URD Elbow Connectivity using the G3 Field Probe

What is the Elbow Connectivity?

Underground Residential Distribution (URD) cable is used to distribute electric power (for example 7200 VAC) via underground cable. Typically, a URD cable is buried between junction cabinets and/or pad-mount transformers where it is terminated on both ends using load break elbows. The elbows connect to elbow bushings inside the cabinets or padmounts so that the circuit can easily be opened or closed by a lineman pulling off or pushing on the elbow to the bushing using an insulated hotstick.

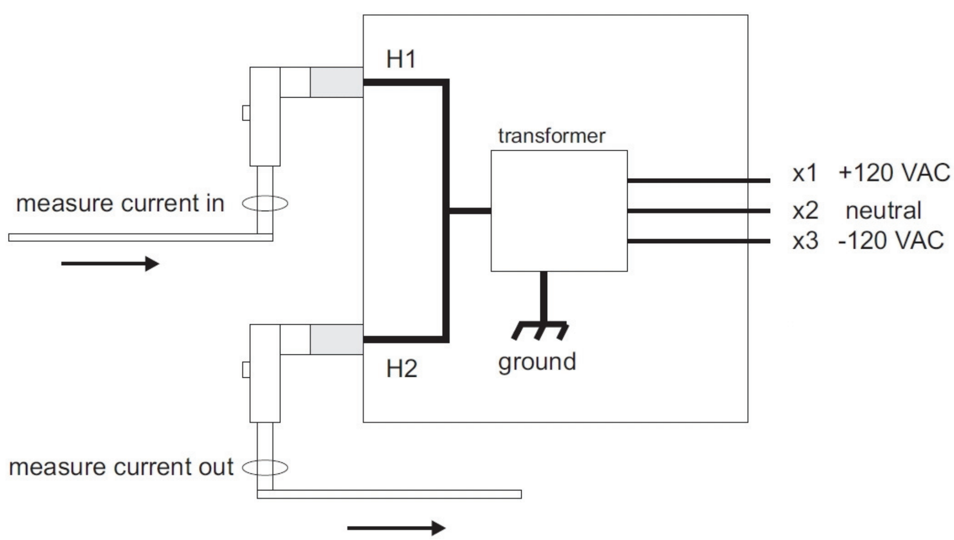
It is important that each elbow be tagged accurately so that the lineman pulls the correct elbow when opening a circuit. If improperly tagged, the lineman may open a live circuit causing an outage to all customers on that circuit.

Why the G3 Field Probe Current Adapter was Created?

Until now, there was no way to easily and positively determine which pair of energized URD elbows in separated cabinets or padmounts are connected to the same URD cable. Although Line locators can trace which cabinets and padmounts are connected, they cannot determine the elbow connectivity of a particular URD cable.

Theory of Operation

A typical padmount transformer is illustrated below. Dozens of these padmounts are typically series daisy chained together to form a long radial or looped circuit through a neighborhood.



Inside the padmount, bushing H1 and H2 are connected together and to the transformer, which converts the URD 7200 VAC power to 120 VAC residential power. Incoming power from the upstream padmount is connected to H1 while H2 provides power to the remaining downstream padmounts. The fact that both bushings (and both elbows) are connected together, prevents the use of a line locator from determining

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which is the H1 elbow and which is the H2 elbow unless one of the elbows is disconnected from the bushing. However, pulling an elbow is not an option in an energized circuit since that would cause an outage to all customers downstream of the pulled elbow.

The G3 current adapter is combined with the G3 Field Probe and a clamp-on current probe to solve this problem. By applying the current probe in the same manner to both the H1 URD cable and the H2 URD cable, the G3 Field Probe will sense if the URD current is flowing into the padmount from its upstream source or flowing out of the padmount to the remaining downstream padmounts.

Applying the G3 Current Adapter

The figure below illustrates how the G3 Current Adapter is combined with the G3 Field Probe and the clamp-on current probe to determine both the phase attribute and the current direction in the URD cable.

