Development of a Prototype Underground Cable Fault Detector

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Abstract—Cable faults are damage to cables which affects the resistance in the cable. If allowed to persist, this can lead to a voltage breakdown. To locate a fault in the cable, the cable must first be tested for faults. This prototype uses the simple concept of OHMs law. The current would vary depending upon the length of fault of the cable. This prototype is assembled with a set of resistors 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 of the same. The fault occurring at what distance and which phase is displayed on a 16X2 LCD interfaced with the microcontroller. The program is burned into ROM of microcontroller. The power supply consists of a step down transformer 230/12V, which steps down the voltage to 12V AC. This is converted to DC using a Bridge rectifier. The ripples are removed using a capacitive filter and it is then regulated to +5V using a voltage regulator 7805 which is required for the operation of the microcontroller and other components.

Keywords—cable; voltage break down; faults; prototype

I. INTRODUCTION

More than 3 million miles of electrical cables are strung overhead across the country. Add to that at least 180 million telephone and cable TV lines, and it's no wonder hurricanes, tornadoes, fires and ice storms are wreaking havoc on the electrical systems each year, causing utility outages that last days, weeks and longer. Power outages over extended periods present major health and safety concerns and economic losses. 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. For utility companies, undergrounding provides potential benefits through reduced operations and maintenance (O&M) costs, reduced tree trimming costs, less storm damage and reduced loss of day-to-day electricity sales when customers lose power after storms. Creative funding options are often available to make the goal of undergrounding a reality. The underground cable system is very important for distribution especially in metropolitan cities, airports and defense service.

Table 1 -Sample Of Electric Outages Caused By Severe Storms (1996 To 2005) In America

Storm Event	Utility	Date	Customers Impacted	Outage Duration (Days)
Hurricanes Katrina & Rita	Entergy	2005	832,000	Power never restored for some in New Orleans
Hurricane Wilma	Florida Power & Light	2005	3,200,000	18
Hurricane Francis	Florida Power & Light	2004	2,800,000	12
Hurricane Isabel	Dominion, VA Power BGE	2003 2003	1,800,000 790,000	14 8
Ice Storm	Kentucky Utilities	2003	146,000	8
Ice Storm	Duke Carolina Power	2002 2002	1,375,000 561,000	9 8
Ice Storm	KCPL	2002	305,000	10
Snowstorm	Carolina Power	2000	173,000	5
Hurricane Floyd	Virginia Power Carolina Power BGE	1999 1999 1999	800,000 537,000 500,000	5 6 8
Ice Storm	Pepco BGE	1999 1999	213,000 360,000	5 5
Ice Storm	Central Maine Power	1998	250,000	21

II. ADVANTAGES AND DISADVANTAGES OF UNDERGROUND CABLE SYSTEM

1. Advantages

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 cables vary widely, but typically underground cable outage rates are about half of their equivalent overhead line types. Potentially far fewer momentary interruptions occur from lightning, animals and tree branches falling on wires which de-energize a circuit and then re-energize it a moment later.

Primary benefits most often cited can be divided into four areas:

Potentially-Reduced Maintenance and Operating Costs:

- Lower storm restoration cost
- Lower tree-trimming cost

Improved Reliability:

- Increased reliability during severe weather (wind-related storm damage will be greatly reduced for an underground system, and areas not subjected to flooding and storm surges experience minimal damage and 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

Improved Property Values:

- Improved aesthetics (removal of unsightly poles and wires, enhanced tree canopies).

Fewer structures impacting sidewalks

2.**Disadvantages**

The main disadvantage is that the underground cables have higher initial cost and insulation problems at high voltages. Another main drawback is that, if a fault does occur, it is difficult to locate and repair the fault because the fault is invisible.

III. TYPES OF FAULT IN UNDERGROUND CABLES

The most common types of fault that occur in underground cables are,

1. Open circuit fault.
2. Short circuit fault.
3. Earth fault.

1. **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 shorted 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.

2. **Short-circuit fault**

When two conductors of a multi core cable come in electrical 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. For this 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. The same is repeated for other conductors taking two at a time.

3. **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. If the megger indicates zero reading, it means the conductor is earthed. The same procedure is repeated for other conductors of the cable.

