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Underground Cable Fault Detection Device Using Microcontroller

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***Abstract:** A fault can be defined as any event that interferes with the normal flow of current. Generally, electrical power systems are exposed to the occurrence of any type of contingency, which may be external or internal. Underground cables are commonly used for transmission and distribution of power particularly in cities. Faults in underground cables hamper the continuous supply of power to industrial facilities and households. This paper details different types of faults commonly occur in underground cables and a device has been developed and tested, using ohm's law principle, for detecting underground faults. This system uses an Arduino microcontroller board and a rectified power supply. Here the current sensing circuits, made with a combination of resistors, are interfaced to Arduino microcontroller board to help of the internal ADC device for providing digital data to the microcontroller representing the cable length in kilometers and displayed on LCD display.*
***Keywords:** Underground Cable, Fault Location, Fault Detection, Microcontroller, Power Transmission*

I. INTRODUCTION

Electric power generated at power station can be transmitted or distributed either by Over Head system or through underground cables. Till last decade, a million miles of cables are threaded in the air across the country for transmission and distribution of power to industries and households. Overhead electricity lines are usually held up by wooden poles or steel towers. Typically overhead lines are more common in rural areas as they are used to cover greater distances. Currently, many countries use underground cables for distribution of power. Underground electricity cables are laid below the ground and are usually found in built up areas such as cities. In general, underground cables are not affected by any adverse weather conditions like pollution, heavy rainfall, snow, and storm, etc. However, the major drawback of underground cables is that they have higher installation costs and can introduce installation problems at high voltages compared to the equivalent overhead system. Also, when any problem occurs in cable, it is very difficult to find the exact location of the fault [1,2]. Underground cable faults commonly occur due to weakness of the cable, insulation failure, and breaking of the conductor. This paper presents the types of faults in underground cables and a device used for locating the faults in underground cables.

II. UNDERGROUND CABLES

Underground cables consists of one central core or a number of cores (two, three or four) of tinned stranded copper conductors (sometimes aluminium conductors are also used) insulated from each other by paper or varnished cambric or vulcanized bitumen or impregnated paper. Fig.1 shows the typical structure of underground cable used for power transmission

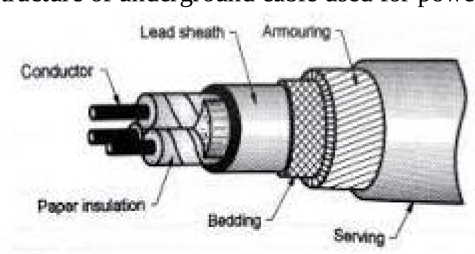

Fig. 1 Structure of Underground Cable

While selecting the rating of underground cables parameters such as current carrying capacity, voltage drop and short circuit rating are considered for economical and optimum size of cable. Cables have one or more than one core depending upon the type of service for which it is intended. It may be (i)single-core (ii) two-core (iii) three-core (iv) four-core etc. For a 3-phase service, either 3-single-core cables or three-core cable is used depending upon the operating voltage and load demand. The Fig.2 below shows the constructional details of a single-core low tension cable.

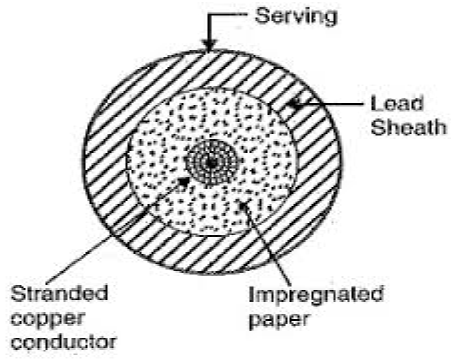

Fig. 2 Single Core Cable

A. Voltage Capacity

Underground cables are generally classified based on voltage capacity.

1) Low-tension (L.T.) cables — upto 1000 V
2) High-tension (H.T.) cables — upto 11,000 V
3) Super-tension (S.T.) cables — from 22 kV to 33 kV
4) Extra high-tension (E.H.T.) cables — from 33 kV to 66 kV
5) Extra super voltage cables — beyond 132 kV

III. CAUSES AND DETECTION OF FAULTS IN UNDERGROUND CABLES

Most of the faults in underground cables occur when moisture enters the insulation, as the paper insulation provided inside the cable is hygroscopic in nature. Other causes include mechanical injury during transportation, laying process or due to various stresses encountered by the cable during its working life. The lead sheath is also damaged frequently, usually due to the actions of atmospheric agents, soil and water or sometimes due to the mechanical damage and crystallization of lead through vibration.

The various types of faults normally observed in underground cables and their causes are given below [3,4]

A. Open Circuit Fault

As the name suggests, this fault involves an open circuit in the conductors. When one or more cable conductors (cores) break, it leads to discontinuity. This discontinuity also occurs when the cable comes out of its joint due to mechanical stress.

