Identification & Location Testing Techniques for Underground Cable Faults

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Abstract— A fault is one of the most important drawbacks in the power system whether it occurs due to instruments failure or cables failure. Mostly fault occurs in conductors or cables due to weakness, in homogeneity or any defect. These faults generally take long time to detect and hence long time to repair the damaged cables and restore the power supply. Long outages cause heavy production loss to industries, revenue loss to power distribution companies and inconvenience to general public. This calls for quick fault location and restoration of power supply in minimum possible time. The aim of this dissertation is to introduce the techniques for pin pointing the location of the different types of faults and to work out the distance or gap of cables through one end to other end.

Key words: Underground Cable Diagnostic, Insulation Diagnostic, Fault Location, Fault Identification, Location Method

I. INTRODUCTION

Underground cables are the replacement of overhead cables providing electrical power or telecommunication with underground cables. It is typically performed for an aesthetic purpose, but also serves the purpose for making the power line less susceptible during high wind, or heavy snow or ice storms. Underground cables cost eight times (the cost per km) when compared to overhead lines. Underground cables are used for transmission in many parts of India as well as other parts of the world. In India cities like Mumbai, Bengaluru, Delhi, Chennai, Hyderabad etc transmission cables of class 66kv to 220 kV have already been laid and are in service. The main problem arises for transmitting the power at the long distance. To achieve a good balance between actual power transmitted and the losses. The transmission has to be done at high voltage i.e. at 33kv and higher. The problem with the higher voltage is that it requires higher insulation that raises the cost of the cables. Long distance underground ac have greater capacitance means it is dangerous for handling such cables, which are more than 80km/100 kms long. The around for them is to use high voltage direct current (HVDC) instead of HVAC. However, the problem with HVDC is to convert the DC into AC at sending and receiving end. As 99% of the systems worldwide work on AC and that would mean more power loss.

II. PRE-LOCATING METHODS

A. Time Domain Reflectometer

Electrical pulses are transmitted into the cable, and a portion of the pulse energy will be reflected back to the instrument from cable discontinuities or faults. The fault characteristic impedance Zi will be different from the cable characteristic impedance Zc, the reflection coefficient is:

$$\rho = (Z_i - Z_c)/(Z_i + Z_c)$$

The reflection pulse voltage is:

$$U_n = \rho U_i = [(Z_i - Z_c)/(Z_i + Z_c)]U_i$$

From the equation (1), when the cable has Open Circuit fault, $Z_i \to \infty$, $\rho=1$, then the reflection pulse is positive. While the cable has Short Circuit fault, $Z_i \to 0$, $\rho=-1$, the reflection pulse is negative. Under normal condition, the fault is usually poor isolation; the absolute value of reflection coefficient is less than 1.

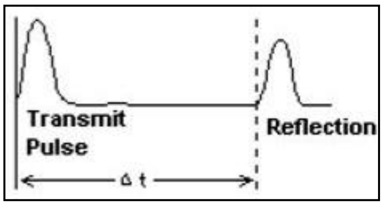

Fig. 1(a): Open Circuit Fault Waveform

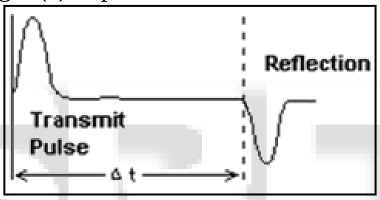

Fig. 1(b): Short Circuit Fault Waveform

Fig.1 Different condition of fault waveform

TDR works like radar. A first time pulse is injected into the cable system at one end (near end). As the pulse travels down the cable, any change in the characteristic impedance (impedance discontinuities) will cause some of the incident signal to be reflected back towards the source. The reflecting pulse source is positive or negative depending on whether the impedance is greater or less than the cable characteristic's impedance. The initial pulse and the reflected pulse are plotted against time on the instrument display, like an oscilloscope. Since, the instrument can be calibrated to determine the speed of the pulse in the cable, the conductor distance to the end of the system can be determined.

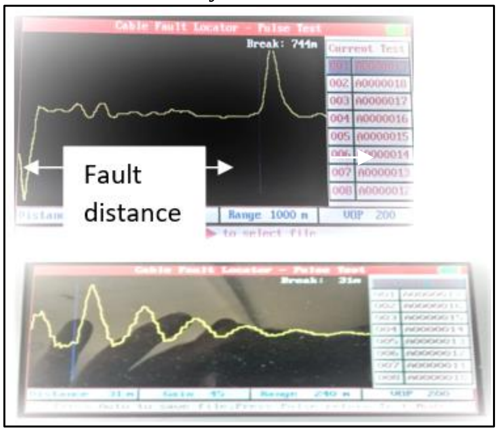

Fig. 2: TDR/Pulse Generator Graph Sequence, Display Of Automatically Measures Multiple Sequence

This information can also be used to locate discontinuities indicated by reflected pulse. In addition, the shapes of the reflected pulses on the instrument display help the operator to determine the nature of the discontinuity.

