# Automatic Cable Fault Distance Locator using Arduino

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**Abstract:** ***This paper presents the method of design of a cable fault location sensor for underground cable fault detection. The aim was to detect the fault location from transmitting or receiving station up to few meters accuracy using an Arduino based kit. The underground cable-based supply system is a common practice in urban areas. As explained in the paper, the system uses the principle of a Varley loop to determine the exact distance of the fault in the underground cable up to the accuracy of a meter. When any fault, e.g. short circuit and earth fault occurs, the length of the fault of the cable can be determined from the fault resistance using the bridge in the Varley loop. A microcontroller is used to make the necessary calculations and display the fault distance after that. After necessary calibration and testing, an accuracy of about 85% is achieved in locating the fault using the method.***

**Keywords:** Arduino; ADC; Varley loop; Underground Cable Fault.

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## 1. Introduction

For the low voltage and medium voltage distribution lines, underground cables have been used for many decades worldwide. To reduce the effects of distribution networks on the environment, underground high voltage cables are used more and more now. Underground cables have been widely used in power distribution networks due to the advantages of underground connection, involving more security than overhead lines in bad weather, less liable to damage by storms or lightning. It is less expensive for a shorter distance, eco-friendly and required less maintenance [1].

But, if any fault occurs in an underground cable, then it is difficult to locate the fault. Therefore, this paper explains one such method developed to detect the location of a fault in a digital way. There is a great requirement of locating the fault point in an underground cable in order to facilitate quicker repair, improvement of the system reliability and reduced outage period [2].

From the works of literature reviewed, it is seen that different designs are proposed by different authors for using various methods to locate the faults in underground cables. Variety of methods such as the techniques using Megger, Optical sensing, Electromagnetic Field and Varley loop sensing are being used for fault detection and pinpointing. The accuracy levels and complexity of the set-up used vary along with the cost of the equipment in various such methods. The earliest techniques recorded in pieces of the literature suggest the use of Megger based techniques for the purpose of locating the fault. The use of optical and electromagnetic methods is relatively new, mainly developed during the last decade [3, 4].

The automatic underground fault locator systems have a higher level of acceptance as compared to manual ones [5]. The automatic fault locator has perceived benefits of protection against any underground faults, i.e., short circuit and open circuit faults. The present system, as described in subsequent sections, is therefore designed to give the exact distance reading from the feeder end to where the fault occurs in underground cable automatically. In addition, it can be taken to any location for operation, whenever the fault occurs and is basically made to serve for the need for a simple and cheap cable fault locator.

## 2. Theoretical Background

In the present work, the Varley loop based testing method is used for locating short-circuit and earth faults in underground cables. This test employs the principle of the Wheatstone bridge [8].

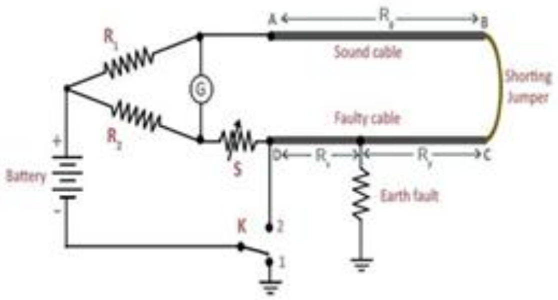


**Figure 1:** Varley loop method for earthed fault

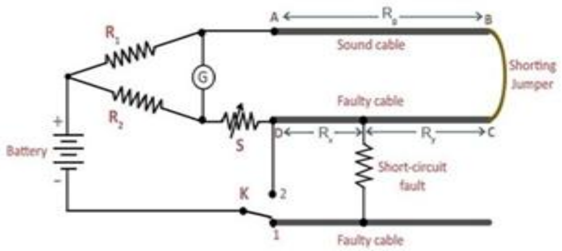


**Figure 2:** Varley loop method for short circuit fault

To locate fault using the Varley loop, connections are made as shown in the circuit diagram of Figure 1 and Fig. 2. Resistors $R_1$ and $R_2$ are fixed, and the resistor S is variable. A stepper motor is to be used to vary the resistance to bring the bridge to a balanced condition. The balanced resistance value will be given to the microcontroller for applying that value to the program to be developed. The program will automatically calculate the distance of fault, based on the algorithm to be developed during the project.