IV. LITERATURE SOURCES

Finding the location of an underground cable fault doesn't have to be like finding a needle in a haystack. The common methods of locating faults are

1. Sectionalizing: This procedure risks reducing cable reliability, because it depends on physically cutting and splicing the cable. Dividing the cable into successively smaller sections and measuring both ways with an ohmmeter or high-voltage insulation resistance (IR) tester enable to narrow down search for a fault. This laborious procedure normally involves repeated cable excavation.

2. Time domain reflectometry (TDR): The TDR sends a low-energy signal through the cable, causing no insulation degradation. A theoretically perfect cable returns that signal in a known time and in a known profile. Impedance variations in a "real-world" cable alter both the time and profile, which the TDR screen or printout graphically represents. One weakness of TDR is that it does not pinpoint faults

3. Murray loop test: It is a bridge circuit used for locating faults in underground or underwater cables. It uses the principle used in potentiometer experiment. One end of the faulted cable is connected through a pair of resistors to the voltage source. Also a null detector is connected. The other end of the cable is shorted. The bridge is brought to balance by changing the value of R_B.

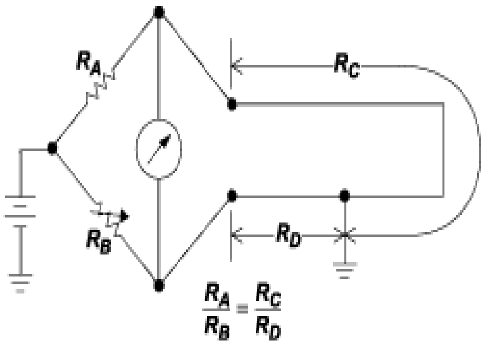


Figure .1.Murray Loop Test

In above figure, R_C is proportional to (l+ (l-x)) and R_D is proportional to l.

Therefore

$R_A/R_B = r = R_C/R_D = (2l-x)/x$ (1)

And hence

$x = 2l/(r-1)$ (2)

Where l is the length on each segment of wire, r is the ratio R_A/R_B and x is the length of faulty segment.

The main disadvantage of this method assumes that only a single fault exists, a low resistance when compared with UG cable resistance and cable conductors have uniform resistance per unit length

4.Varley loop test: If the fault resistance is high , the sensitivity in Murray bridge is reduced and Varely oop may be more suitable but only a single fault exists. Except that here the ratio arms are fixed and a variable resistance is connected to the test end of the faulty cable.

The drawbacks of the above methods can be overcome to certain extent by this method in which the concept of **OHM's law is applied.**

V. EXPERIMENTAL SETUP

In this project simple OHM's law is used to locate the short circuit fault. A DC voltage is applied at the feeder end through a series resistor, depending upon the length of fault of the cable current varies. The voltage drop across the series resistor changes accordingly, this voltage drop is used in determination of fault location.

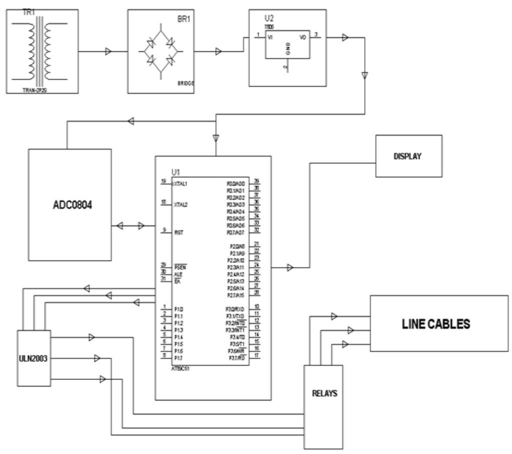


Figure.2 .Block Diagram

Explanation: The project is assembled with a set of resistors representing cable length in KMs and fault creation is made by a set of switches at every known KM to cross check the accuracy of the same. The voltage drop across the feeder resistor is given to an ADC which develops a precise digital data which the programmed microcontroller would display the same in Kilo meters. The fault occurring at what distance and which phase is displayed on a 16X2 LCD interfaced with the microcontroller. In this project we use a microcontroller from 8051 family which is of 8-bit. The program is burned into ROM of microcontroller written in either Embedded C or assembly language. The power supply consists of a step down transformer 230/12V, which steps down the voltage to 12V AC. This is converted to DC using a Bridge rectifier. The ripples are removed using a capacitive filter and it is then regulated to +5V using a voltage regulator 7805 which is required for the operation of the microcontroller and other components.

