Determining the Energized Status of URD Cable

New Technology

There are millions of miles of Underground Residential Distribution (URD) cable buried throughout the world. Until now, there was no way to determine if this cable is energized or not. A current probe around the outside of the cable cannot be used because outgoing center conductor current is canceled out by the equal-magnitude opposite-direction concentric neutral current. An electric field probe outside the cable cannot be used either because the URD cable semicon completely shields the center conductor voltage.

The new URD Probe™ by the Origo Corporation solves this problem and now allows utilities to determine if a URD cable is hot or de-energized before spiking or cutting into it. The URD Probe™ can also be used in conjunction with the Origo PhaseID System to determine the phase attribute of URD cable.

Principal of Operation

The URD Probe™ is a precision instrument that is gripped with a "shotgun" hot stick and allows a lineman to precisely probe the URD cable to a predetermined depth using a fine needle. As soon as the needle penetrates the outer semicon shield, the needle capacitively couples to the center conductor to determine the energized status of the cable. The needle does not penetrate through the primary insulation surrounding the center conductor but only the outer semicon which shields the center conductor electric field.

The lineman places the URD Probe™ over the cable to be tested and slowly applies downward pressure on the hot stick. As pressure increases, a fine needle begins to protrude from the probe into the cable. The cable penetration depth in mils (milli-inches) is precisely monitored on the probe LCD display. A mechanical hard penetration stop, based on the cable type, is set prior to probing the cable to prevent over-penetration into the cable.

When the needle touches the grounded semicon, a red light may illuminate indicating that the remaining needle penetration depth required to penetrate the semicon is on the order of 50 mils. As soon as the semicon is penetrated, the red light extinguishes and the yellow (cable hot) light illuminates if the cable is energized.

If the cable is energized, the LCD display toggles between the needle depth and a coupled voltage magnitude number which is related to the center conductor voltage and the needle distance from the conductor. The URD Probe™ also provides an output monitor jack that allows the cable phase attribute to be determined using the Origo PhaseID System.

The URD Probe™ positioned over a short section of URD cable is illustrated below.

Origo URD Voltage Probe

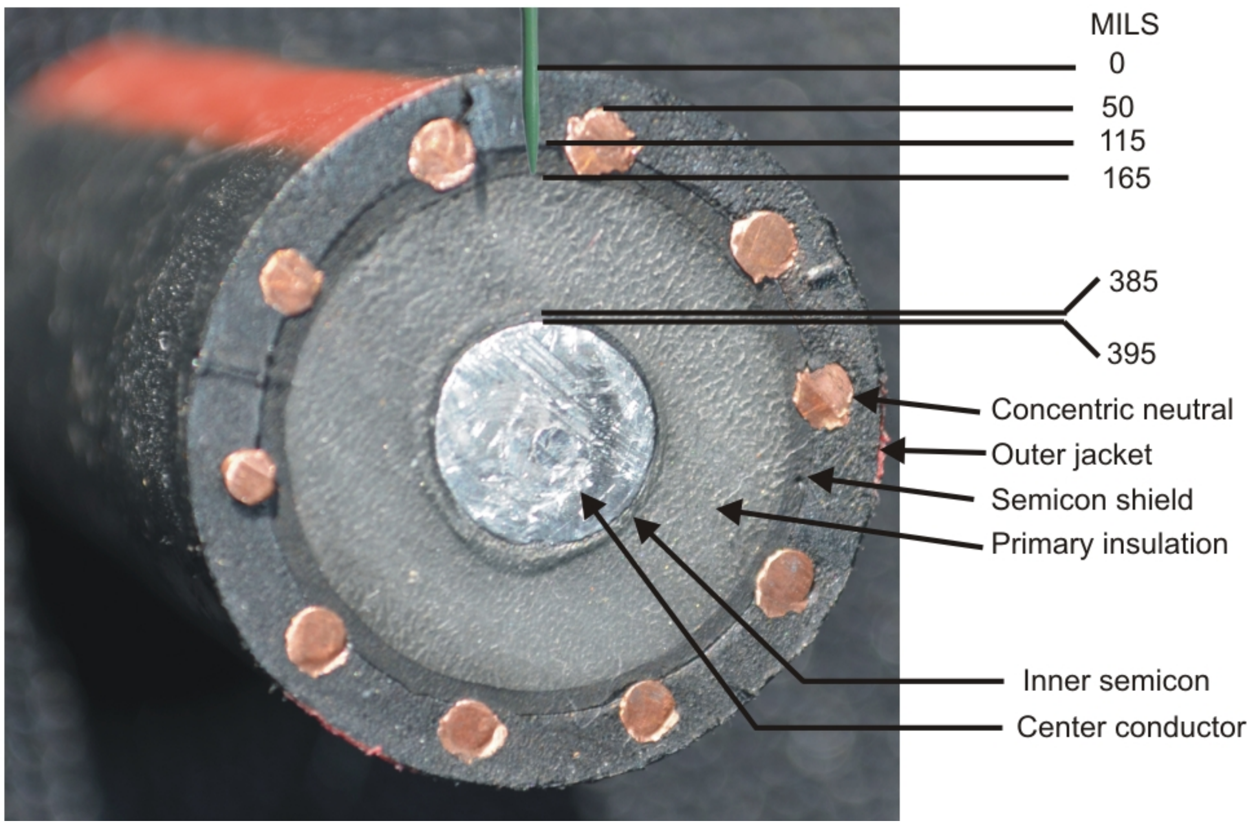
- Determine if cable is energized.
- Indicate voltage level.
- Measure phase attribute with Origo PhaseID System.