## 3. System Designs

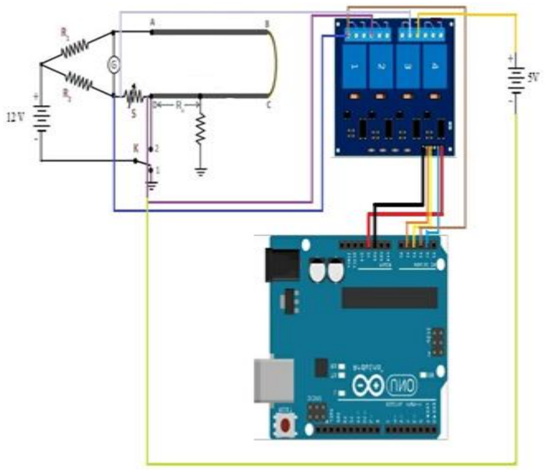


**Figure 3:** Circuit diagram of automatic cable fault distance locator

The fault detector system is designed to utilize the bridge balance technique. In this test, the switch K is first thrown to position 1. Then the variable resistor S is varied until the galvanometer shows zero value (i.e., the bridge is balanced).

Let us say; the bridge is balanced for the value of S equal to $S_1$. Then,

$$\frac{R_1}{R_2} = \frac{R_g + R_y}{R_x + S_1}$$

Let, $R_g + R_y = R_3$

$$\frac{R_1 + R_2}{R_2} = \frac{R_3 + R_x + S_1}{R_x + S_1}$$

$$R_x + S_1 = \frac{R_2 (R_3 + R_x + S_1)}{R_1 + R_2}$$

$$\boxed{R_x = \frac{R_2 (R_3 + R_x) - R_1 S_1}{R_1 + R_2}} \quad \text{........ eq. (i)}$$

Now, the switch K is thrown to the position 2, and the bridge is balanced by varying the resistor S. Say, the bridge is balanced at the value of resistor S is equal to $S_2$. Then,

$$\frac{R_1}{R_2} = \frac{R_3 + R_x}{S_2}$$

$$\boxed{R_1 S_2 = R_2 (R_3 + R_x)} \quad \text{........ eq. (ii)}$$

Now, putting the result of eq.(ii) in eq.(i),

$$R_x = \frac{R_1 (S_2 - S_1)}{R_1 + R_2}$$

Since the values of $R_1$, $R_2$, $S_1$ and $S_2$ are known, $R_x$ can be calculated. When $R_x$ is known, the distance from the test end to the fault point $L_x$ can be calculated as,

$$L_x = R_x / r$$

Where, r = resistance of the cable per meter.

Now, when the bridge is in a balanced condition, the relay module consisting of 3 relays will be interfacing with the Varley loop circuit. The relay 1 and relay 2, which is connected between the two ends of the terminal of variable resistor S, trip when the galvanometer reads zero value. Therefore, the relays 3, which is connected as shown in Figure 3, will then extract the balanced resistor, which will then be fed to the Arduino for distance calculation from the equation $L_x = R_x / r$.

### 3.1 Block Diagram

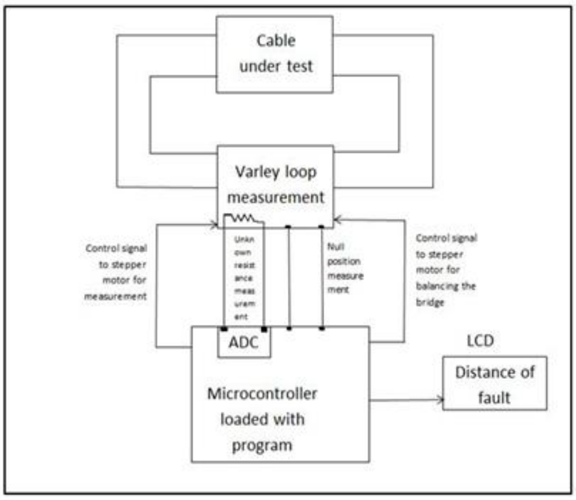


**Figure 4:** Block diagram of automatic cable fault distance locator

At first, the Varley loop bridge is brought into a balanced condition. The variable resistor is used to vary the resistance to bring the bridge to the balanced condition.

The relays are connected across the terminals of the variable resistor S. The relays will be operated (tripped) by a signal sent from the microcontroller when the bridge is in a balanced condition. The balanced resistance value will then be given to the microcontroller. The change in resistance will then be converted automatically to the faulty distance of the cable. The program has been developed for making the system automatic.

### 3.2 Automatic Cable Fault Distance Locator Algorithm and Components

The microcontroller is interfaced with the relay module circuit. The analog pins of the microcontroller are connected with the input pins of the relay module, which consists of three relays to be operated. The $V_{cc}$ pin of the relay module is supplied from the Arduino board. Accordingly, the contacts of the relays are connected, as shown in the above circuit diagram. These contacts operate according to the program being fed from the Arduino microcontroller, and therefore the required operation works satisfactorily.

