- **Working Current:** 15mA
- **Detecting Range:** 2cm - 4.5m
- **Trigger Input Pulse width:** 10uS

APPLICATIONS

- Robot navigation
- Obstacle avoidance
- Engineering measurement tools
- Industrial control system

3. 16x2 LCD Display

- **Type**: Character LCD screen
- **Role**: Displays messages like "Fault at 4m", "No Fault",

etc. This helps the user know the status and exact location of the cable fault.

- **Connected via**: Digital pins on Arduino (usually through I2C module or directly)

Fig 3 LCD Display.

5. LEDs (Red, Green, Blue)

- **Type:** Visual indicators
- **Role:**
- **Green LED**: Cable condition is normal
- **Red LED:** Fault detected
- **Blue LED:** System is scanning or active

Fig 4 LEDS

6. Relay Board

• **Type:** Electromechanical switch

• **Role:** Controls high-voltage devices based on fault conditions. Arduino sends a low-voltage signal to activate the relay safely

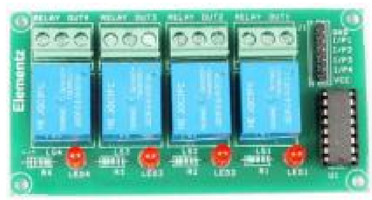


Fig 5 Relay Board

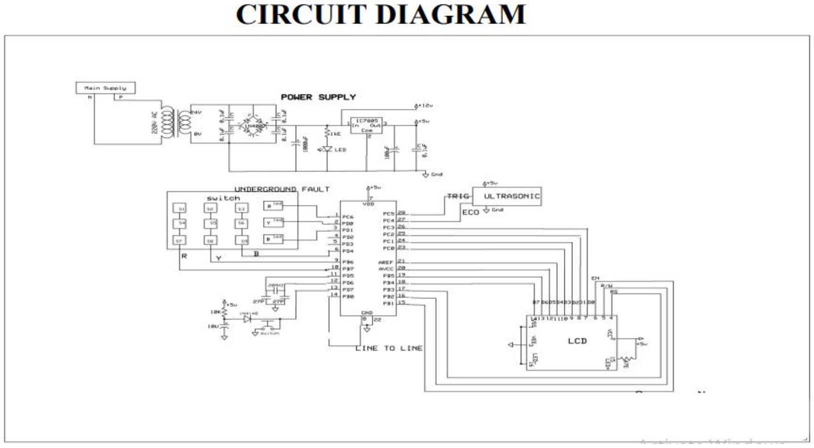
FEATURES

• **Input voltage:** 12VDC
• **Driver unit:** ULN2003A
• **Isolation unit:** In4007
• **Fast switching**
• **Motor forward and reverse operation**

APPLICATIONS

• Ac load Switching applications
• Dc load Switching applications
• Robotic applications

CIRCUIT DIAGRAM



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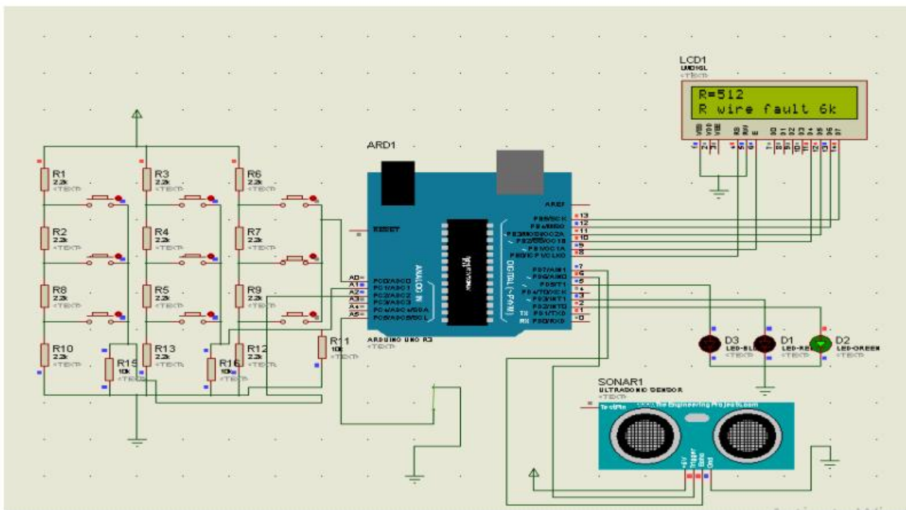
CIRCUIT DIAGRAM EXPLANATION

The underground cable fault detection system uses an Arduino microcontroller to detect and locate faults in a simulated cable made of series-connected resistors. These resistors form a potential divider network, and voltage is measured at various points. When a fault occurs—simulated by pressing a switch—the voltage at the faulted segment drops. The Arduino reads this voltage change, calculates the fault location based on the voltage drop, and displays the distance on an LCD. The system is powered by a 5V DC supply and may also include an ultrasonic sensor for measuring the straight-line distance. This setup helps quickly identify fault locations without digging

SIMULATION



PROPOSED SYSTEM

System Operation

1. Continuous Monitoring: System continuously monitors voltage along the cable.
2. Fault Detection: Potential divider network detects voltage changes caused by faults.
3. Data Processing: Arduino microcontroller processes voltage data and calculates fault distance.
4. Display: Fault location and distance are displayed on the alphanumeric display.
5. Straight-Line Detection: Ultrasonic sensor ensures accurate straightline detection of cable faults.

SOFTWARE MODULE REQUIRED

1.Arduino IDE

• Used for writing and uploading the code to the Arduino UNO.
• **Programming language:** C++

2.Proteus Design Suite

• Used for simulating the entire circuit before hardware implementation.
• You can test sensors, LCD, and Arduino connections virtually.

APPLICATIONS

• Monitoring power distribution networks for underground cable faults.
• Monitoring industrial automation systems for underground cable faults.
• Monitoring smart grids for underground cable faults.
• Monitoring renewable energy systems for underground cable faults.
• Monitoring telecommunication networks for underground cable faults.

- Monitoring commercial buildings for underground cable faults.
- Monitoring residential buildings for underground cable faults.
- Monitoring hospitals for underground cable faults.
- Monitoring data centers for underground cable faults.
- Monitoring airports and seaports for underground cable faults.

ADVANTAGES

- Reduced human effort
- Time-saving and faster maintenance
- Less software requirements
- Applicable to all types of cables
- Cost-effective
- Accurate fault sub-location detection
- Less complexity

V CONCLUSION

In conclusion, the Automated Underground Cable Fault Detection System offers numerous benefits, including accurate fault detection, reduced human effort, timesaving, and cost-effectiveness. Its simplicity, applicability to various cable types, and minimal software requirements make it an ideal solution for efficient and reliable underground cable maintenance.

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