URD Cable

A typical standard 15 KV cross-linked polyethylene (XLP) URD 133% insulation cable is illustrated below. The cable diameter is 1.12” and the primary insulation is 220 mils thick.

When the needle touches the outer jacket, the LCD will read 0 mils. If the needle touches a grounded concentric neutral wire, the red light will illuminate at approximately 50 to 60 mils which indicates the lineman should discontinue the penetration and move the needle position slightly and try again.

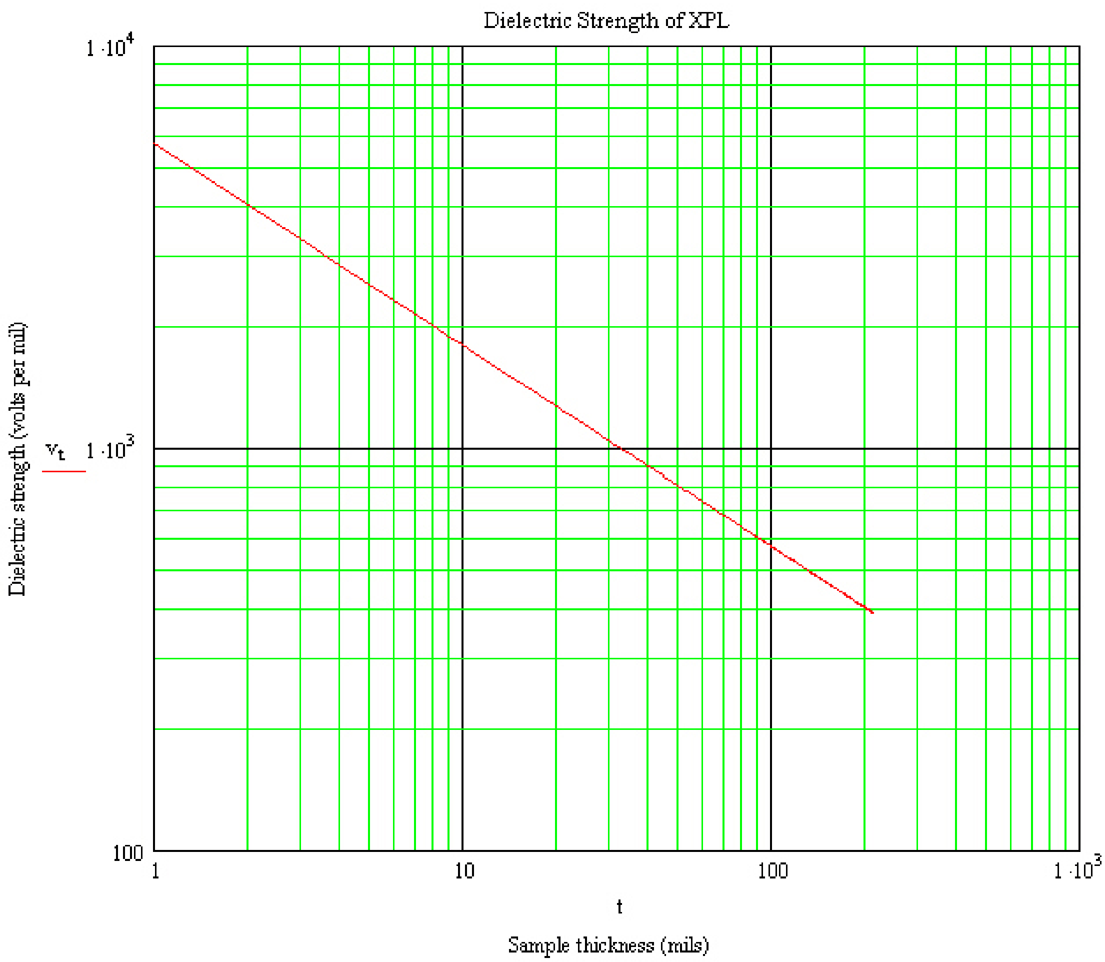
At approximately 115 mils, the red light may illuminate as the needle enters the grounded semicon shield. As soon as the red light goes out (at approximately 165 mils) a yellow light will illuminate if the URD cable is energized. If the yellow light does not illuminate by a hard stop preset at 175 mils, the URD cable is not energized.



Dielectric Strength of XLP Insulation

The standard test method for dielectric strength of solid electrical insulating materials at commercial power frequencies is documented in ASTM D149. The mean dielectric strength for cross linked polyethylene in a 44 mil thick sample is 861 volts per mil (V/mil). The dielectric strength for any thickness XLP can be found using the formula below which is plotted for thickness from 1 mil to 220 mils.