1) *Fault Detection and Observation:* An open circuit is characterized by infinite resistance which is utilized in fault detection. The conductors at the far end are bunched together (shorted) and earthed. Then the resistance between each conductor and the earth is measured using a megger. If there's an open circuit in a conductor, the megger will read infinite when connected between that conductor and the earth.

B. Short Circuit Fault

It occurs only in multi-cored cables. When two or more conductors of the same cable come in contact with each other, then a short circuit fault occurs. It is impossible to detect visually without taking the cable apart. A short-circuit fault occurs when the individual insulation of the cables is damaged. It can also be detected using a megger.

1) *Fault Detection and observation:* A short-circuit is characterized by zero resistance. This is utilized in fault detection. The resistance between any two conductors is measured using a megger. This is done for all the conductors, two at a time. If the megger reads zero, it indicates that a short-circuit fault has occurred between those two conductors.

C. Earth Fault

When any of the conductors of the cable comes in contact with the earth, it is called an earth fault. This usually occurs when the outer sheath is damaged due to chemical reactions with soil or due to vibrations and mechanical crystallization. It is somewhat similar to a short circuit fault as the current again takes the least resistive path and flows through the earth. This fault can also be detected using a megger.

1) *Fault Detection and Observation:* The megger is connected between the conductor and the ground and megger reading is noted. This is repeated for all the conductors of the cable. If an earth fault is present, the megger will show nearly zero reading.

IV. METHODS OF FAULT LOCATION

Fault location methods can be classified into different types as discussed below [5].

A. *Online Method*

The online method uses and processes the sampled current and voltages to determine the fault points. This method is less used for underground cables in comparison to overhead lines.

B. *Offline Method*

This method uses a special instrument to test out the service of cable in the field. The offline method is classified into two methods such as the tracer method and the terminal method.

1) *Tracer Method:* In this method fault of the cable is detected by walking on the cable lines. The fault location is denoted from the electromagnetic signal or audible signal. This method is used to find the fault location very accurately.
2) *Terminal Method*: The terminal method is used to detect the location of the fault in a cable from one end or both the ends without tracking. This method is used to find general areas of the fault to accelerate tracking on buried cable.

V. FAULT DETECTION DEVICE

To detect fault in a cable a fault detection device has been designed using the ohm's law principle. When a low voltage dc is applied to the feeder end through a series resistor, then the current would differ based on the location of fault occurred in the cable. In case there is any short circuit occurred from line to ground, the voltage across series resistor alters accordingly and it is fed to an analog to digital converter to develop precise data, which the pre-programmed 8051 microcontrollers will display in kilometers. The block diagram of the device developed is given below.

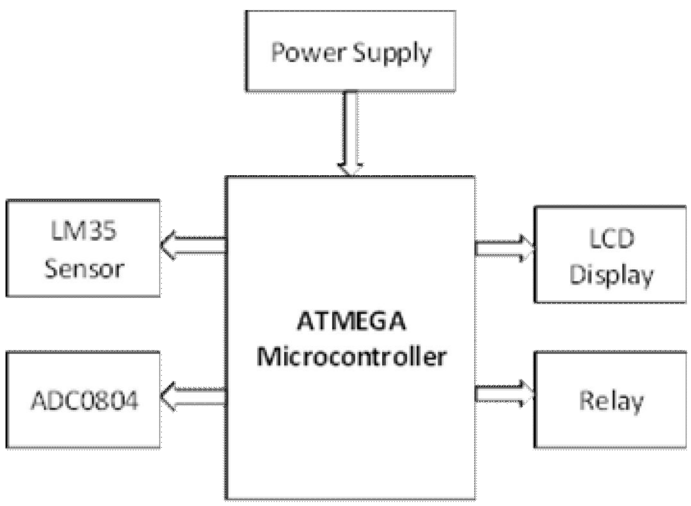

Fig. 3 Block diagram of underground cable fault locator

The four parts of the model include – DC power supply, cable, controlling, display parts. DC power supply consist of AC supply of 230V step down using transformer, the bridge rectifier converts AC signal to DC and regulator is used to produce constant DC voltage. The cable part consists of set of resistors and switches. Current sensing part of cable is represented as set of resistors and switches are used as fault creators to indicate the fault at each location. This part senses the change in current by sensing the voltage drop. The controlling part consists of analog to digital convertor that receives input from the current sensing circuit, converts this voltage into digital signal and feeds the microcontroller with the signal. The display part consists of the LCD display interfaced to the microcontroller which shows the status of the cable of each phase and the distance of the cable at the particular phase, in case of any fault.

A. Working Of Fault Location Device

The AT89S52 microcontroller is used which consume low power and gives high performance. It is a CMOS 8bit microcontroller with 8K bytes of programmable Flash memory. Three relays are used for each phase and the common points of the relays are grounded and the Normally Open points of the relay are connected to the inputs of Resistors. Since, the three phase cable input as supply needed for the relays is higher than that of the Arduino, relay driver is used to boost the supply and provide it to the relays. A 230V AC supply is applied to the transformer from where it is stepped down to 12V AC. From the transformer the alternating current gets converted into direct current when it passes through a bridge rectifier. The 12V DC then goes to the voltage regulator where it gets converted from 12V DC to 5V DC. Regulated 5V DC is used for supplying power to the Arduino and LCD.

