

Cable fault locating can be quite challenging even though there is a number of fault locating techniques and quite a few tools to help out with underground cable faults. Most of these issues are due to technicians not properly interpreting the test results and then selecting the wrong tool for the task at hand, and ultimately a lot of wasted time is due to taking a shortcut in the process.

The challenges of underground fault locating may be minimized significantly by understanding

the equipment and techniques available. Education and experience in cable fault locating will help correct and make improvements in interpreting of the results and definitely will help correct and make improvements in the selection of which equipment and technique is most appropriate for a particular task. However, only a high level of awareness is going to correct wasted time that is afforded through taking shortcuts.



Figure 1 – KEP Fault Locating Equipment

► Thumping a Cable

One of the oldest and most popular techniques out there is a technique called the capacitor discharge technique or thumping a cable. In application this technique is actually very straightforward and simple. In essence, a device called the thumper, or surge wave generator, creates a high voltage surge which is

launched out onto the faulted cable. This surge of energy will travel along the cable conductor. If it reaches an area of dielectric breakdown or a failure in the insulating material, the transmitted energy will discharge through the gap at the fault and discharge all of the energy through the faulted insulation. All the fault current will then

come back through the neutral or shield on the cable, back into the surge wave generator, and then will be dissipated safely to earth potential.

If a several thousand volt surge is sent into the cable, and all that energy is discharged through the gap or fault, it is going to cause a small explosion. Buried in the ground, this small explosion will cause a percussion and sound

wave to travel up through the layers of earth. As a result, a thumping sound can be heard on the surface of the ground. To locate the defect in the underground cable, a repair crew has to walk along the surface of the ground listening for this thumping sound. Once the fault is pinpointed, the crew digs a hole and repairs the faulted cable.

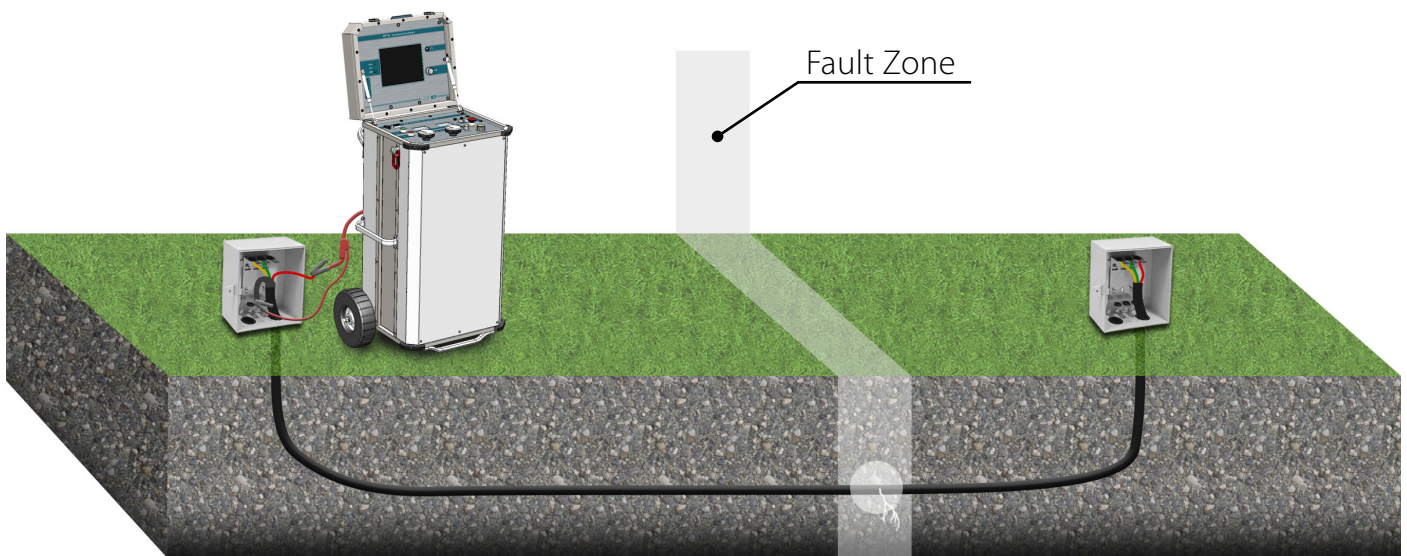


Figure 2 – Capacitive discharge (Thumping)

