OPEN CIRCUIT & SHORT CIRCUIT CABLE FAULT DETECTION USING ARDUINO

[1] Saurabh Kumar, [2] Kumari Shradha
[1] Associate Manager, [2]Assistant Professor
[1]Coke Oven Department, [2]ECE Department
[1]Jindal Stainless Limited ,Jajpur,India, [2]Raajdhani Engineering College, Bhubaneswar, India

Abstract: This paper is a study on underground fault location model using arduino. Underground distribution cables faces with various technical difficulties regarding detecting and locating their faults. Different factors like remarkable charging currents, cable construction and variations from the variety of bonding and grounding methodologies. Arduino is basically an open source hardware used to create interactive electronic objects consisting of various analog and digital pins, serial communication interfaces, including USB on some models, for loading programs (C++, C, and java) from personal computers. The LCD (liquid crystal display) used is of 16*2 displays. In this paper, concept of ohm's law is used. To detect a fault in the cable, the cable must first be tested for faults. When any fault like short-circuit occurs, voltage drop will vary depending on the length of fault in cable, since the current varies. A set of resistors are therefore used representing cable length in kilo meters and fault creation is made by a set of switches at every known kilo meters (km's) to cross-check the accuracy . The fault occurring at what distance and which phase is displayed on a LCD interfaced with the arduino. The underground cable system is especially used for distribution in metropolitan cities, airports and defense service, because underground cables are not affected by any adverse weather conditions.
Index Terms - **Underground cable, fault location, arduino, LCD, USB.**

I. INTRODUCTION

Concerns about the reliability of overhead lines, increases in their maintenance and operating costs, and issues of public safety and quality-of-life are leading more and more utilities and municipalities to the realization that converting overhead distribution lines to underground is the best way to provide high quality service to their customers, undergrounding provides potential benefits through reduced operations and maintenance costs, reduced tree trimming costs, less storm damage and reduced loss of day-to-day electricity sales when customers lose power after storms[1]. The underground cable system is very important for distribution especially in metropolitan cities, airports and defense service, because underground cables are not affected by any adverse weather condition such as storm, snow, heavy rainfall. But when any fault occur in cable, then it is difficult to locate fault.

The aim of this project is to determine the distance of underground cable fault from base station in kilometers. Now the world is become digitalized so the project is intended to detect the location of fault in digital way. The underground cable system is more common practice followed in many urban areas. In case if any fault occurs for any reason at that time the repairing process related to that particular cable is difficult due to not knowing the exact location of cable fault[2]. The fault can be any defect, inconsistency, weakness, current diversion from its intended path caused by breaking of conductor and failure of insulation.

The objective of this project is to determine the distance of underground cable fault from base station in kilometers using an Arduino board. The underground cabling system is a common practice followed in many urban areas. There are many electrical, telephone and other signal cables are laid underground. Many time faults occur due to construction works and other reasons. At that time it is difficult to dig out cable due to not knowing the exact location of the cable fault.

II. ADVANTAGES OF UNDERGROUND CABLE FAULT DETECTION

This includes aesthetics, higher public acceptance, and perceived benefits of protection against electromagnetic field radiation (which is still present in underground lines), fewer interruptions, and lower maintenance costs. Failure rates of overhead lines and underground cable is vary widely, but typically underground cable outage rates are about half of their equivalent overhead line types. Potentially far fewer mo interruptions occur from lightning, animals and tree branches falling other wires which de-energize a circuit and then reenergize it a mom moment later [3].

Primary benefits most often cited can be divided into four areas

- Highly, reduced Maintenance and Operating cost.
- Lower storm restoration costs.
- Increased reliability during severe weather (wind-related storm dame will be greatly reduced for an underground system.
- Improved Reliability.
- Not subject related to flooding and storm surges experience minimal damage and in interruption of electric service.

- Less damage during severe weather.
- Far fewer momentary interruptions.
- Improved utility relations regarding tree trimming.
- Improved Public Safety.
- Fewer motor vehicle accidents.
- Reduced live-wire contact injuries
- Fewer Fires.