VI. ALGORITHM AND FLOWCHART

Algorithm:

Step1: Initialize the ports, declare timer, ADC, LCD functions.

Step2: Begin an infinite loop; turn on relay 1 by making pin 0.0 high.

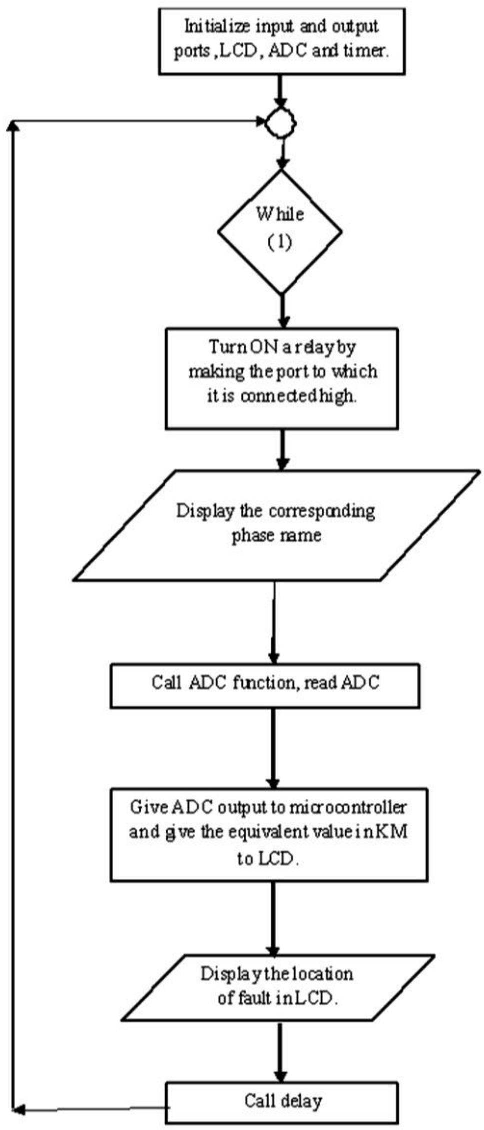
Step3: Display "R:" at the starting of first line in LCD.

Step4: Call ADC Function, depending upon ADC output, displays the fault position.

Step5: Call delay.

Step6: Repeat steps 3 to 5 for other two phases.

Flow Chart



VII. CIRCUIT DESCRIPTION

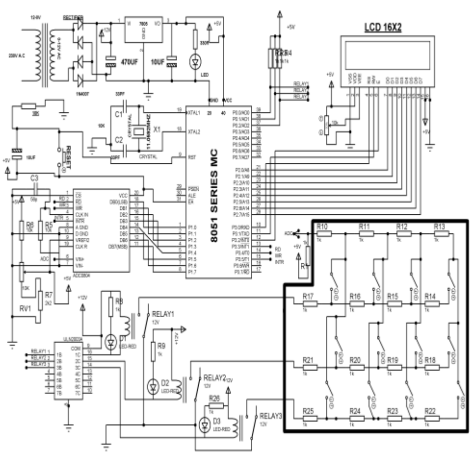


Figure.3. Circuit Diagram

1. Power Supply: The circuit uses standard power supply comprising of a step-down transformer from 230Vto 12V and 4 diodes forming a bridge rectifier that delivers pulsating dc which is then filtered by an electrolytic capacitor of about 470µF to 1000µF. The filtered dc being unregulated, IC LM7805 is used to get 5V DC constant at its pin no 3 irrespective of input DC varying from 7V to 15V. The input dc shall be varying in the event of input ac at 230volts section varies from 160V to 270V in the ratio of the transformer primary voltage V1 to secondary voltage V2 governed by the formula V1/V2=N1/N2. As N1/N2 i.e. no. of turns in the primary to the no. of turns in the secondary remains unchanged V2 is directly proportional to V1.Thus if the transformer delivers 12V at 220V input it will give 8.72V at 160V.Similarly at 270V it will give 14.72V.Thus the dc voltage at the input of the regulator changes from about 8V to 15V because of A.C voltage variation from 160V to 270V the regulator output will remain constant at 5V.