$$v_t := \mathrm{round}\left(861 \cdot \sqrt{\frac{44}{t}}\right)$$

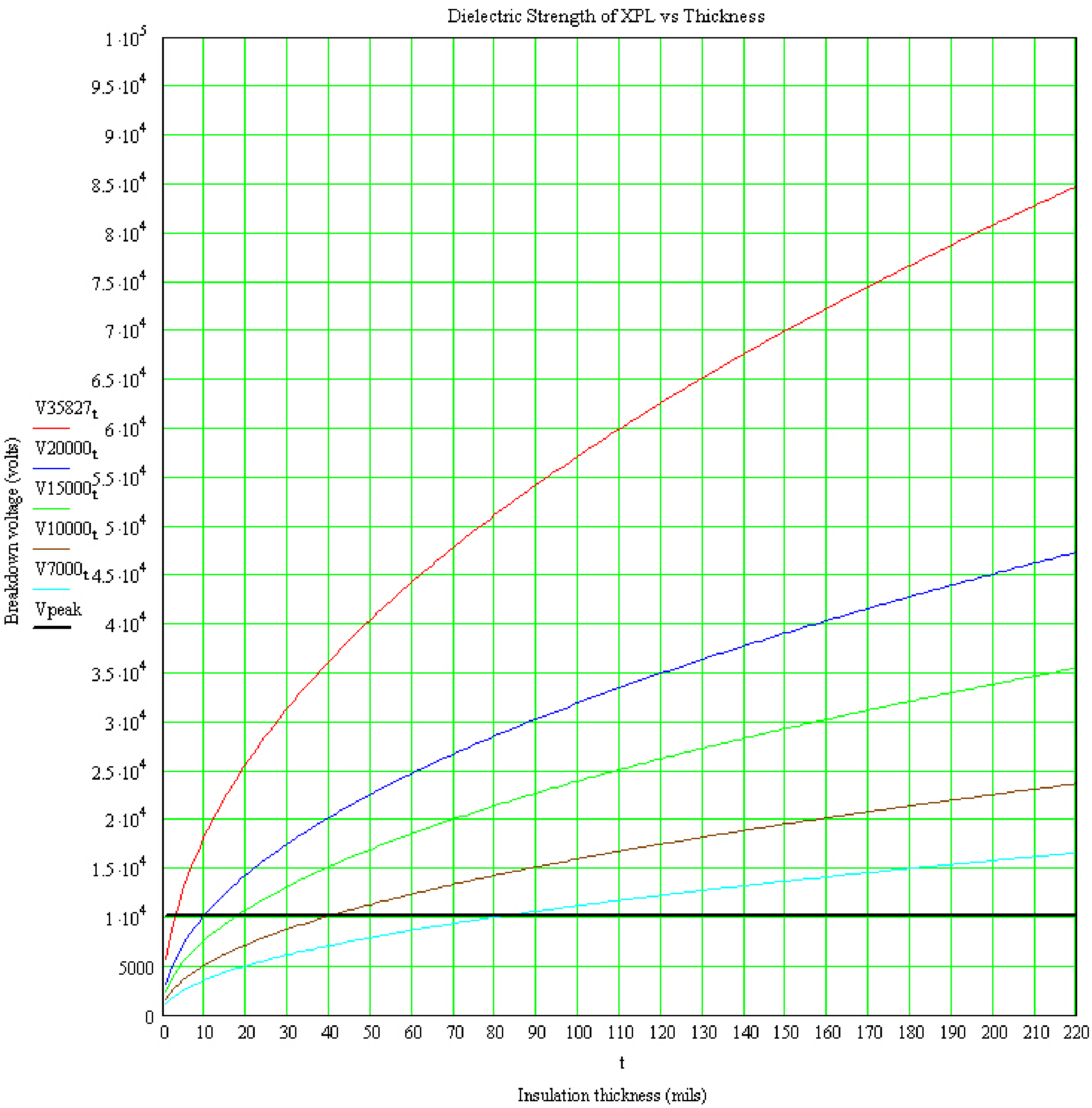


This graph illustrates that dielectric strength is not linear with thickness. The breakdown voltage of a 1 mil thickness is 5,711 volts. For a 2 mil thickness, it is 4,038 volts per mil times 2 mils or 8,076 volts. For a 10 mil thickness it is 1,806 volts per mil times 10 mils or 18,060 volts.

Dielectric strength is typically stated for standard sample thickness of either 1/8" (125 mils) or 1 millimeter (mm) which is 39.37 mils. These thickness give 511 V/mil and 910 V/mil respectively.