The G3 Current Adapter is attached to the G3 Field Probe in place of the G3 Wand. The clamp-on current probe is plugged into the G3 Current Adapter and clamped onto the URD cable just below the elbow and above the point at which the URD cable concentric neutral wires are stripped back. The current probe must be applied above the neutral wires because URD center conductor and neutral conductor currents are essentially equal amplitude and opposite phase and therefore cancel out in the current probe.

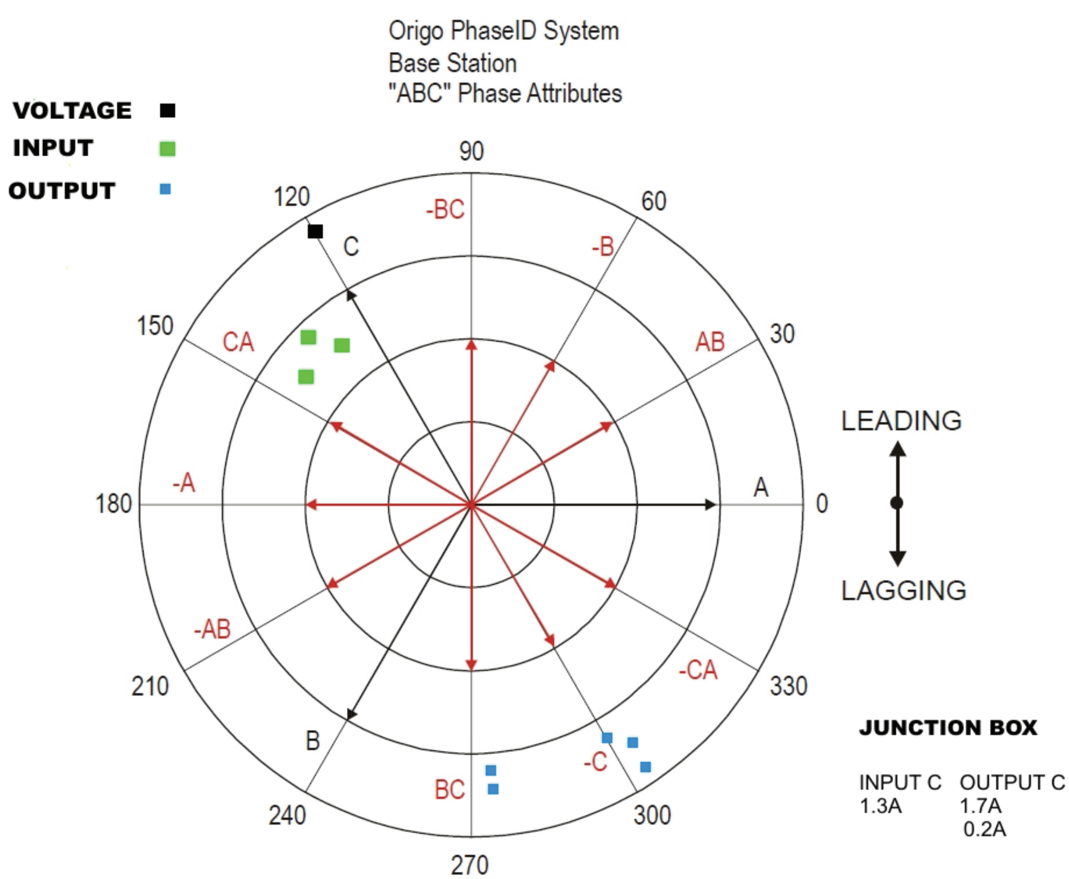
Tagging Reference Phase Setup

The first step in using the G3 Current Adapter is to setup the Origo PhaseID tagging reference phase. Typically, the user will already have the voltage tagging reference phase setup for the circuit being phased.

To initially setup the current tagging reference phase, apply the current probe to a URD cable in which you know its phase and the direction of its elbow current. For example, take a regular PhaseID voltage phase measurement on the elbow capacitive test point of an elbow you know is phase A. Auto Config to indicate its voltage phase attribute is A with nearly zero degrees phase error. Save this tagging reference phase as Voltage.pid (for example).