When fault is induced by operating any of the switches (to F position), they impose conditions like LG, LL, LLG fault as per the switch operation. As a result of the fault, there is a change in voltage value. This voltage value measured across the resistance and is fed to the ADC of the Arduino. Using this value, the Arduino computes the distance. Finally the distance of the fault from the base station is displayed in kilometer. The device has been successfully tested in the laboratory. It is planned to test the device in actual site conditions in the future.

VI. CONCLUSION

Underground cables, laid below the ground, are suitable for power transmission and distribution for highly populated cities. However, faults occur in the cables resulting in disruption of power supply. The paper presents the device developed for locating the underground cable faults. The underground cable fault locator is tested and favorable results were obtained. This hardware model can locate the exact fault location in an underground cable. Further this work can be extended by using capacitor in an AC circuit to measure the impedance which also locates the open circuited cable fault, unlike the short circuited fault only are located using resistors in DC circuit in the above device.

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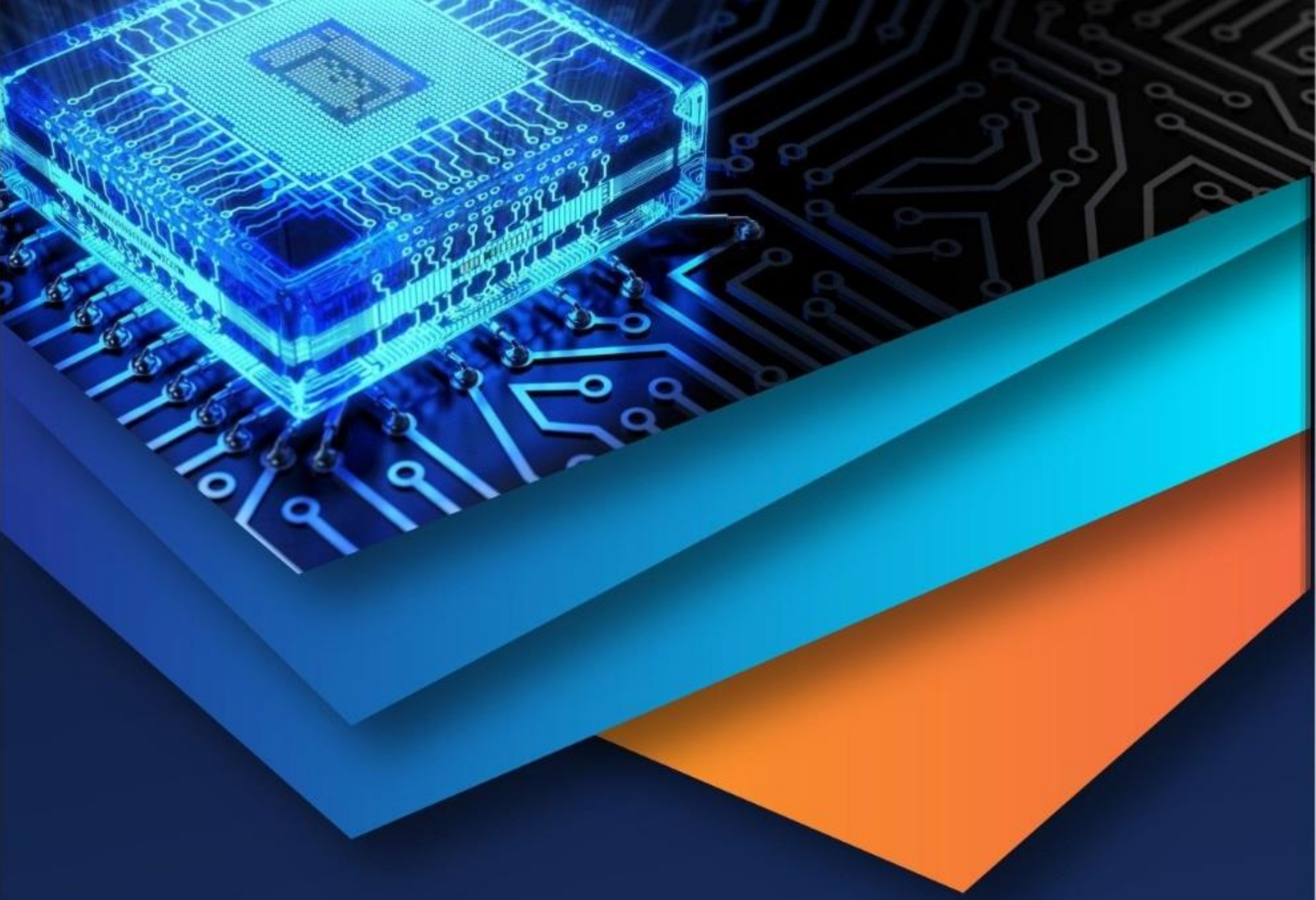

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