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Cable and Cable Fault Locating - Part 3

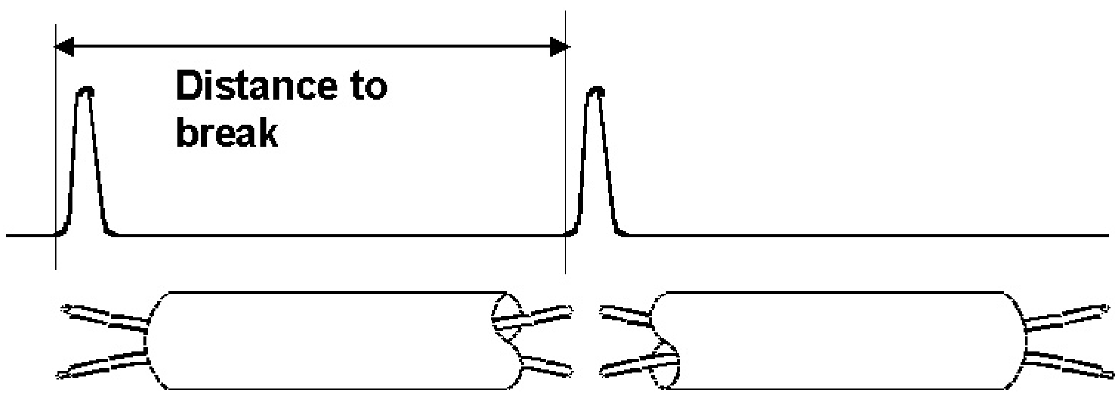
This is the third of a four part series on cable and fault locating technologies that are in common use today. This installment is on using Time Domain Reflectometers (TDRs).

TDRs have been used in the CATV and Telecommunications industries for many years and are now growing in popularity for troubleshooting a wide variety of cable problems. They also have several other uses that can benefit the operations of utility companies. Heat tracing cables can be inspected with this method, theft of service can be detected, cable lengths can be determined for inventory purposes. Even metal loss on exposed neutrals can be located!

A TDR is the most convenient tool to find short circuits between conductors and open circuits in the tested cable where there is no associated path to ground that can be used for 'A-frame' type ground fault locating. A TDR is usually more accurate for cables in duct where the path to ground may not be at the point of the fault but rather at an unrelated duct damage (i.e. crack or joint).

A basic TDR consists of a pulse generator circuit connected to a display similar to an oscilloscope and both of these are connected to an external connection with test leads. Most TDRs include circuitry to adjust the amplification of the outgoing and returning pulses, cursors to measure pulse timing and width, internal batteries and other controls we will cover further on.

The theory of a TDR is that it transmits a pulse of energy that travels or propagates along a cable. A portion of the energy will reflect back to the sending end whenever it passes a relative change in the impedance of the cable. The time the reflections take to return is proportional to the distance. If we know the approximate speed of the pulse in the cable and multiply it by the time the reflection takes to return, the distance to the anomaly is easily calculated. Most TDR



instruments automatically do the math, displaying the distance in feet or meters.

The polarity of the reflection also tells you more about the fault. A reflected pulse that increases in amplitude (as in the above example) tells the user it is an open circuit at the problem. If the pulse comes back pointing downward, this indicates a lowering of impedance or short circuit.

The speed of the pulse in the cable is not at the speed of light as we might expect but typically closer to half that value. This speed measurement is usually called either 'Velocity of Propagation' (VOP) or 'Propagation Velocity Factor (PVF). There are different methods of expressing the speed, the two most common are as a percentage of the speed of light, the other is in meters per microsecond. The impedance of a cable limits the speed or velocity of the pulse so we need to review this topic. Cable impedance is different from resistance; it includes the sum of all of the reactive resistance we encounter in a cable. The source of this reactance is from four sources:

- the DC resistance of the wire
- the resistance between the conductors through the insulation
- the capacitance created by the insulated conductors
- the inductance of the cable.

The single biggest factor affecting the impedance, and hence speed, is insulation material. For example, signals in coaxial cable propagate at close to 85% of the speed of light, polyethylene (PE) results in a speed of around 65%, and cross-linked PE (XLPE) is a little slower yet at around 54%.

A TDR does require that there are at least two individual conductors in the cable under test, insulated from each other. Multiple single conductors, not in a common jacket often can’t be tested as there is too many impedance changes due to changes in the spacing. This may be overcome by capturing a copy of the traces when the system is new and comparing it to future results after the cable has failed.

TDRs do have a couple of limitations. The impedance of the fault must be quite different from the normal impedance. Series faults have to be close to an open circuit, a corroded or 'green' high-resistance area is often missed. Similarly, a fault to earth or another conductor must be below approximately 300 ohms. Another is that the accuracy of the distance is very dependent on the accuracy of the VOP selected. 1% inaccuracy means potentially digging a 5' hole to find the fault if we are 500' away from the test point. Still another consideration is that a TDR gives a distance to the fault but it does not locate the cable. For this reason, TDRs may be used in conjunction with a cable locator and a measuring wheel to find the true path of the cable. Any cable in slack loops and pole bases, including the 1 meter of depth, must also be accounted for. Finally, the fault must be 'persistent', that is the fault must be there at low voltages. Arcing faults that short only when high voltage is applied require the use of a high voltage surge generator also known as a 'thumper'. Some modern thumpers have the equivalent of a TDR built into them to reduce the number of surges required and thus reduce the electrical over-voltage stress on the cables. Their use are covered next month.