Breakdown Voltage of XLP Insulation

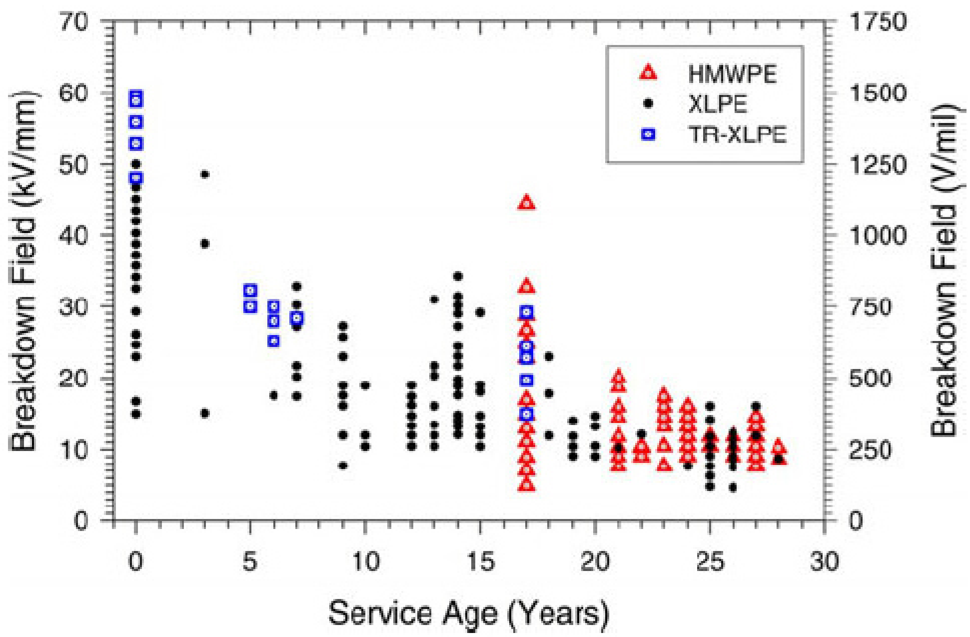
The graph below illustrates the breakdown voltage of XLP versus thickness in mils for cable samples whose dielectric strengths are 35,827, 20,000, 15,000, 10,000, and 7,000 volts per mm (V/mm). The horizontal Vpeak trace represents the peak 60 Hz voltage (10,182) for 12.5 KV service (7200 volts phase to ground).



The top red trace (V35827) represents the dielectric strength (V/mm) of new XPL cable. Note that the breakdown voltage for 220 mil insulation is 84,691 volts. Penetrating this insulation with the URD Probe™ needle by even as much as 20 mils only reduces the breakdown voltage from 84,691 volts to 80,749 volts.

For the cyan bottom trace (V7000), 20 mils penetration reduces the breakdown voltage from 16,547 volts to 15,777 volts which is still higher than the peak 60 Hz voltage of 10,182 volts.

The figure below is from reference 1 which tested the dielectric strength of a large number of 1 mm thick samples from aged URD cable. They report that very few samples had breakdowns occur below 7 kV/mm.