Advantages and Disadvantages of Thumping a Cable

The advantages of the capacitor discharge technique are that it is very accurate to do pinpointing and is easy to learn. This technique requires fairly minimum training, in particular, some safety training on how to properly handle the instrument, how to properly make connections, and how to set the various controls.

The weak point of this technique is that it is extremely time consuming and potentially harmful if misused. In some cases it may take

hours or even days to walk the cable and definitely locate the fault. During that time the cable is exposed to high voltage surges, leading to a higher rate of repeat failures on the service age polyethylene cables. Repetitive thumping could be accelerating the vented tree channel growth of other water trees that under natural aging may have lasted several more years of service life. In essence, the cable is being set up for a future fault in the process of trying to find

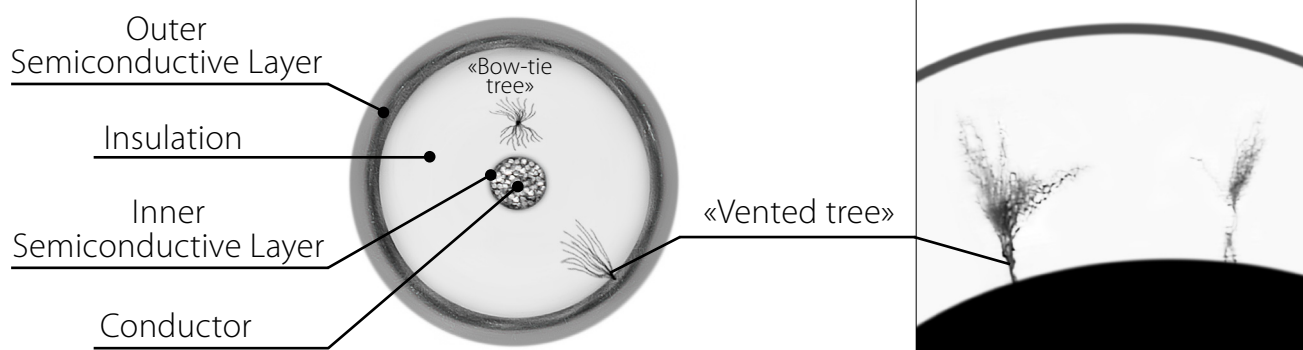


Figure 3 – Water tree sample

the current fault. Thus, this technique, if used all by itself, can be potentially harmful. The same is not necessarily true for the paper insulated lead-covered cables, where typically higher voltages and more energy is required to locate faults, with no noticeable damage to the cable.

Also this technique will not find faults that do not arc over. So, for instance, if there is a dead short, what is called a bolted fault, where basically the conductor and neutral have come together and bonded, if there is no gap, there is no sound no matter how much energy and voltage is discharged into the circuit. There is no energy being discharged or jumped across, there is just basically a constant current loop. So, since there will not be an acoustic event, it will not be possible to pinpoint a bolted fault, or a dead short. Again, in order to have sound, there needs to be a gap, and there needs to be air.

Another challenge for the capacitor discharge technique is a gap that is too large. For instance, the cable blows apart, and in the process of blowing apart the conductor had burned back into the dielectric material, or the neutral had burned back, causing a sizable distance in that gap. No matter how much voltage is applied to it, the gap is physically too large to actually arc across. The choice here may be the burn down technique, with the insulation resistance burnt away to reduce the gap size in order to get the thumper to discharge an arc across properly. But, again, this is going to come with stress to the cable.

To reduce the amount of stress applied to the cables under test, the surge or thumping technique is combined with pulse echo.