III. TYPES OF FAULT IN UNDERGROUND CABLE

Most common types of fault that occur in underground cables are: 1. Open circuit fault. 2. Short circuit fault. 3. Earth fault.

Open Circuit Fault : When there is a break in the conductor of a cable, it is called open circuit fault. The open-circuit fault can check by a megger. For this purpose, the three conductors of the 3 core cable at far end are short tied and earthed. Then resistance between each conductors and earth is measured by a megger. The megger will indicate zero resistance in the circuit of the conductor that is not broken. However if a conductor is broken the megger will indicate an infinite resistance [1].

Short Circuit Fault : When two conductors of a multi core cable come in critical contact with each other due to insulation failure, it is so called as short circuit fault. Megger can also be used to check this fault [5]. The two terminals of a megger are connected to any two conductors. If the megger gives a zero reading it indicates short-circuit fault between these conductors.

Earth Fault : When the conductor of a cable comes in contact with earth, it is called earth fault or ground fault. To identify this fault, one terminal of the megger is connected to the conductor and the other terminal connected to the earth. The megger indicates zero reading; it means the conductor is earthed [3]. The same procedure is repeated for other conductors of the cable

IV. SIGNIFICANCE OF UNDERGROUND CABLE FAULT

For electrical usage, transmission lines form the backbone of power systems. With regard to reliability and maintenance costs of power delivery, accurate fault location for transmission lines is of vital importance in restoring power services and reducing wastage of time as much as possible. Underground power cables have been widely implemented due to reliability and environmental concerns. To improve the reliability of a distribution system, accurate identification of a faulted segment is required. In the conventional way of detecting fault, an exhaustive search in larger scale distance has been conducted. This is time consuming and inefficient, Not only that the manpower resources are not utilized, but also the restoration time may vary depending on the reliability of the outage information. Hence an efficient technique to locate a fault can improve system reliability. Power systems need an accurate and automatic fault location method due to number of key factors namely: reliability of supply, quality of supply, reducing operating costs of repairs and charging staff works practices, and low tariff charges to maintain a competitive edge.

The trend of transmission line construction from overhead to underground is increasing even though the underground system costs more for initial construction. However, the underground system requires faster detection and correction of accidental faults along the lines for more reliable service. Various methods have been developed to reduce damage and inference. But most of fault detection methods have shortcomings. Some have low accuracy, some are difficult to apply because of surrounding environment, and some give unwanted damage to healthy neighboring cable and facilities [3-4]. Another method that is pulse echoing method is also used. This method use time difference between incident and reflected pulse to calculate fault location detection and it has relatively high accuracy because it use short period pulse. Although it has high accuracy, pulse echoing method has some drawbacks. When we apply this method to low impedance accident, the error will be increased. If cable is not open circuit and there is no impedance change, there are no reflected pulse waves, and it is difficult to find fault location.

Because it is also very expensive system, on-line monitoring and fault location detection of cable using arduino or microcontroller is a better automatic digital way to locate faults.