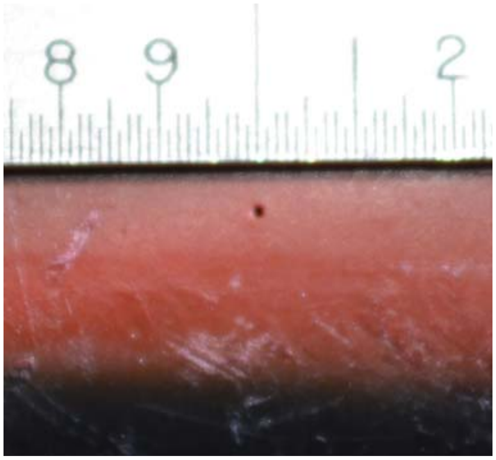


Water Trees

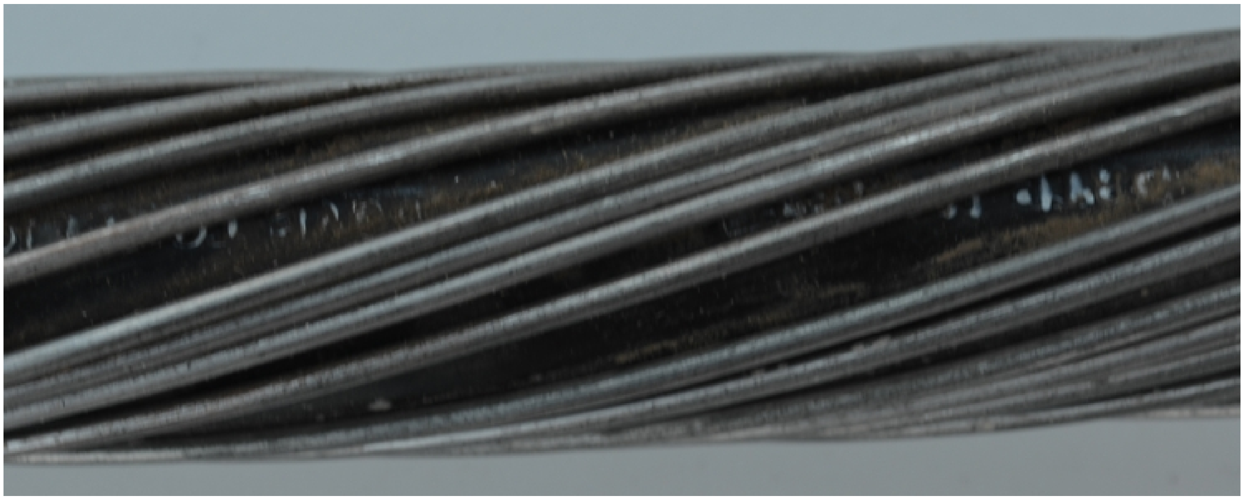
Although manufacturing voids and contaminants can reduce the dielectric strength in URD insulation, the primary cause is the presence of water trees. Water trees typically form over time when voltage and moisture are present and can turn into air voids or conductive electrical trees. Typical water trees are illustrated below where water has penetrated the semicon in unjacketed cable. Modern jacketed URD cables have greatly reduced the formation of water trees compared to previous unjacketed cables.

No Cable Damage Due to Probing

The URD Probe™ small diameter tapered needle does not cut the cable jacket but rather simply displaces it as illustrated below. When the needle is removed, the resiliency of the jacket material partially closes the small penetration hole. The ruler scale marks below are 10 mils apart.



This small 10 mil hole is certainly very benign compared to the fact that unjacketed cable (illustrated below) has no jacket at all over its entire length. Unjacketed cable has been used for decades and hundreds of thousands of miles of this cable are still in service.



Also, semicon is much more resilient than jacket material and a 10 mil diameter needle penetration hole in semicon appears to completely close within a short period of time after the needle is removed.

Therefore, probing either jacketed or unjacketed URD cable does not require any patching or other maintenance after being probed using the URD Probe™.

Safety

A certified hot stick should always be used to apply the URD Probe™ for safety. The input impedance of the needle probe is on the order of 20 megohms so the needle does not place any load on the cable. However, the URD Probe™ is not designed to directly contact powerline voltages. It depends on the normal cable insulation for isolation.