▶ Time Domain Reflectometry for Cable Fault Locating



Figure 4 – Time Domain Reflectometry for Cable Fault Locating. Pulse Echo

Another time-proven cable fault locating method is time domain reflectometry (TDR), which has some variations, including the pulse

echo, arc reflection, and impulse current. This section will focus on the pulse echo method, its principle, benefits and associated issues.

The Basics of Pulse Echo

The pulse echo technique is performed with a time domain reflectometer (TDR), which combines a transmitter and a receiver. The transmitter sends out a low voltage high frequency pulse of a short duration onto a cable. This pulse of energy travels along the surface of the cable until it encounters some type of disruption manifested in a change within the characteristic impedance of the cable; these mismatches in the characteristic impedance

of the cable may be caused by the start of the cable, splices in the cable, transformers, faults, etc. Depending upon the magnitude of the impedance change, either part or all of the transmitted energy reflects and travels back to the time domain reflectometer. In essence, this technique creates an electronic or a graphical roadmap of the underground cable showing different events along that path.

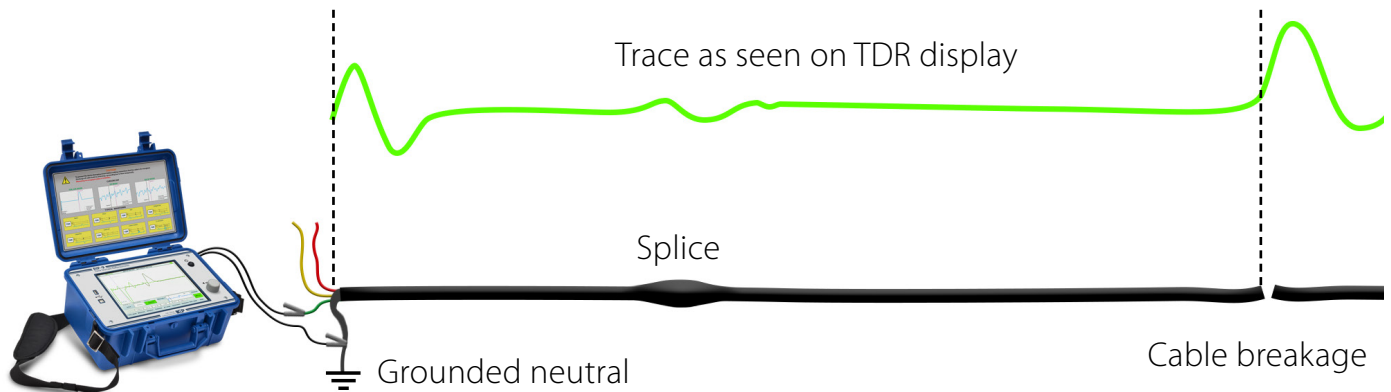


Figure 5 – TDR Return Cable End

The elapsed time of a transmitted pulse traveling the entire length of a cable and the pulse reflections produced by deviations from the harmonious structure of the cable are shown on a screen. These reflections are then shown in a time sequence.

So, on the graphic display of a time domain reflectometer, the first event is the pulse or the start of the cable and then the first mismatch impedance, second mismatch impedance, etc. Everything is shown in a time domain format. Thus, time domain reflectometers make it possible to see into a cable, visualizing different cable landmarks such as splices, transformers,

cable transition areas, the start and end of a cable, etc. In addition to this, TDR also provides the ability to take measurements of the cable length and relatively easily locate faults that are in series with the cable transmission path, such as a broken or open conductor, neutral or severe corrosion building up on a concentric neutral, separated splices or sealed off cable ends, etc. To a lesser extent the pulse echo technique can be used to locate a shunt cable fault or faults in the dielectric material in the cable, provided that the resistance of the insulation fault is of value less than 10 times the characteristic impedance of the cable being viewed.