The magnitude of the reflection at a discontinuity is calculated as the reflection coefficient or ρ. It is calculated as:

$$\rho = (Z_i - Z_c) / (Z_i + Z_c)$$

Where, Z_c is the character impedance of the cable and Z_i is the impedance of discontinuity.

The value of ρ ranges from 1 (open circuit) to -1 (short circuit). A reflection coefficient of zero indicates there is no reflection, implying that the cable system terminates at impedance equal to the characteristic impedance of the tested system.

B. *Bridge Testing Method*

The fault resistance of poor Insulation is very high, much more than the cable's surge impedance, the pulse reflection is very weak and it is difficult to judge the fault point. At this time, we should use Bridge test mode. The tester also has mega meter and ohmmeter function.

We assume that the resistance of the whole cable is R, if we can test the resistance between the fault point and the other terminal is Ra, and we know that the length of centre yarn is La, and then we can get the following conclusion:

$$L_a = (R_a/R)\ L$$

The centre yarn rate is changes according to the temperature and different diameters of line, but the influence is the same in the range of the cable's length. If we use R_a/R this proportion calculation method, we can remove the influence.

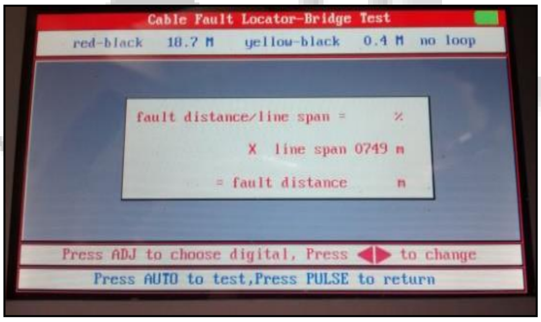

Fig. 3: Bridge Sequence, Display of Automatically Measures Sequence

Fig. 4: Example of CFL Unit (up to 8km)-TFL-5

When testing, the testing will calculate the R_a/R automatically, and then we should input some data in order to calculate the L_a. If the diameter of the whole cable is the same, we need only input the cable's length (L); If the cable has many different diameters, we need input part diameters and part length of the cable (See details in the third part) The tester adopts intelligent bridge technology, users only need to connect the line well, input the length, part diameters etc, press some keys, and then the fault point will be calculated out.

III. PIN-POINTING METHODS

A. *Acoustic Method*

For cables laid inside conduits, which have similar individuality with through unknown cables, pin-pointing high resistive and alternating faults are often difficult. Acoustic method can be used to pin-point the accurate fault location. As signal source, a surge generator is used in recurring pulsing mode. High energy pulses from a surge generator (SSG) create a voltage pulse to go along the cable. Flashover happens at the point of the fault. These recurring noises/sounds are detected from the surface ground by using a ground microphone, receiver and headphone. Nearer the distance from the fault to the microphone, the higher amplitude it will identify from the flashover noise. If it is placed directly on top of the fault position, the highest level of flashover noise can be detected. Using a higher energy surge generator would have an enhanced effect on creating higher flashover noise. The flashover noise may differ depending on.

How cavernous the cable conduits are buried, but the flashover noise is regularly audible even when the cable fault is inside the conduit. The acoustic fault location set comprising the receiver (UL30) and the ground microphone (BM30) contain the special characteristic of digital proliferation time - distance measurement. Firstly, the ground microphone measures the electromagnetic signal that can be recorded all beside the cable where the HV impulses are travelling. As this signal is obtainable all the length of the cable trace towards the fault, it can supplementary be used to make sure that the "cable trace" is followed. The maximum signal can authenticate that the location of the ground microphone is now directly above the cable. Secondly, the ground microphone perceives the flashover noise approaching from the fault via the ground when it gets more rapidly to the fault location. Therefore, every flashover activates two unlike triggers, Electromagnetic Trigger and Acoustic Trigger. The two signals have dissimilar propagation velocity. Further the distance to the fault influences the divergence in triggering the acoustic trigger and electromagnetic trigger. The digital receiver automatically converts the deliberate time (propagation time) from the fault location and indicates the distance with a digital meter. According to the meter indication, anywhere the distance signal is the nearest, the fault location can be locate. By detecting both electromagnetic and acoustic signal, the precise position of the fault location can be determined. This particular characteristic increases the performance compared to further 'acoustic only' pick-up sets. Besides, the electromagnetic indication can moreover support in doing uncomplicated cable tracing.

