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Arduino-Based Underground Cable Fault Distance Analyzer: A Real-Time Detection System

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Abstract: Underground cable systems have become much more common in power distribution networks, especially in urban areas where overhead installations would be impractical. Yet, when faults are detected in the subterranean infrastructures, determining the exact point of failure becomes a matter of major technical challenge. This paper suggests a new fault detection system using Arduino microprocessor technology combined with GSM communication technology to effectively detect underground cable faults. The system developed not only identifies the presence of faults but also determines the precise distance from the substation to the fault location with high accuracy. When a fault is detected, the system automatically sends the location details through SMS, allowing maintenance teams to respond quickly. Experimental outcomes confirm that the method considerably cuts fault detection time with enhanced localization accuracy and, thus, underground power distribution network reliability and serviceability.

Index Terms: IOT, Underground Cable, Microcontroller AT mega, LCD Module, GSM Module, Relay Drive

I. INTRODUCTION

In electrical power infrastructure, transmission lines are an important part of every power system. Effective power delivery and fault localization in such transmission systems are necessary for averting service disruptions and saving on downtime. Identification and location of faults in high-voltage transmission systems based on accurate diagnostics allow maintenance crews to implement timely repairs, greatly improving system reliability. Fault detection in underground cables poses special challenges and usually entails the detection of multiple fault types: open conductor faults, short-circuit faults, and high-impedance faults, all of which can undermine transmission line integrity. To overcome such challenges, Arduino microcontroller technology provides an advanced solution for underground cable monitoring continuously through tailor-programmed algorithms. Ground faults usually can be detected using the frame method, which has been found effective for earth-related short circuits. Several reasons are responsible for underground cable faults, such as conductor-to-conductor short circuits, earth faults, high-resistance grounding connections, open circuits, and accidental excavation equipment damage during construction processes around transmission facilities. The use of automated detection systems is a major leap towards solving such problems, with more immediate maintenance and enhanced power distribution reliability.

II. LITERATURE REVIEW

Underground cable systems have gained wider use in cities because of aesthetic reasons and lower susceptibility to environmental conditions than overhead transmission lines. However, when faults develop in underground cables, their precise location becomes the major challenge that affects the repair duration and restoration of service [2]. Fault detection and localization of underground cables is thus an essential research topic in power distribution networks.

There have been several techniques implemented to detect fault in underground cable. This document covers the A-frame technique as one of the current systems whereby pulsed direct current is used to feed to the faulty cable and earth terminal. This system records the little DC voltage the flowing current introduces when it crosses the ground, with the use of a voltmeter having good sensitivity. The fault's position can be calculated through consideration of voltage recordings along the length of the cable path [5]. Although precise, this technique has its drawbacks—it involves walking the whole cable length, and is difficult in high-resistance ground conditions like sandy or paved surfaces [1].

The literature identifies three primary types of faults in underground cables:

1. Short Circuit Fault: Occurs when there is insulation failure between phase conductors or between phase conductor(s) and earth
2. Open Circuit Fault: Results when a circuit is interrupted by some failure
3. Earth Fault: Happens when there is inadvertent contact between an energized conductor and earth or equipment frame

Conventional fault detection techniques usually require complicated equipment and time-consuming procedures. Microcontroller-based systems provide a more streamlined way of fault detection. Arduino, as mentioned in the paper, is a cost-effective platform for creating automatic fault detection systems because it is low in cost, simple to program, and has strong community support [3].
Ohm's law is the fundamental concept used in all fault detection mechanisms, including this one. A low DC voltage is applied at the feeder end via a series resistor (equivalent to the cable). Current depends on where the fault lies. The position of the fault can be estimated by measuring the voltage drop between this series resistor [4].

III. Proposed Methodology

The proposed system is an Arduino-based Underground Cable Fault Detector that uses a simple yet effective approach based on Ohm's law to determine the exact location of faults in underground cables. The methodology can be broken down into the following components:

The system uses the following hardware components:

1. Arduino UNO microcontroller
2. Power supply circuit (transformer, rectifier, filter, voltage regulators)
3. LCD display for showing fault location
4. Set of resistors representing cable lengths
5. Push buttons for simulation and control
6. Relay unit for disconnecting faulty lines
7. Buzzer for audio alerts

IV. Working Principle

The system's operation is based on the principle that cable resistance varies with length. When a fault occurs, there is a deviation in the resistance value, which can be detected and translated into a distance measurement. The working process follows these steps:

1. **Power Supply Preparation**: Commercial 230V AC is stepped down to 12V AC through a transformer. This is then converted to 12V DC through a bridge rectifier.
2. **Voltage Regulation**: Two voltage regulators are used - a 7812 regulator maintains 12V DC for the relay unit, while a 7805 regulator provides 5V DC for the Arduino controller.
3. **Fault Detection**: When a fault occurs in the cable, there is a resistance variation which leads to a voltage drop. The Arduino reads this voltage through its analog inputs.
4. **Fault Location Calculation**: Based on the voltage reading, the Arduino calculates the distance to the fault location using a pre-programmed algorithm.