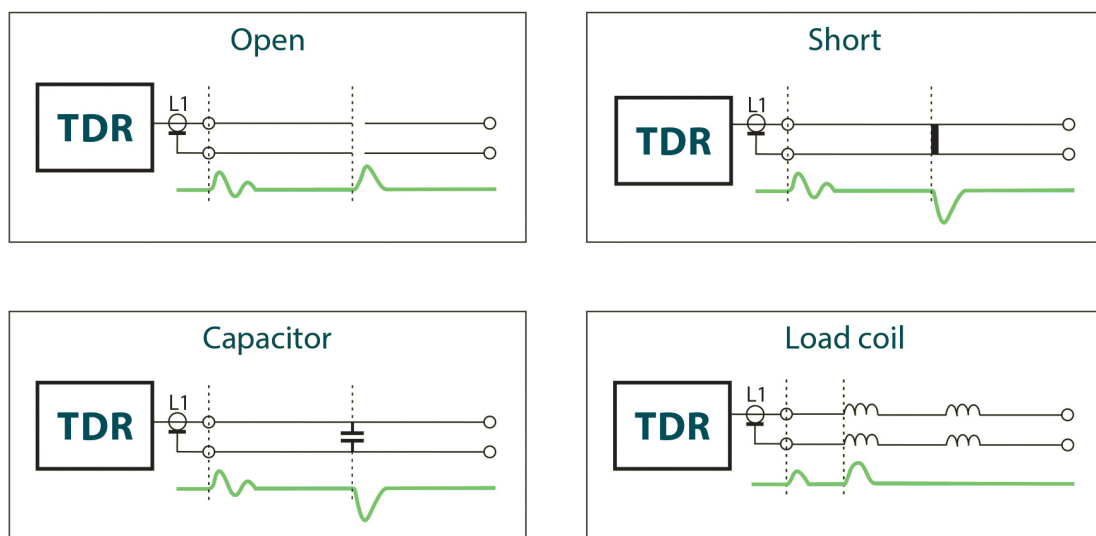


Figure 6 – Typical Waveforms

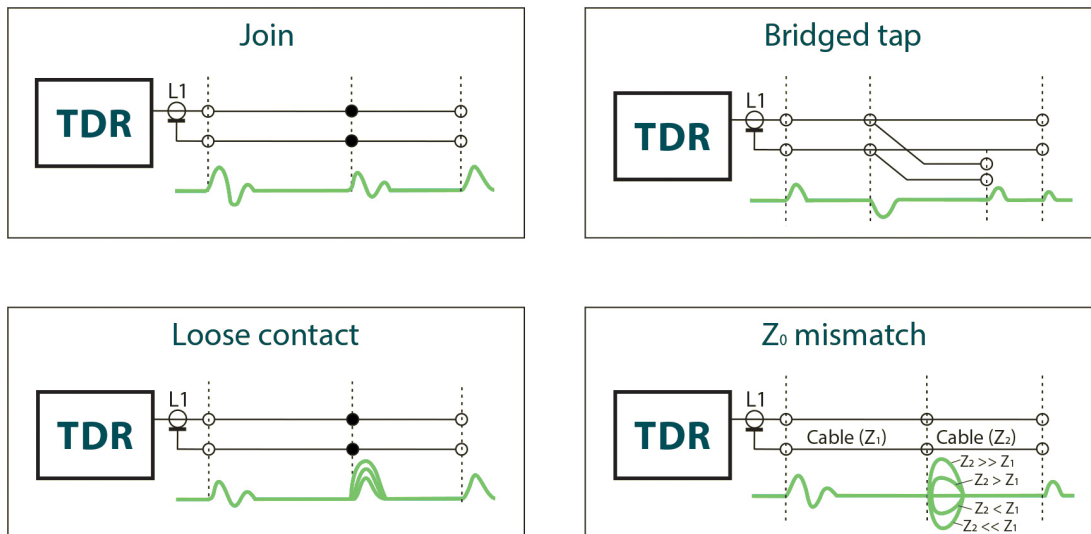


Figure 7 – Typical Waveforms

Finding the Distance to the Cable Fault

Measurements on a time domain reflectometer are made by measuring time. The TDR actually measures the amount of time it takes a pulse to launch out onto a cable, and then it starts to measure the elapsed time to when those reflections start to come back in. To find out the distance to where the pulse traveled, the TDR automatically takes the total amount of time that a pulse takes to leave and to return, divides that by half and then multiplies that by the speed at which the pulse is traveling.