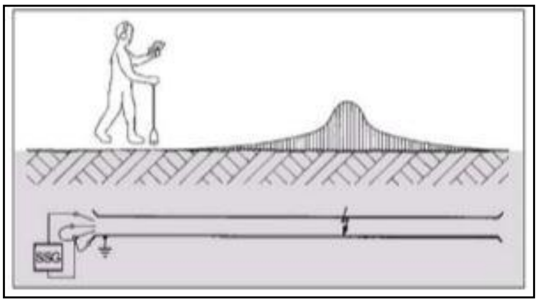

Fig. 5: Schematic Connection and Shape of Acoustic Signal-Acoustic Fault Location

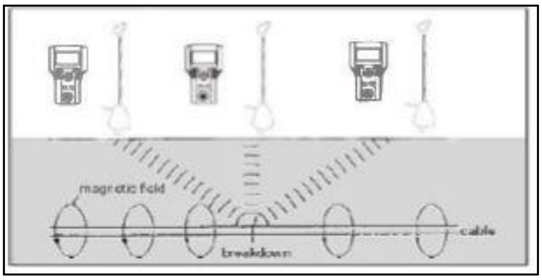

Fig. 6: Electromagnetic Signal along the whole cable, Acoustic Signal at Point of Flashover

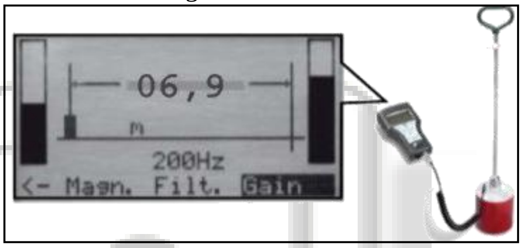

Fig. 7: Example of Signal Pick Up set BM30 and UL30, UL30 Digital Receiver Indicates Electromagnetic and acoustic signals and the distance to the fault location (e.g. 6.9 meters)

B. *Step Voltage Method*

With a surge generator would not be capable to make a flashover at the fault end while the cable faults have undeviating contact to the soil or ground. When there is no audio signal or no flashover noise is capable of being heard, cable fault pin-pointing with the acoustic method is not likely. This situation is mostly consequential from a entirely burnt cable fault that is furthermore resistive to the nearby soil. These kinds of cable faults can then be pinpointed by using the step voltage method. Faults in low voltage cables as well as conduct cables (signal lines) are frequently complicated to pin-point; this is because the high voltages that useful to the cables do not have sufficient surge energy to create a strong audible flashover. As these cables are mainly unprotected, cable faults in most cases appear to have a straight contact to the adjacent soil. The step voltage method becomes further appropriate in such case. An additional fault kind presentation similar condition is the cable sheath fault. As there is no exact potential point, a fault at the external defensive PVC insulation of a XLPE cable cannot be positioned via the acoustic method. Accordingly, it is again hard to create a sturdy flashover noise. The step voltage method enables the localization of the cable scabbard faults. This method also enables to position several sheath faults along a cable. In here, two potential earth probes are used mutually with the receiver. As soon as the earth probes are located on the ground the length of the cable trace, the potentiometer in the receiver will point to the way with higher potential which is the fault end. Follow the direction until the potentiometer points to zero. The fault position is then determined.

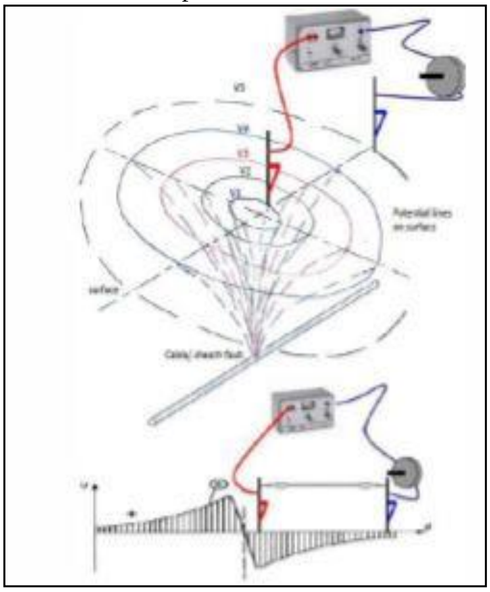

Fig. 8: Step voltage methods, KMF I Receiver are connected to two earth probes

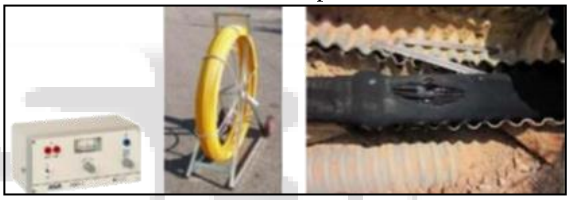

Fig. 9: Example of KMFI Receiver (left), Conduit Rod (middle), Photo of cable fault in conduit (right)

IV. CONCLUSION

Underground cable faults cannot be avoided due to many factors such as road widening, transportation improvement, digging conceded out for repairs of other underground utilities etc. There are many ways of using different techniques to locate cable faults inside conduits. By knowing and applying different cable fault location techniques, it would become easier and faster for the electrical technicians to locate cable faults even when the cables are laid inside conduits. The important points are to understand the environmental conditions, for example soil conditions, weather conditions, road conditions, etc., as well as understanding the cable fault conditions.

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