Now use the G3 Current Adapter and clamp-on current probe to take a current phase measurement. Always apply the current clamp so that its reference arrow points towards the elbow. Assume that you know that the URD current is flowing into the elbow. Auto Config to indicate its current phase attribute is A with nearly zero degrees phase error. Save this tagging reference phase attribute as Current.pid (for example). You now have the current tagging reference phase corrected for the static phase shift due to the G3 Current Adapter and current probe.

The figure below illustrates the results obtained in a junction cabinet with 1 phase C input elbow and 2 phase C output elbows.

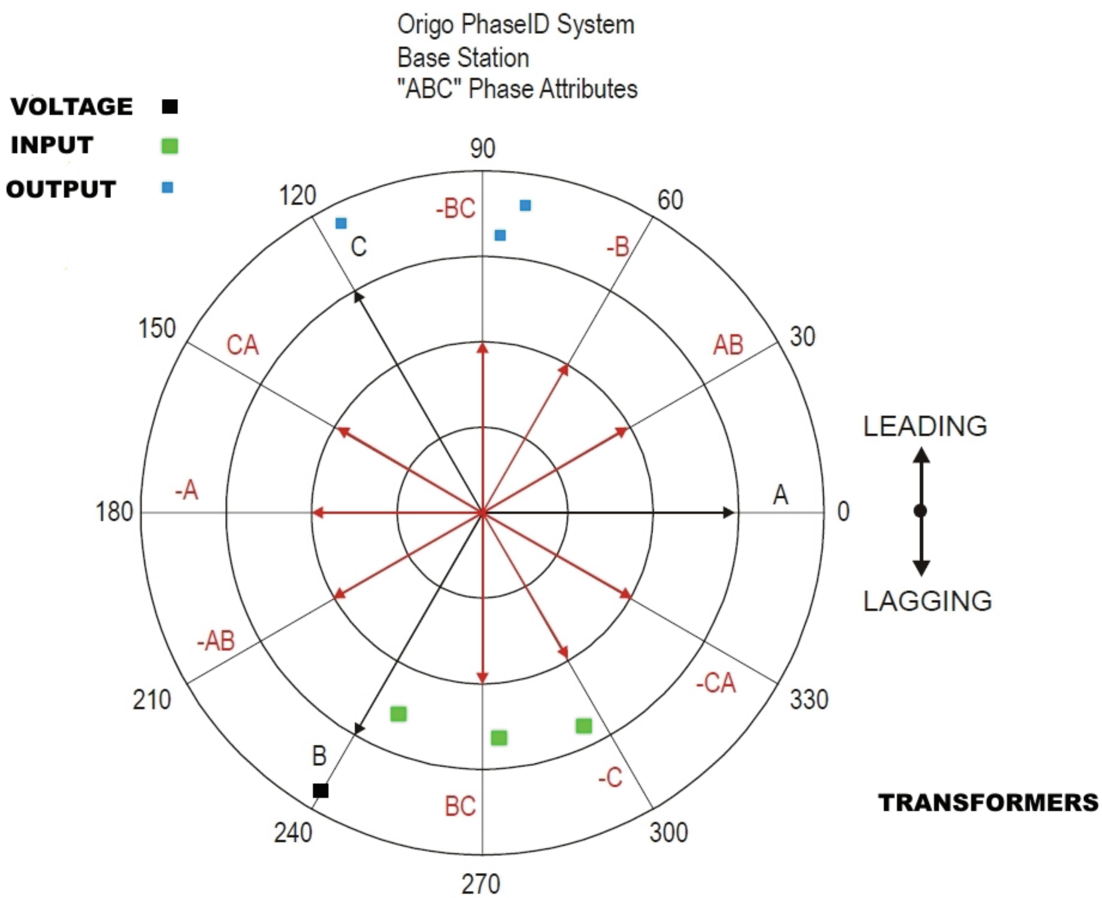


The black square is the voltage phase measured on the input elbow capacitive test point. The green squares are from multiple current phase measurements on the same elbow. Note that the current phase is nearly in phase with the voltage.