The algorithm for the program is as the following:

Step 1: Start.
Step 2: Initialize the pin modes and variables (pot resistance), and flag variables.
Step 3: Voltage analog read by the ADC.
Step 4: Check for voltage value.
Step 5: When voltage = 0, set pin A1, A2, A3 high and low to pin A4 and read analog voltage across the resistance (pin A4).
Step 6: Converting voltage to the resistance value.
Step 7: Print resistance value.
Step 8: Else if voltage > 0, set A1, A2, A3 low and make A4 high.
Step 9: Halt.

The components used for the work are shown in Table 1.

**Table 1**: Components Used in Automatic Cable Fault Distance Locator Using Arduino

| Sl. No. | Name of components | Ratings | Quantity |
|---|---|---|---|
| 1 | Microcontroller | ATMEGA328P | 1 |
| 2 | Battery | 12 V | 1 |
| 3 | LCD | 16x2 | 1 |
| 4 | Resistors | 470 Ω, 100 Ω, 220 Ω, 47 Ω, 330 Ω | 1 each |
| 5 | Variable Resistors | 10 Ω | 1 |
| 6 | Relay | 5 V | 3 |

## 4. System Analysis and Implementation

The output results obtained from the microcontroller are shown in Figure 5 when the voltage across the galvanometer goes higher than zero value, which implies that it is in an unbalanced condition.

The output result of the voltage when the bridge is in the balanced condition is shown in Figure 6. During a balanced condition, the voltage value is zero, and therefore the Arduino reads the resistance value from the Varley loop circuit and displays in the serial monitor of the Arduino.

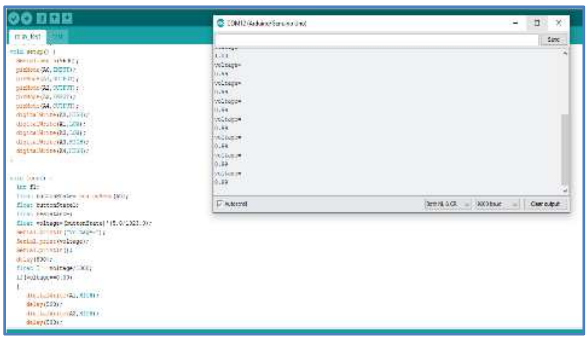

**Figure 5**: Output result during the unbalanced condition

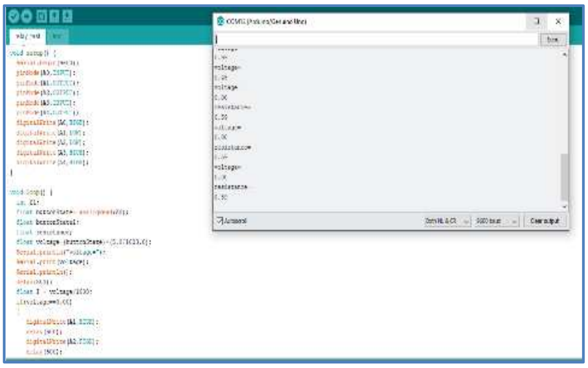

**Figure 6**: Output result during a balanced condition

During the testing of the project, it was found that if the unknown resistance value is very small, then it is difficult to bring the bridge to the balanced condition. The bridge is very sensitive, and the voltage deflects randomly if the unknown resistance is very small. But, through much continuous trial, the voltage could be made stable, by choosing proper ratings of standard arm resistances. After that, the bridge could be interfaced with the Arduino for making the system automatic.

The relay module is interfaced with the microcontroller, and when the voltage across the galvanometer is higher than zero value, the relays do not trip. But, as soon as the Arduino reads zero value, it automatically sends signals for tripping the relays.

## 5. Conclusion

In the present project, it was intended to study the process of detection of the exact location of circuit fault in the underground cables from the feeder end in few meters by using an Arduino microcontroller. The Arduino microcontroller is used to detect the changes in the output voltage of the bridge circuit. As soon as a fault occurs in the cable, the bridge is balanced at some other resistance than the normal condition. That resistance is then used to produce the voltage across the analog input ports of the microcontroller, and thus the fault location is determined using an algorithm.

The project using the Varley loop test is expected to detect the fault by detecting the resistance, which in turns can be translated into distance using an algorithm. Then the microcontroller is used to display the fault distance from the source end in the LCD display.

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