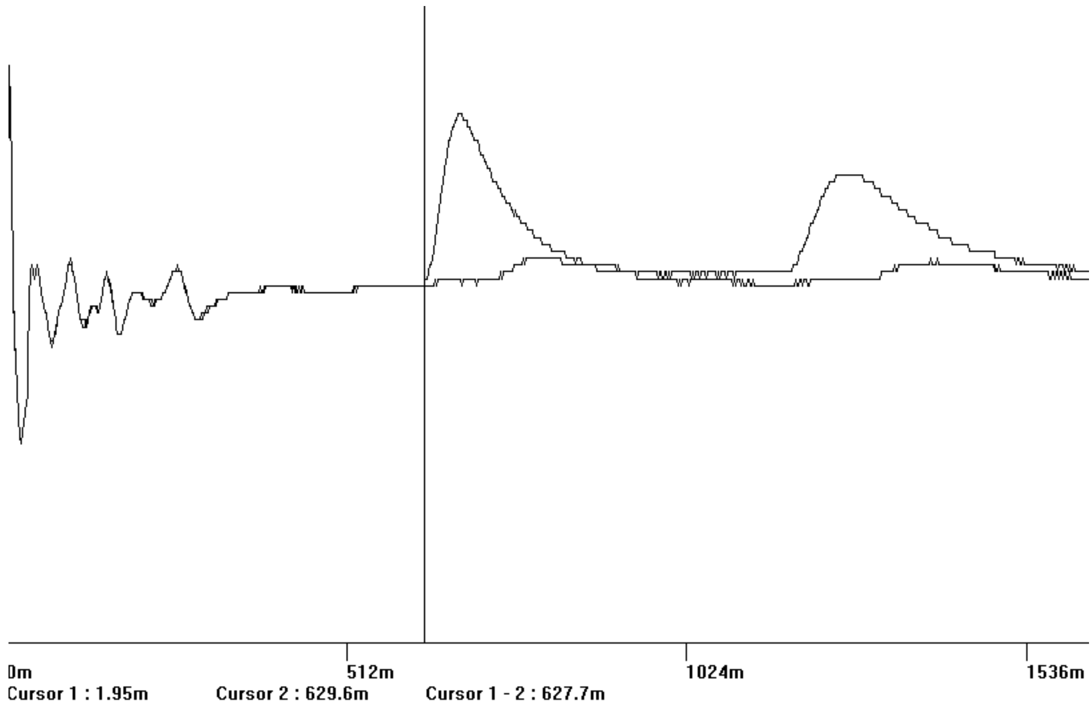
Advanced control of a TDR usually includes several functions.

Pulse Width is usually adjustable for a couple of reasons. A wider pulse will have more energy and be able to test longer distances and show up smaller faults. The trade-off is that faults can be difficult to detect if they are close to the normally occurring reflection caused by the test lead to cable connection or close behind another fault. Narrow pulses give more useable resolution but no more accuracy. An additional but less known use of this is that a narrower pulse has a higher fundamental frequency. A cable that may pass a test with a wider pulse may have problems that show up when a narrower pulse is used. These problems may affect the performance of upper channel signal strength on CATV applications but be completely invisible at power frequencies.

Another advanced control is amplification. Control over the vertical amplification of the displayed trace allows smaller faults with weak reflections to still be detected. Faults can be as small as a pinch on coax and still show up.

A screen zoom function is desirable to allow more accurate placement of a cursor when measuring distances. The resolution of the LCD screen will affect the accuracy of cursor placement and the ability to zoom in to improve the resolution will give greater accuracy.

Two channels and/or memory settings give additional trouble-shooting ability. Due to their



design, or environment (temperature and moisture for example), some cables may show a 'noisy' trace that is difficult to interpret. Comparing a trace on a bad phase to the equally difficult trace on a phase known to be operational will often allow the fault to be detected. TDRs that can show both traces at the same time or even better, mathematically subtracting one trace from the other, make many faults show up very well.

Training. The best equipment manufactured can still not give the needed information if the operators don't understand how to effectively use it. Make sure training and applications support is available, included, and utilized when purchasing test equipment.

The uses of a TDR are just about limitless. Technicians and engineers in any industry using cables can usually find ways of detecting and locating their problems. This includes fire suppression and detection systems; aircraft, shipboard power and communications cables, underground primary and secondary cable, street lighting, mine cables, heat tracing cable and more.

A typical TDR application can be to locate an open circuit in a three conductor power cable in duct. Because of the duct, there is no path to ground to use an a-frame. The graph below shows two traces; one channel on the known good phase shows an open circuit at approximately 1200 meters, the other wire is open circuit at 629.6 meters thus easily showing the fault. Up to the point of the fault the cable exhibit several reflections that when laid on top of one another are easily diagnosed as being normal.

Next month we will be covering cable fault locating using a high voltage surge generator.

If anyone has cable or cable fault locating questions, please e-mail me at the address below and I will send you a reply. With your permission, I would like to share some of these situations in future articles.

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