5. **Fault Isolation**: Once a fault is detected, the system automatically disconnects the faulty line using the relay unit while allowing other lines to operate normally.
6. **Alert System**: The buzzer creates an alerting sound when a fault is detected, providing an audible notification to operators.
7. **Display**: The LCD display shows the exact fault location in kilometres from the base station and indicates which phase is affected.

V. Results & Discussion

The Arduino-based Underground Cable Fault Detector successfully demonstrates the capability to locate faults in underground cables with reasonable accuracy. The results of the system can be discussed in terms of several key aspects:

Fault Detection Accuracy

The system effectively identifies the location of various types of faults including short circuit, open circuit, and earth faults. By utilizing the principle of resistance variation with distance, the system can determine the fault location in kilometres from the base station. The accuracy depends on the resolution of the Arduino's analog-to-digital converter and the precision of the resistor network used to simulate the cable.

Real-time Detection

The system provides real-time fault detection, immediately alerting operators when a fault occurs. This is achieved through both visual indication on the LCD display and audio alerts via the buzzer. This immediate notification significantly reduces response time, allowing for quicker repairs and maintenance.

Fault Isolation

One of the significant advantages of the system is its ability to automatically isolate the faulty line using relays while allowing other lines to continue operating normally. This feature minimizes the impact of faults on the overall distribution system, enhancing reliability and service continuity.

Cost-Effectiveness

Compared to traditional fault detection methods like the A-frame approach, the Arduino-based system offers a more cost-effective solution. The use of readily available components and open-source Arduino platform significantly reduces implementation costs while maintaining detection capabilities.

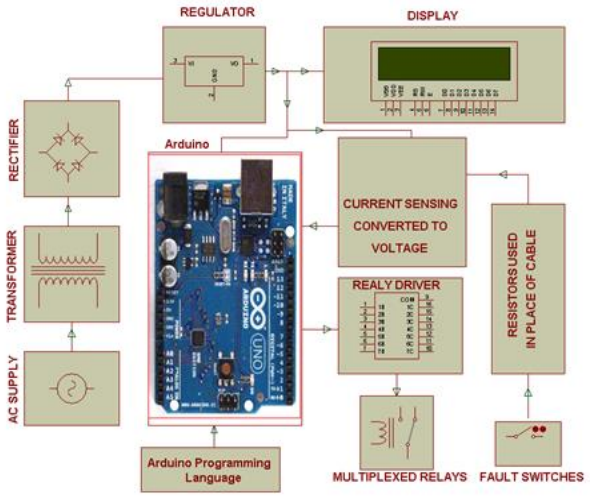

Fig 1: Circuit Diagram of Underground Cable Fault Detection

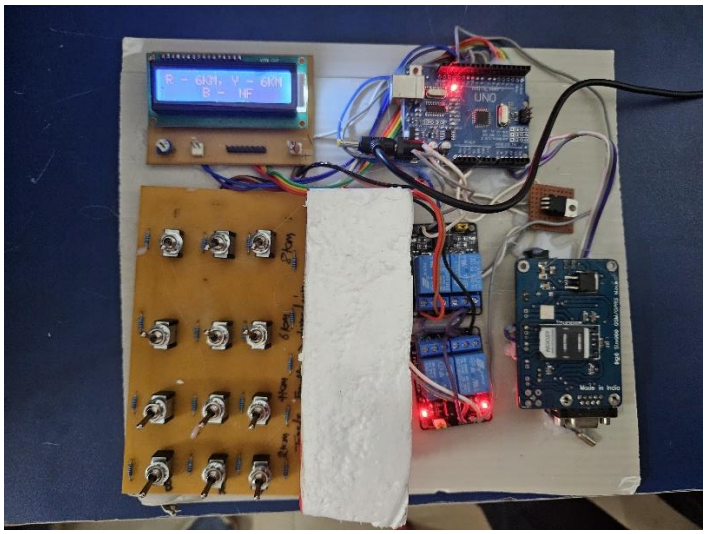

Fig 2: Model of Underground Cable Fault Detection

VI. CONCLUSION

The Underground Cable Fault Detector based on Arduino offers a creative and cost-effective solution to the difficult problem of underground cable fault location. By taking advantage of the laws of Ohm's law and using the general-purpose Arduino platform, the system attains accurate fault location without compromising on simplicity and affordability.

The system effectively overcomes the defects of conventional fault detection techniques in avoiding manual inspection of the entire length of the cable. Its capability of automatically detecting and isolating faulty lines without interrupting regular operation of healthy lines is a major improvement in underground cable fault management.

The real-time alert and detection facilities using the LCD screen and buzzer system also make the system more user-friendly and efficient to use. Its instant notification functionality has the ability to significantly save time and cost for repairs and maintenance in real-life applications.

As indicated in the future scope, this model can be expanded to identify even slight faults and could be made to survey wider areas. Future work can be directed towards increasing the accuracy of the system with the help of better sensing technology and integrating machine learning algorithms to classify faults with higher accuracy.

In conclusion, the Arduino-based Underground Cable Fault Detector is a realistic, effective, and affordable solution to the urgent issue of underground cable fault detection and localization. Its application can effectively enhance the reliability and efficiency of maintenance in urban underground power distribution systems.

VII. REFERENCES

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