The blue squares are from multiple current phase measurement on the two phase C output elbows. Note that for both output elbows, the current phase is nearly 180 degrees out of phase with the current phase of the input elbow.

The figure below illustrates the results obtained on a daisy chain of transformers on phase B. Here the green square input elbow current phases are close to the black voltage phase. Likewise, the blue output elbow current phases are essentially out of phase with the voltage phase.

Since daisy chained padmount transformers each contain two elbows on the same phase, only one current phase measurement is required in each padmount to identify the elbows. If the measured elbow is an input elbow, then the elbow not measured must be the output elbow, and vice versa.



Interpretation of Results

The phase spread of the current phases with respect to the voltage phase is caused by the power factor of the circuit. In an AC circuit, voltage and current are in phase only when the load is resistive. In a typical residential URD circuit the load is inductive which increases the phase angle between voltage and current. Power factor varies constantly as customers turn on inductive air conditioners or resistive heaters, etc.

Once the tagging reference phase is established for a typical URD circuit, it can always be adjusted for other circuits by clicking the Auto Offset icon in the PhaseID program. Since the phase offset due to the G3 Current Adapter and current clamp is constant, varying phase angle from circuit to circuit gives an indication of the relative power factors between those circuits.

It is only necessary for the input elbow voltage and current phase be adjusted to be nearly equal so that it is immediately obvious which elbows are input elbows and which are output elbows.

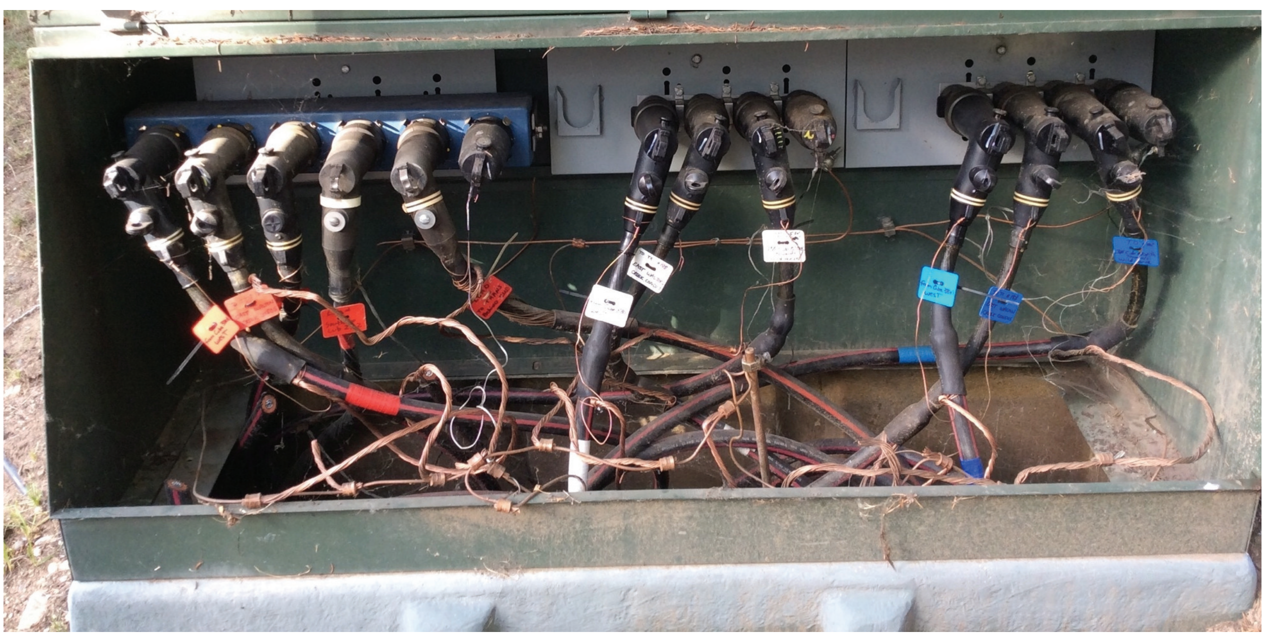
Complex Junction Cabinets

A large junction cabinet is illustrated below which contains multiple phases, input elbows, and output elbows.