V. METHODOLOGY

The Project detects the location of fault in underground cable lines from the base station in kilometers using an arduino board. It uses the standard concept of ohms law i.e., when a low dc voltage is applied at the feeder end through a series resistor to the cable lines, then current would vary depending upon the location of fault in the short circuited cable.
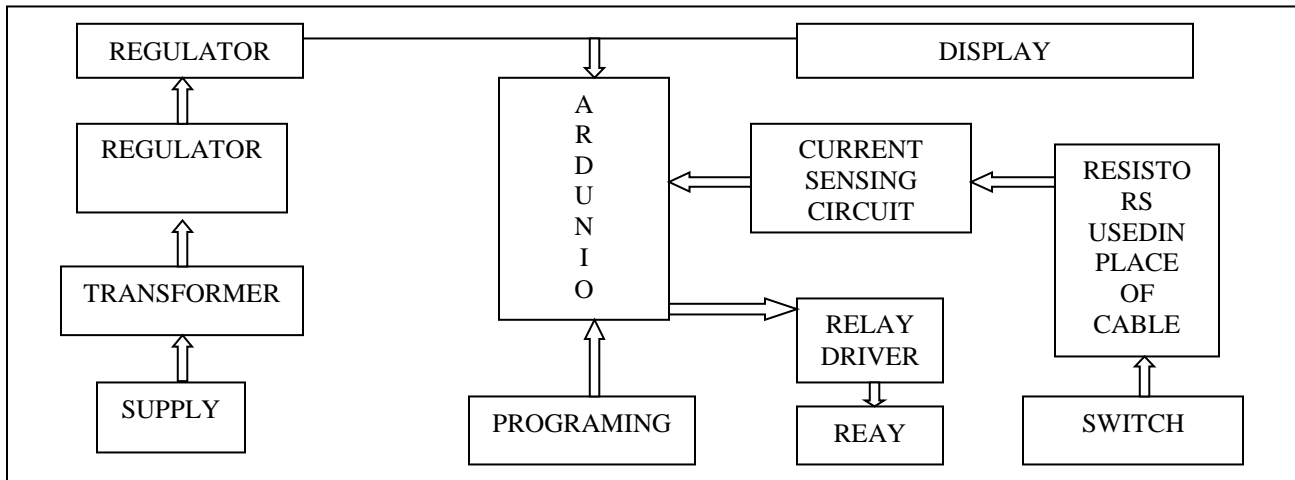
Figure 1: Block diagram for Cable Fault Detector

The project is assembled with a set of resistors representing cable length in KM's and fault creation is made by a set of switches at every known KM to cross check the accuracy of the same. The fault occurring at a particular distance and the respective phase is displayed on a LCD interfaced to the Arduino board. Further this project enhanced by measuring capacitance of cable which can even locate the open circuited cable.

When there is a short circuit , the voltage across series resistors changes accordingly and fed to an ADC to develop precise digital data which the programmed arduino would display using LCD in kilometers[4]. The project consists of series of resistors representing cable length in kilometers and fault creation is made by a set of switches at every known km.

The hardware requirement of this project are LCD, Crystal, Relays, Relay Driver IC, Transformer, Diodes, Voltage Regulator, Resistors, Capacitors, LEDs, slide switches, Arduino board Power supply- The 230V supply is stepped down to a 12V supply by a step down transformer which is then converted to DC using a bridge rectifier. AC ripples are filtered by using capacitor and filtered supply is then supplied to the input pin of voltage regulator 7805. At the output of regulator we get a constant 5V DC supply which is supplied to the arduino and other components in the circuit [2].

1. **Arduino-** It is a powerful single board computer, an open source hardware platform allowing creating interactive electronic objects. It consists of arduino board, set of various analog and digital I/O pins, serial communication interfaces, including USB on some models, for loading programs from personal computers [5]. Its platform provides an integrated development environment (IDE) based on the processing project, which includes support for C, C++ and Java programming languages. This method features an Atmel Atmega328 operating at 5v with 2kb RAM, 32kb of flash memory for storing programs and 1kb of EEPROM for storing parameters [4]. The clock speed is 16 MHz which translates to executing about of 300,000 lines of C source code per second.

2. **Relay Driver Uln2003 -** It is a monolithic high voltage and high current Darlington transistor arrays. It consists of seven NPN Darlington pairs that feature high voltage outputs with common cathode clamp for switching inductive loads [5]. It has high current carrying capability of about 500mA.

3. **Liquid Crystal Display-** Most common displays are 16*2 and 20*2 display. The standard refers to as HD44780U, which refers to the controller chip which receives data from an external source (LCD) and communicates with the LCD[4].

4. **Rectifier**- It converts ac into pulsating dc with the help of a bridge rectifier.

