Online Partial Discharge Testing of HV Cable: Single Test Vs Feeder Mapping

Online Partial discharge testing of HV cables is a fundamental tool for understanding the condition of underground HV cables within a distribution network. However, people will often test and analyse single HV cables in isolation, without considering the configuration of the network as a whole. Through practical testing, EA Technology has shown that the ideal practice for online testing of HV cables is to map an entire feeder, not just testing individual cables.

By Thomas Whyte - EA Technology

As energy distribution networks age, it is desirable for network operators to obtain high quality condition data so they can make informed decision on the lifespan on their assets. For underground HV cables, an accurate and low-cost solution to obtain asset condition data is through online partial discharge testing. Depending on how the project of testing is completed, the data quality can vary. Due to this, understanding the limitations and outside influences of the testing methods is critical to ensure a successful test program.

PARTIAL DISCHARGE ON CABLES

Once a PD event has occurred through the electrical insulation of a cable, a set of radio frequency current pulses both equal in magnitude but opposite in polarity are seen on the line conductors and the earth conductor. On-line PD detection utilises this effect by measuring these pulses using High Frequency Current Transformers (HFCT's) placed on the earth sheath of the cable.

These current pulses are analysed using two different methods, Phase Resolve Partial Discharge (PRPD) patterns and waveform analysis.

Figure 1 *HFCT around earth sheath*

Examination of PRPD patterns is a common approach for all partial discharge analysis. The patterns show the relationship between the amplitude of the PD signals and the position on the sine wave that they are occurring. A PRPD pattern is used to determine the presence and type of partial discharge source but cannot alone determine its location on the HV cable.

Waveform analysis employs similar analysis methods as time domain reflectometry (TDR) testing. The partial discharge current pulses are known to reflect of high impedance points in the HV network, such as cable terminations. This results in the initial partial discharge pulse being reflected, enabling analysis to pinpoint the origin of these signals. An example of this is shown in Figure 2.

TESTING IN PRACTICE

What EA Technology has found is that while the current pulses created from partial discharge sources reflect off high impedance points, on distribution networks a portion of the high frequency signals will also travel through the impedance point. In practice this means that a PD source located in the joint of a HV cable will send signals that will travel down the cable, through the termination e.g. at a ring main unit, and potentially further down other HV cables.

This phenomenon can cause confusion when analysing isolated cable data, as both the PRDP and waveform analysis can give indications that a partial discharge source is present on the cable being tested. When in reality these signals are being imported from a cable further down the feeder.

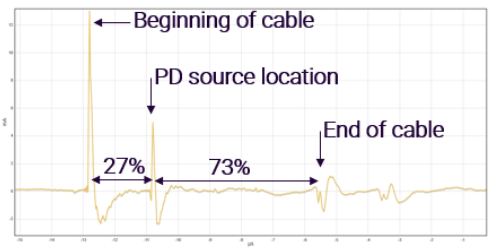


Figure 2 *PD Waveform Analysis on HV Cable*

It has also been found that partial discharge present in other connected HV assets such as switchgear or transformers will also be coupled onto the HV cables, giving indications to the unwary that partial discharge is present on the HV cables.

Due to these factors EA Technology recommends that when online partial discharge testing is done on distribution cable networks, the best approach is to take a wholistic approach. Systematically mapping an entire feeder as well as partial discharge testing the switchgear/RMU/HV pole at each end of the cables for potentially imported PD sources will provide the most valuable results.

CASE STUDY: 22KV FEEDER ANALYSIS

Recently EA Technology performed a project to perform online partial discharge testing across and entire 22kV feeder. This case study will detail how the partial discharge signals propagated along the feeder and how the analysis process was done in order to identify the source of the signals, ensuring no false positives were given.

The spur of the feeder that is being analysed for this study comprised of 14 sections of 22kV XLPE cables, spanning over 5km. The XLPE cables terminated into hybrid style pole top terminations, shown in Figure 3.