To identify all elbow connectivity, the first task is to simply measure the current phase of all elbows. This segregates the elbows into input and output elbows for each of phases A, B, and C.

the second task is to identify the cabinets and/or padmounts to which this junction cabinet is connected. This may be determined either from the utility's circuit maps or via line locator.

If multiple output elbows on the same phase exit this junction cabinet, the input elbows in the downstream cabinets or padmounts, that are on the same phase, can be first identified.



For example, suppose this junction cabinet as two output elbows on phase A and you found two other cabinets or padmounts that each had a phase A input elbow.

To determine which phase A output elbow of this junction cabinet goes to which phase A input elbow in the other two cabinets or padmounts, simply compare the actual currents between the output and input elbows. To do this, plug the clamp-on current clamp into your multi-meter and measure the currents on all 4 elbows in question. In most cases, each connected pair will measure a similar currents. As long as each pair of currents are very different, it will be obvious which output elbow is connected to which input elbow.

If the currents are nearly similar, two linemen can simultaneously measure currents at the separated cabinets and communicate their readings via cell phone. As URD currents are constantly changing with load variations, it will be obvious which output elbow in one cabinet is connected to which input elbow in the other cabinet.

Measure Phase Attribute on Dead Front Elbows and 3-phase Feeders

On many older URD circuits, the elbows may not contain capacitive test points. Since URD cable and elbows totally shield electric fields, voltage phase attribute cannot be measured. However, assuming you already have established the voltage and current tagging reference phase for the substation feeding this dead front circuit, you can simply use the G3 Current Adapter and clamp-on current probe to measure current phase and thus determine the phase attribute of this dead front circuit.

If 3-phase URD feeders supply power to a balanced load, such as a 3-phase motor, all current is consumed in the load and there is no neutral return current. In general, the sum of multiple loads on a 3-phase feeder is not balanced. The unbalanced current flows back to the source as neutral current. For example, the average current on each URD feeder cable might be around 100 amps and the return current on one or more URD cable neutrals might be on the order of 10 amps.

In essentially all situations, the outgoing current on all URD 3-phase feeders far exceeds any neutral return current. Therefore, the G3 Current Adapter allows the phase attribute of each URD feeder cable to be measured simply by placing the clamp-on current probe around any point on the URD cable. It doesn't have to be placed above the point near the elbow at which the neutral wires are stripped back from the center conductor.

This allows the PhaseID System to measure phase attribute of 3-phase URD feeder cables in a trench. It has also been demonstrated the phase attribute of lead shielded 3-phase feeder cables can also be measured using the G3 Current Adapter.

Conclusion

The goal in modern Smart Grid systems is to completely identify and characterize all aspects of the distribution system. This includes such things as determining the GPS location of all assets along with mapping and tagging all circuit segments and nodes.

Older systems require a large effort to be converted to a modern Smart Grid system. Until now, tagging or verifying URD cable elbows tags was typically not even attempted since no fast simple method existed to do so on energized cable. This is not the case now when using the G3 Current Adapter and G3 PhaseID System.

The majority of URD elbows are used in neighborhood URD circuits. In large neighborhoods, 50 or more padmount transformers may be daisy chained together. Tagging or verifying these padmount elbows now simply requires a single lineman to open each padmount, current phase measure one URD elbow in that padmount, and apply the tag. In a few hours, the entire neighborhood can be accurately tagged.

Contact

A wealth of information on the Origo PhaseID System is available on our website. If you have any questions or require assistance, call or email Origo. Thanks.

Origo Corporation
http://ww.origocorp.com
480-473-1995
gpiesinger@origocorp.com