A very important setting on the time domain reflectometer is velocity of propagation. Velocity of propagation is the speed at which high frequency pulses are traveling on a given cable and the speed at which these pulses

travel will be influenced by the type of dielectric material and the thickness of the cross-sectional geometry of the cable.

Yet, even not knowing the details of the given cable, like its velocity, total length, and not knowing the particularities of the circuit, it is still possible to get very accurate results using a time domain reflectometer by simply taking advantage of the fact that the cable has two ends. To find a cable disruption in this case, it is necessary to measure the distance to the fault from both ends with the same velocity value; even if the velocity value is wrong, the fault will be pinpointed accurately.

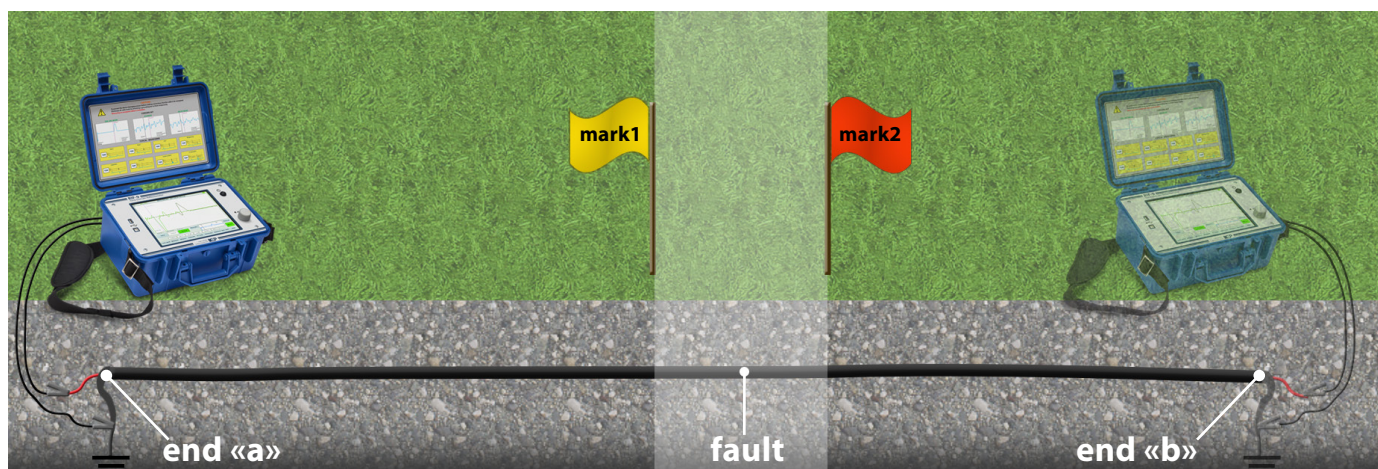


Figure 8 – If Velocity of Propagation is not known

To locate the fault, the distance should be first measured from end “a” and then marked on the ground. After that, the distance to the fault should be measured from end “b” and marked on the ground as well. In result, if the velocity was set too low, the fault will be undershot from both sides, with the true fault location being between the two markers. Naturally, if the velocity was set too high, the fault is going to be overshoot from

both sides, with the true fault location still being between the markers. Hence, even with very little information about the cable and no knowledge of the right velocity value, accurate results can be received by simply doing bidirectional measurements. When measurements are made on a longer cable, the total cable length can be divided into smaller sections.

Advantages and Disadvantages of Pulse Echo

The strong point of the pulse echo technique is that it enables relatively easy and fast faultfinding. All the results are shown on the TDR screen, which means there is no need to walk along the cable path tracking the fault. Another important advantage is that this approach uses safe low voltage pulses, preventing stress to the cable and making the process safe for technicians. The time domain reflectometer can be used on various cables all the way up through a low voltage, medium voltage and high voltage on electrical power cables. The obtained pulse echo

signatures can be used for diagnostic values. For instance, to examine the splices within a three phase circuit, it is possible to capture all three phases, overlay them together and examine some of the issues that may be occurring on one phase and not occurring on another phase.