5. **Voltage Regulators-** It is required to maintain a constant voltage level. Here we use 7805 voltage regulator

   The Software requirement in this project are languages like embedded c, java etc

VI.ALGORITHM AND FLOWCHART
Algorithm of Resistance measurement

```
┌──────────────────────────────────────────────┐
│   INITIALZE INPUT & OUTPUT PORTS LIKE ADC,CD   │
│                  & TIMER                        │
└──────────────────────────────────────────────┘
                     │
                 ◇ WHILE ◇
                     │
┌──────────────────────────────────────────────┐
│   TURN ON THE ARDUNIO BY MAKING THE INPUT      │
│                  PORT HIGH                      │
└──────────────────────────────────────────────┘
┌──────────────────────────────────────────────┐
│           DISPLAY THE PHASE NAME               │
└──────────────────────────────────────────────┘
┌──────────────────────────────────────────────┐
│          CALL ADC FUNCTION ,READ ADC           │
└──────────────────────────────────────────────┘
┌──────────────────────────────────────────────┐
│         GIVE ADC OUTPUT TO ARDUNIO BOARD       │
└──────────────────────────────────────────────┘
┌──────────────────────────────────────────────┐
│         DISPLAY LOCATION OF FAULT ON LCD       │
└──────────────────────────────────────────────┘
┌──────────────────────────────────────────────┐
│                  CALL DELAY                     │
└──────────────────────────────────────────────┘
```
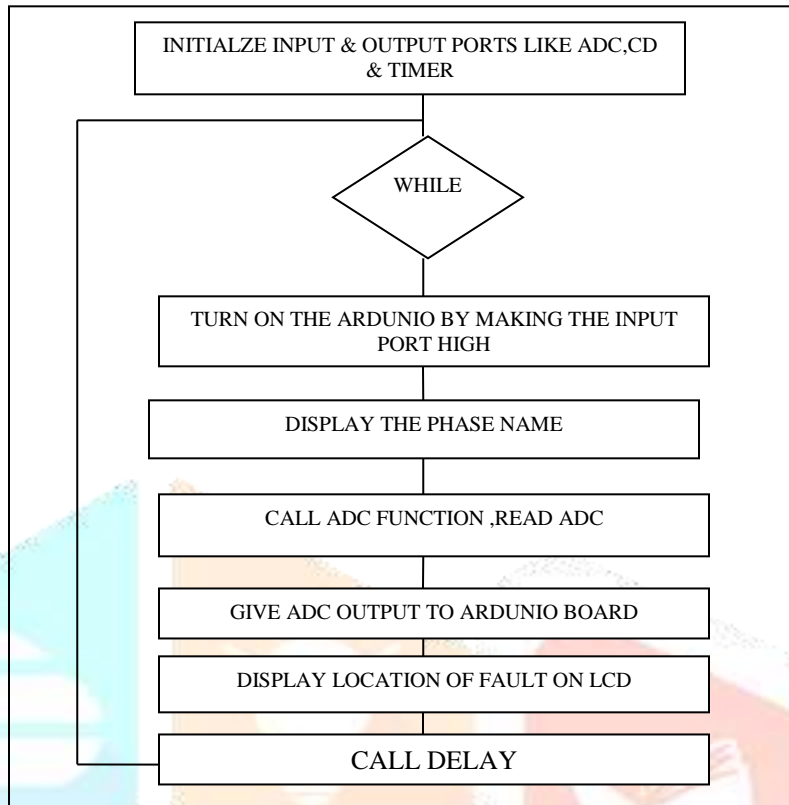
Figure 2. Flowchart of Underground Cable Fault Detector

Algorithm of programming used in underground cable fault detection [4]
1. Step: Initialize the ports, declare timer, ADC, LCD functions.
2. Step: Begin an infinite loop; turn on relay 1 by making pin 0.0 high.
3. Step: Display ―R:‖ at the starting of first line in LCD.
4. Step: Call adc Function, depending upon ADC output, displays the fault position.
5. Step: Call delay.
6. Step : Repeat steps 3 to 5 for other two phases