Water trees primarily form on the outer surface of the cable insulation starting at the semicon. Therefore, penetrating into a water tree with the probe needle should not reduce the cable breakdown voltage at that point since a water tree essentially represents an insulation void.

However, it is theoretically possible that a cable imperfection water tree or electrical tree could exist around the center conductor. If the needle penetrated directly above this tree, then the needle penetration would reduce the cable breakdown voltage at that point.

If the cable insulation was already degraded enough to be on the verge of failure due to a center conductor water or electrical tree and the needle probe occurred directly over this tree into non-degraded insulation, then it is possible that an arc could form between the needle and the concentric neutral.

For this potentially rare occurrence, always use a hot stick when probing a cable.

Bottom Line

Currently, the only safe method of cutting into URD cable is to spike them first. Spiking is potentially dangerous because spiking forms a low impedance high current arc.

With the Origo URD Probe™, cables can now be safely probed to determine if they are energized or not prior to spiking or cutting.

The Origo URD Probe™ can also be used to determine if a cable is dead and abandoned, to identify a disconnected (perhaps faulted) cable, or for other cable identification purposes.

Additionally, the Origo URD Probe™ can be combined with the Origo PhaseID System to determine the phase attribute of each cable in a trench. This allows splicing into the desired phase for new add-on construction.

Go to www.origocorp.com for additional information on the PhaseID System.

References

1. "Service Aged Medium Voltage Cables – A Critical Review of Polyethylene Insulated Cables"; Arthur V. Pack, Jr., PE; Conference Record of the 2004 IEEE International Symposium on Electrical Insulation, Indianapolis, IN USA, 19-22 September 2004.