One of the drawbacks of the pulse echo technique is that traces that result from complex circuits can be difficult to interpret. For example, in a circuit with several “T” or “Y” connections, when the reflections from them are overlaid,

it can result in a very complicated wave form. This means that it may be very difficult to make meaning of all these reflections. The recommended practice in this situation is to use differential pulse echo: basically, a picture of a good cable phase is taken, and then a picture of the faulted cable phase is made. Everything that is common, all the areas where they share common "T" and "Y" connections, transitions, etc., all these images will be the same. So, the two common data points from these two waveforms

are subtracted, which will display the points of difference or potential fault on the bad phase.

Another problem is that it is impossible to locate with pulse echo alone a dielectric fault or insulation fault where the resistance value is ten times or greater the characteristic impedance of the cable being viewed. In this case the recommended technique is arc reflection, and it will be discussed below.



Trace description:

1. Positive reflection at the cable end
healthy core
2. Negative reflection at the faulty point (short circuit)
faulty core

Figure 9 – Comparison Method

► Arc Reflection Technique (ARC)

The technique of Arc Reflection (ARC) combines the surge wave generator (thumper) and the pulse echo technique (TDR) for the purpose of locating high resistance shunt faults and intermittent shunt faults.

Although the pulse echo technique is a very

good tool for a low voltage cable application, a problem occurs when this method is used on medium voltage electrical power cables.

To locate vented trees, which basically form a hole in the insulation, a breakdown voltage is typically required. The pulse echo tool by itself

is very low voltage in nature. So, if the fault requires some level of breakdown voltage, the low voltage pulse echo energy will travel straight past the fault never seeing it. The TDR will just show the reflection of energy off the terminating event or the end of the cable.

Yet, if a high voltage breakdown surge is applied at the same time that the pulse echo pulses are sent, when the fault breaks down due to the high voltage surge and the arc jumps through the faulty insulation, the pulse echo wave will reflect off that arc.

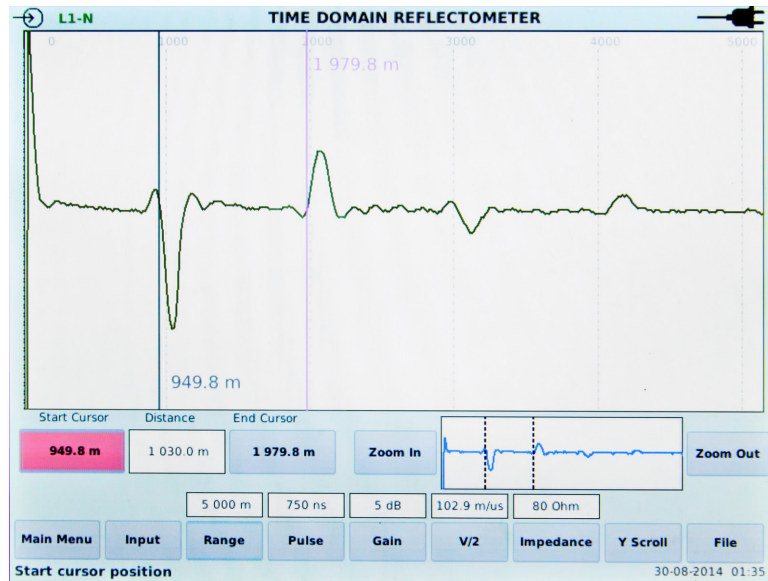


Figure 10 – Arc Reflection

For the ARC, a coupling device (a filter, or a power separation unit) is introduced into the circuit allowing the high voltage surge generator and low voltage time domain reflectometer to be combined simultaneously to the faulted cable. The function of the surge generator is simply to transmit a high voltage surge into the faulted cable. This surge momentarily reduces the resistance of the shunt fault. During the high

voltage impulse time interval the pulse echo technique is applied.