Algorithm of Capacitance measurement
1. Step: Set discharge pin to INPUT (so it can't discharge the capacitor)
2.Step: Set charge pin to OUTPUT and make it HIGH
3. Step:Record the start time with *millis()*
4. Step: the voltage repeatedly in a loop until it gets to 63.2% of total voltage.
5. Step: After the cap is charged, subtract the current time from the start time to find out how long the capacitor took to charge.
6. Step : Divide the Time in seconds by the charging Resistance in ohms to find the Capacitance.
7 Step: Report the value with *print* on Serial monitor.
8 Step: Discharge the capacitor. To do this:
9.Step: Set the charge pin to Input
10 Step: Set the discharge pin to OUTPUT and make it LOW

11Step :Read the voltage to make sure the capacitor is fully discharged

12 Step: Loop and do it again

VII.ARDUINO BASED UNDERGROUND CABLE FAULT DETECTION CIRCUIT

Capacitance Measurement Circuit: Each Arduino capacitance meter relies on the same basic property of capacitors- the time constant. The time constant of a capacitor is defined as the time it takes for the voltage across the capacitor to reach 63.2% of its voltage when fully charged. Larger capacitors take longer to charge, and therefore have larger time constants. An Arduino can measure capacitance because the time a capacitor takes to charge is directly related to its capacitance by the equation:
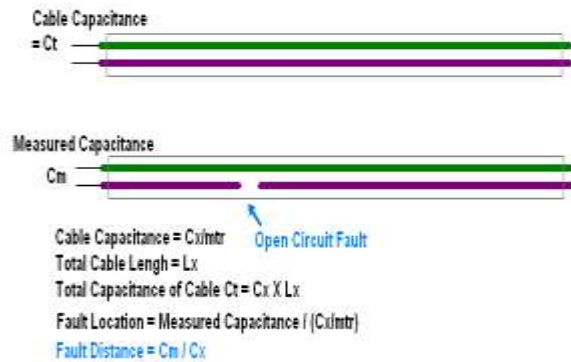
Figure 3. Open Circuit Cable Fault.   Figure 4. Capacitance measurement circuit
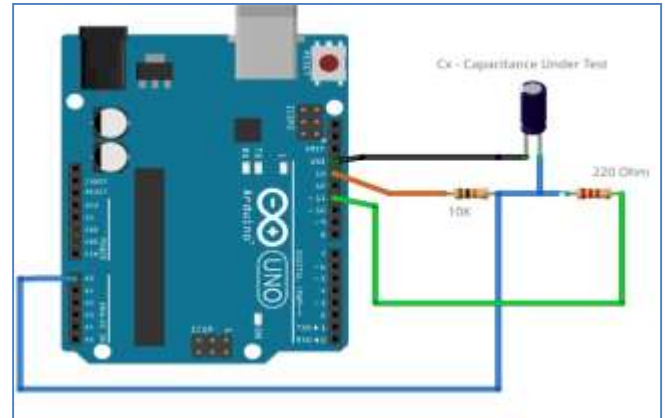
Open circuit Fault measurement :Open Circuit can be detected by measuring the capacitance between two wires. Capacitance of cable changes according to the length. The length of cable varies based on the location of cable cut (open). As the cable is open parallel wire capacitance gets reduced based on this we can calculate the fault location.

```
/* Capacitance Measurement
* Theory   A capacitor will charge, through a resistor, in one time constant, defined as T seconds where
*    TC = R * C
*    TC = time constant period in seconds
*    R = resistance in ohms
*    C = capacitance in farads (1 microfarad (ufd) = .0000001 farad = 10^-6 farads)  *
*    The capacitor's voltage at one time constant is defined as 63.2% of the charging voltage.
*/
#define analogPin      0        // analog pin for measuring capacitor voltage
#define chargePin     13        // pin to charge the capacitor - connected to one end of the charging resistor
#define dischargePin   11        // pin to discharge the capacitor
#define resistorValue  10000.0F   // 10K change this to whatever resistor value you are using
                  // F formatter tells compiler it's a floating point value
unsigned long startTime;
unsigned long elapsedTime;
float microFarads;          // floating point variable to preserve precision, make calculations
float nanoFarads;
void setup(){
  pinMode(chargePin, OUTPUT);    // set chargePin to output
  digitalWrite(chargePin, LOW);
  Serial.begin(9600);          // initialize serial transmission for debugging
}
void loop(){
  digitalWrite(chargePin, HIGH); // set chargePin HIGH and capacitor charging
  startTime = millis();
  while(analogRead(analogPin) < 648){    // 647 is 63.2% of 1023, which corresponds to full-scale voltage
```

```
  }
  elapsedTime= millis() - startTime;
 // convert milliseconds to seconds ( 10^-3 ) and Farads to microFarads ( 10^6 ),  net 10^3 (1000)
  microFarads = ((float)elapsedTime / resistorValue) * 1000;
  Serial.print(elapsedTime);      // print the value to serial port
  Serial.print(" mS    ");        // print units and carriage return


  if (microFarads > 1){
   Serial.print((long)microFarads);      // print the value to serial port
   Serial.println(" microFarads");       // print units and carriage return
  }
  else
  {
   // if value is smaller than one microFarad, convert to nanoFarads (10^-9 Farad).
   // This is a workaround because Serial.print will not print floats
   nanoFarads = microFarads * 1000.0;     // multiply by 1000 to convert to nanoFarads (10^-9 Farads)
   Serial.print((long)nanoFarads);        // print the value to serial port
   Serial.println(" nanoFarads");         // print units and carriage return
  }
  /* discharge the capacitor  */
  digitalWrite(chargePin, LOW);            // set charge pin to  LOW
  pinMode(dischargePin, OUTPUT);              // set discharge pin to output
  digitalWrite(dischargePin, LOW);         // set discharge pin LOW
  while(analogRead(analogPin) > 0){         // wait until capacitor is completely discharged
  }
  pinMode(dischargePin, INPUT);            // set discharge pin back to input
}
```