The regulated 5V DC is further filtered by a small electrolytic capacitor of 10µF for any noise so generated by the circuit. One LED is connected of this 5V point in series with a current limiting resistor of 330Ω to the ground i.e., negative voltage to indicate 5V power supply availability. The unregulated 12V point is used for other applications as and when required.

2. Reset: Pin no 9 is provided with a re-set arrangement by a combination of an electrolytic capacitor and a register forming RC time constant. At the time of switch on, the capacitor gets charged, and it behaves as a full short circuit from the positive to the pin number 9. After the capacitor gets fully charged the current stops flowing and pin number 9 goes low which is pulled down by a 10k resistor to the ground. This arrangement of reset at pin 9 going high initially and then to logic 0 i.e., low helps the program execution to start from the beginning. In absence of this the program execution could have taken place arbitrarily anywhere from the program cycle. A pushbutton switch is connected across the capacitor so that at any given time as desired it can be pressed such that it discharges the capacitor and while released the capacitor starts charging again and then pin number 9 goes to high and then back to low, to enable the program execution from the beginning. This operation of high to low of the reset pin takes place in fraction of a second as decided by the time constant R and C.

For example: A 10µF capacitor and a 10kΩ resistor would render a 100ms time to pin number 9 from logic high to low, there after the pin number 9 remains low.

3. External access (EA): Pin no 31 of 40 pin 8051 microcontroller termed as $\overline{EA}$ is required to be connected to 5V for accessing the program form the on-chip program memory. If it is connected to ground then the controller accesses the program from external memory. However in this project internal memory it is always connected to +5V.

4. ULN 2003 relay driver IC: ULN2003 is an IC which is used to interface relay with the microcontroller since the output of the micro controller is maximum 5V with too little current delivery and is not practicable to operate a relay with that voltage. ULN2003 is a relay driver IC consisting of a set of Darlington transistors. If logic high is given to the IC as input then its output will be logic low but not the vice versa. Here in ULN2003 pins 1 to 7 are IC inputs and 10 to 16 are IC outputs. If logic 1 is given to its pin no 1 the corresponding pin 16 goes low. If a relay coil is connected from positive to the output pin of the uln2003, (the relay driver) then the relay contacts change their position from normally open to close the circuit as shown below.

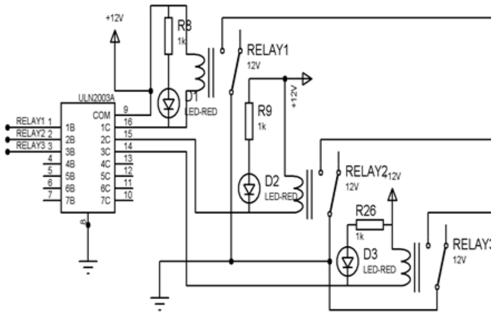


Figure.4. Relay Driver And Relay

VIII. OPERATIONAL EXPLANATION

1. Connections: The output of the power supply which is 5v is given to the 40rth pin of microcontroller and GND is connected to its 20^{th} pin. Port 1.0 to 1.3 of microcontroller is given to 18 to 15 pin of ADC0804. Relay's 1, 2, &3 are given to pins 1B, 2B&3B of ULN2003A and port0.0 to 0.2 of microcontroller. Port 3.0 to 3.5 of microcontroller are given to pin 2,3,5 of ADC0804. Pin's 16,15,14 of ULN2003A are given to relay's RL1,RL2,RL3 which drives set of resistor's (R17, R16, R15, R14), (R21,R20,R19,R18) and (R25, R24, R23, R22).

2.Working: The project uses four sets of resistances in series representing cables i.e. R10,R11,R12,R13 and R17,R16,R15,R14,then R21, R20,R19,R18, then R25, R24, R23, R22 as shown in the circuit diagram, one set for each phase. Each series resistors represents the resistance of the underground cable for a specific distance thus 4 such resistances in series represent 1-4kms. 3 relays are used to common point of their contacts are grounded while the NO points are connected to the input of the R17, R21 & R25 being the 3 phase cable input. R10 is fed with a series resistor R1 to 5v supply. The common point of R10 & R1 is given to input pin of 6 of ADC0804 duly wired as explained above.