In other words, the momentary reduction in the shunt resistance established by the high voltage impulse, or arc created at the fault will create a point of reflection for the low voltage pulse transmitted by the time domain reflectometer and help to identify the fault.

Advantages and Disadvantages of Arc Reflection

The strong point of the ARC is that it helps localize any fault that will sustain an arc during the thumper pulse. Even though a surge wave generator is used, this method significantly reduces the amount of stress that is traditionally

associated with the thumping technique because only one or two surges into the cable are needed in order for the pulse echo to be able to find the fault, display that image and measure the distance.

So, the amount of stress to the cable is considerably decreased by reducing the number of surges it's going to take to find this overall fault, and the output voltage is regulated by the reflection filter or power separation unit.

One disadvantage of this method is that long cables with very highly attenuated dielectrics or a lot of corrosion on the neutrals can very quickly absorb the reflected pulses of the pulse echo technique. Thus, if the TDR does not have enough transmitted pulse energy to overcome these very long cables or high corrosion is bleeding down the signal, it may not be possible to see the end of the cable or the actual fault

event just because the signals attenuate before they get back to the receiver.

Also, if it's a complex circuit with many branches and therefore a lot of reflections, the waveform can be difficult to interpret. In this case, a differential technique called differential arc reflection can be applied.

The first step is to get a standard low voltage pulse echo waveform and then capture that image. Then, the high voltage surge is applied to the cable, the arc or flashover is created and the time domain reflectometer displays a new waveform showing the reflection from the arc.

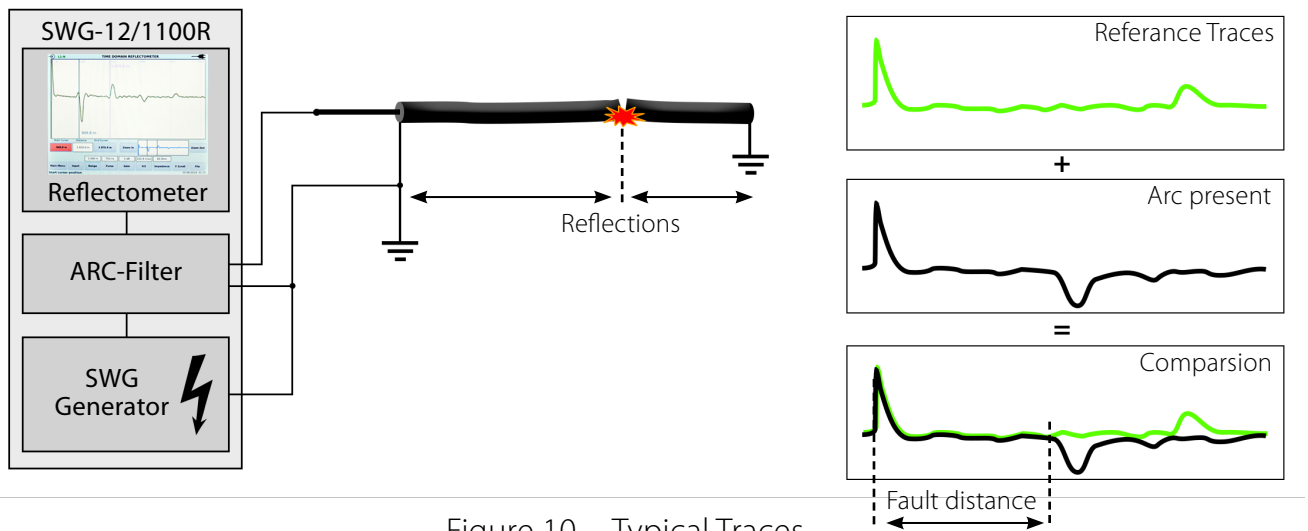


Figure 10 – Typical Traces

Since the result is two wave forms which are really just an accumulation of data points, the computer or the analyzer will cancel everything common, getting rid of all the unwanted

reflections. This will clearly show points of difference where the arc took place, allowing to very quickly visualize and measure the distance to the flash point, or reflection point of the arc.