Short Circuit Fault Measurement :Short circuit can be determined by measuring resistance between two cables at one end (base station). The value of resistance tells us the exact location of short circuit.The circuit is consists of 4 line display, arduino and resistance measurement circuit. Main component of the underground cable fault detection circuit is low value resistance measurement. It is constructed using a constant current source of 100mAmps. It can measure very low value resistance as the cables have around 0.01 Ohm/meter resistance. For 10meter cable resistance becomes 0.1 Ohm. This circuit can measure resistance up 50 Ohm, Maximum cable length it can check up to 25000 meters
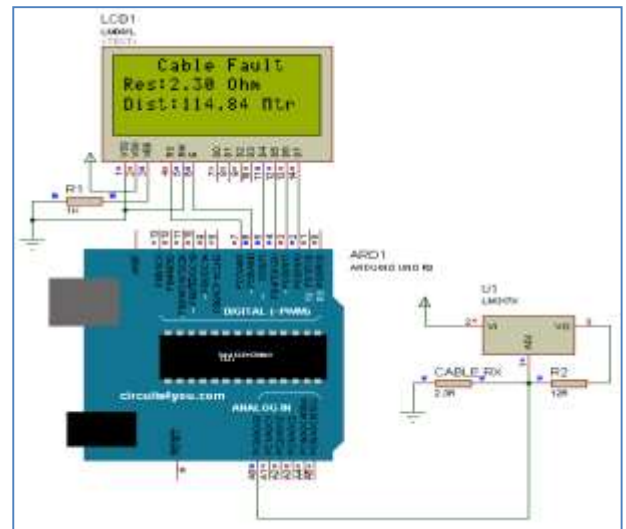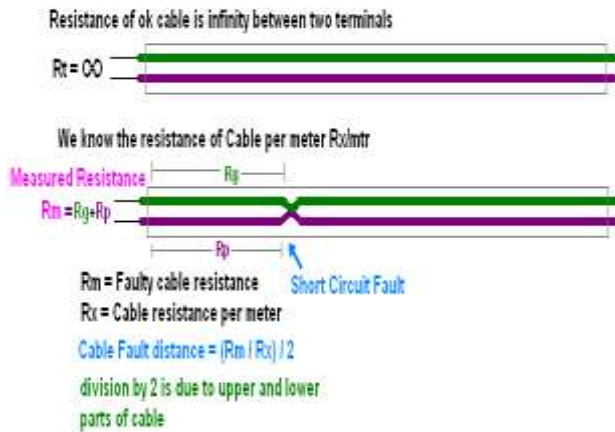
Resistance of ok cable is infinity between two terminals