3. Operating procedure:

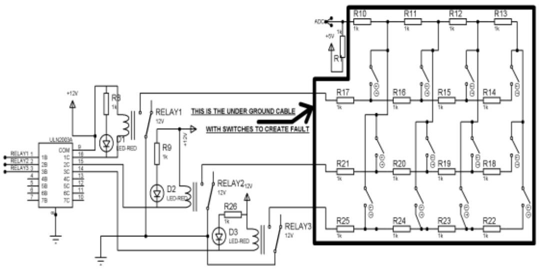


Figure.5. Resistor And Switch (Cable Part)

While any of the 12switches (representing as fault switches) are operated they impose conditions like line to ground (LG), line to line (LL), line to line to line(3L) fault as per the switch operation. The program while executed continuously scans by operating the 3relays in sequence of 1sec interval. Thus any NO point while driven to GND through the common contact point of the relay develops a current flow through R1 & any of the cable by the fault switch depending on the created fault. Thus the voltage drop at the analog to digital (ADC) pin varies depending on the current flow which is inversely proportional to the resistance value representing the length of cable in kilometres. This varying voltage is fed to the ADC to develop an 8 bit data to the microcontroller port1. Program while executed displays an output in the LCD display upon the distance of the fault occurring in km's. In a fault situation it display's R=3km if the 3km's switch is made ON. Accordingly all other faults are indicated.

IX. OBSERVATION AND RESULT

Observation:

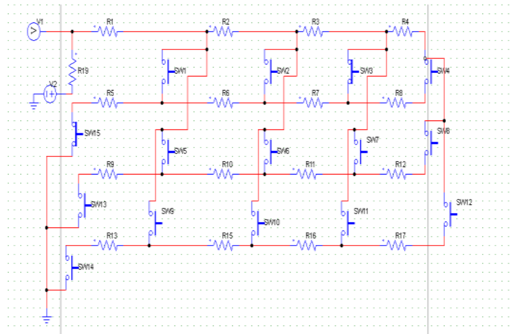


Figure 6: Simulation Of Resistor And Switch Part (Cable) Using Psim

The four sets of resistances in series representing cables i.e. R1, R2, R3, R4 and R5, R6, R7, R8 then R9, R10, R11, R12, then R13, R15, R16, R17and twelve switches representing faults are simulated using PSIM. Switch SW3 is closed. This results in a voltage drop across R19 and the resulting waveform is shown in figure

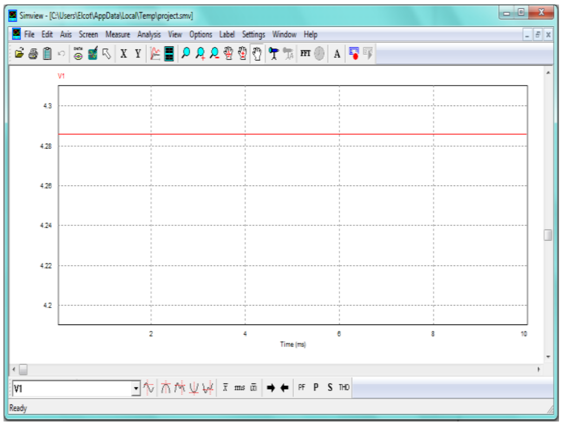


Figure .7.Output Waveform In PSIM

The voltage across R19 when various switches are closed is tabulated as follows:

Table 2 -Simulation Output In Psim

S. No.	Switch closed	Voltage across series resistor (V)	Distance at which Fault occurred (Km)	ADC Output
1	SW1	3.33	1 Km of first cable	170
2	SW6	4.00	2 Km of second cable	204
3	SW11	4.29	3 Km of third cable	219
4	SW4	4.44	4 Km of fourth cable	227

Result: In this method the short circuit fault at a particular distance in the underground cable can be located using simple concepts of OHM's law enables to rectify fault efficiently

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