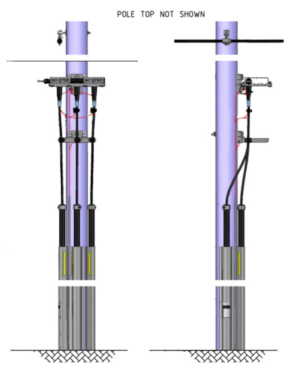


Figure 3 *Hybrid style Pole top terminations*

Each run of cables was tested for partial -discharge using HFCT's from both ends of the cable and each pole top termination was tested using the TEV, ultrasonic and UHF test techniques. This method of testing ensures that all partial discharge sources would be identified and localised.

Figure 4 below shows a heat map of the feeder spur indicating the origin of the PD source as well as the PD signals identified on each HV cable as well as at each cable termination.

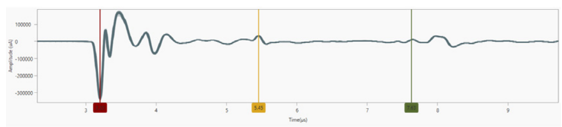
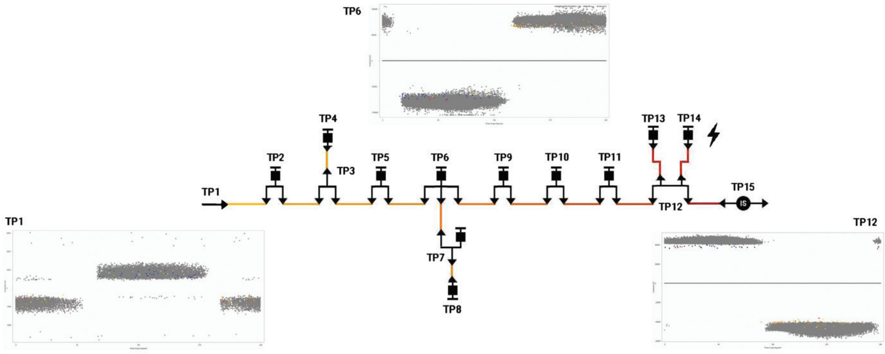


Figure 4 *Test Point 10 - Waveform analysis*



It was found that at test point 1 no local PD was identified. However clear indications of partial discharge could be seen on the HV cable. This trend continued along the feeder, with amplitude slowly increasing as the test points move closer to the origin of the PD signals.

However, the single PD defect was identified during the local testing at test point 14. TEV testing of the HV pole at test point 14 identified very high-level TEV signals, time of flight location was used to verify that these signals originated at the top of the HV pole. This was further confirmed by using UHF testing. Ultrasonic testing was able to localise the PD source to the red phase termination. Due to the construction of the termination and the PD signals identified it was concluded that these sources were likely caused by a poor HV connection in the termination.

Analysing the PRPD plots shows how far the partial discharge signals can travel across the full feeder. Partial discharge signals were identified on all test points using PRPD analysis and waveform analysis revealed significant reflections at five separate test points.

What is important to consider is the ramifications if a full program of partial discharge testing was not carried out.

In a scenario where the client had chosen to carry out only HV cable testing, choosing not to perform local PD testing at each cable termination, then it would have been possible to identify a high-level PD source was present. The data would have indicated that the source was likely closer to test point 14, however the waveform analysis may have flagged multiple false positives.

If the client had chosen to perform targeted cable analysis on only specific cables along the feeder. Then it would not have been possible to localise the PD source at all. An online partial discharge test at any test point on the feeder would have revealed a partial discharge source was nearby. However, without the ability to analyse the feeder as a whole, no final conclusion could have been drawn.

SUMMARY

Online partial discharge testing of HV cables is a low cost and efficient way of providing network operators with a clear insight into the condition of their HV cables. However, when planning a test program, the practicalities of the test method and analysis need to be considered.

Due to the interconnected nature of a HV distribution feeder, to gain best results it is crucial to consider the interconnection of the entire network, rather than preforming isolated analysis on individual assets.

Due to this EA Technology recommends the systematic analysis of an entire feeder, or section of a feeder, rather than isolated tests of specific HV cables. All online partial discharge testing of HV cables, should also incorporate partial discharge testing on the HV assets along the feeder to ensure that no partial discharge signals are being imported onto the cable from other assets, resulting in false positives. T&D

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