$Rt = \infty$

We know the resistance of Cable per meter Rx/mtr

Measured Resistance   Rg

$Rm = Rg + Rp$

Rp

Rm = Faulty cable resistance   Short Circuit Fault

Rx = Cable resistance per meter

Cable Fault distance = (Rm / Rx) / 2

division by 2 is due to upper and lower
parts of cable

Figure 5 : Short Circuit Cable Fault

Figure 6. Resistance measurement circuit

Arduino Code for Underground Cable Fault Detection

```
/*
 circuits4you.com
 Arduino Based Underground Cable Fault Detection
 */
// include the library code:
#include <LiquidCrystal.h>

// initialize the library with the numbers of the interface pins
LiquidCrystal lcd(7, 6, 5, 4, 3, 2);
const double Rc = 0.01;    //Cable Resistance per meter its 0.01 Ohm/Mtr
void setup() {
  // set up the LCD's number of columns and rows:
  lcd.begin(16, 4);
  // Print a message to the LCD.
  lcd.print("  Cable Fault  ");
}
void loop() {
  double Vx=(5.0/1024.0) * analogRead(A0);  //Voltage across Rx
  double Rx = Vx / (1.25/12);  //Cable Resistace  (1.25/R2)=I Constant
 Current Source

  //Display Cable Resistance
  lcd.setCursor(0, 1); // set the cursor to column 0, line 2
  lcd.print("Res:");
  lcd.print(Rx);
  lcd.print(" Ohm");

  //Display Fault Location
  lcd.setCursor(0, 2); // set the cursor to column 0, line 3
  lcd.print("Dist:");
  lcd.print((Rx/Rc)/2);  //Find Location of Fault
     lcd.print(" Mtr");
```
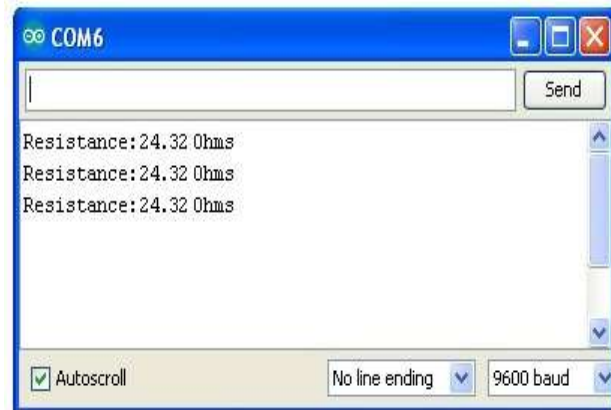
VIII. RESULT

<u>Result of Capacitance Measurement</u> :The code will wait on this line If there is no capacitance Connected while(analog Read(analog Pin) < 648)   // 647 is 63.2% of 1023, which corresponds to full-scale voltage .Connect the capacitor between test terminals and observe the serial monitor will show the result. If no capacitance is connected serial terminal will not show anything. Circuit can be tested with different resistor values to simulate various fault conditions.

Figure 7 : Result of Capacitance Measurement   Figure 8 : Result of Resistance Measurement

IX. CONCLUSION

   Circuit has been tested with different resistor values to simulate various fault conditions. It displays exact location of short circuit. In this paper the exact location of short circuit fault at a particular distance in the underground cable from feeder end in km can be located by using arduino 8051. The concept of OHM's law is used so fault can be easily detected and repaired .We have also used capacitance Measurement Technique and it finds the the fault.

X. ACKNOWLEDGMENT

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