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Irish overview of Partial Discharge (PD) testing applications and subsequent lessons learned.

PD measurement and analysis are effective for identifying the condition of cable insulation for various applications. It can be used to detect degrading cable insulation or to monitor cables insulation at various times of a cable's lifespan. This methodology can be adapted using the relevant IEC Standards (IEC 60270, IEC 60840 and IEC 62067) to ensure the quality of power cables insulation, cable accessories during manufacturing, on-site cable commissioning (acceptance testing) and troubleshooting when in service. This contribution will demonstrate how PD measurements and analysis can be utilised after cable installation to ensure an efficient High Voltage cable installation while also providing useful practice to adapt permanent quality assurance of the installed cable asset in Ireland.

One recent application of PD testing in Ireland has been on the Kilpaddoge-Knockanure 220kV cable project. This single circuit 220kV underground cable was installed in the south west of Ireland to facilitate the connection of new renewable generation. The cable route (Figure 1) is approximately 22 km and consists of 36 joints per phase. The cable route was installed in public roads as well as various off-road locations to cater for river crossings.

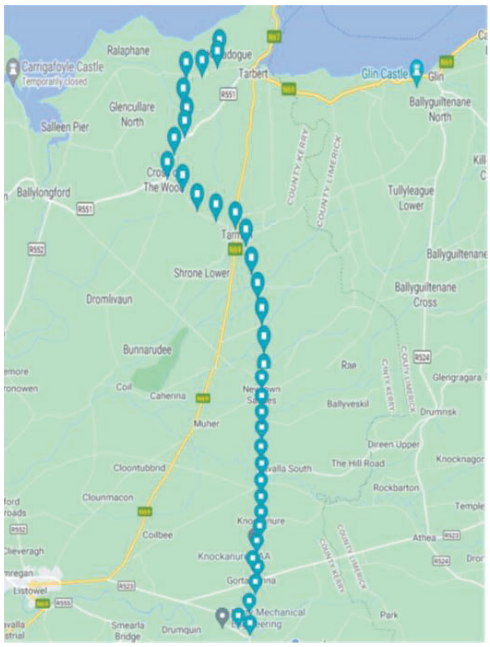

Figure 1- Kilpaddoge-Knockanure 220kV Cable Route

This cable circuit is designed to a minimum continuous rating of 660 MVA. An AC voltage withstand test (216 kV for 60 minutes) and a LIRA test was required as part of the PD testing. According to the manufacturer's datasheet, the maximum phase capacitance is specified as 322 nF/km. As this was a theoretical value, it was determined that a capacitance value of 322 nF/km for 22 km length cables was sufficient to energise the cable to 216 kV (1.7 Uo compliant with IEC 62067). In order to achieve this rating, 3 Resonant Test Set (RTS) units rated at 260 kV and 83 A were required to be connected in parallel. The RTS units installed would require an external diesel generator (2 MVA) to energise the cable to 216 kV. The Kilpaddoge-

Knockanure 220kV cable route is connected into GIS switchgear at both ends, it was not possible to connect the test voltage directly onto the cable conductor at either termination. Temporary test terminations were installed at the first joint bay out from each station. Due to the number of joint bays on the circuit 36 PD sensors (HFCT) and 35 sensors (PFCT) that supply a reference voltage to the installed PD monitors were required.

Figure 2 - PD Testing Arrangement

The configuration of the PD test is outlined in Figure 2 above with all equipment labelled in position at joint bay 1 (JB1). The generator output (2 MVA) was connected to the input of each trailer mounted RTS unit. PD sensors (Figure 3) were connected below the cable terminations and all joints of the cable under test. Coaxial cables connected to PD monitors were used for measuring data during the PD test on the open cable link boxes. Test leads were positioned on the HV terminals, the earth of one phase and a PD calibrator instrument.

Figure 3 - PD Sensor installed

The PD testing used a voltage ramping technique which followed the starting of the diesel generator. Table 1 below shows the ramping sequence adopted to the PD test. The purpose of this process is to confirm the various test voltages for specific durations which leads to confirmation that PD testing on the installed cable can occur. During the final test voltage (216 kV), PD is to be monitored at each location (joint bay) once. Due to the number of joint bays being tested, a crew of 6 mobile test engineers collected PD data for up to 5 minutes at each joint bay. The technique used is an example of Joint Hopping/ Leapfrogging where PD measurements are taken from joint to joint. Alternative methods were identified such as Intermediate PD Testing, but it was decided this Joint Hopping techniques will result in more accurate PD data for analysis. Following the PD Test no issues were identified onsite and the cable was suitable for commissioning and energizing.

Test Voltage	*Duration*	*Reason*
64 kV (0.5 Uo)	Approximately 2 minutes	Verify and monitor the stability of the voltage and current being used in the PD test.
127 kV (1.0 Uo)	5 - 30 minutes	To record baseline PD at rated operating voltage and troubleshoot if required.
180 kV (1.4 Uo)	1 - 2 minutes	Intermediate step was to monitor any PD on the installed Kilpaddoge-Knockanure 220kV cable.
216 kV (1.7 Uo)	60 minutes per phase	PD is to be monitored at each location (joint bay) once. Due to the number of joint bays being tested, a crew of 6 mobile test engineers will collect PD data for up to 5 minutes at each joint bay.

Table 1- Voltage Ramping Sequence

This specific PD testing example provided several challenges such as the logistical challenges with test site set up, equipment delivery and interactions with the local public roads. An important factor in the PD testing procedure is the interaction with the GIS switchgear at the remote end stations of the circuit. GIS Switchgear makes it very difficult to make a direct connection onto the cable being tested and suppliers are reluctant to perform tests through the installed switchgear due to risks around reducing equipment lifespan.

A further challenge identified was in how to apply such resonant AC testing to longer and higher voltage circuit planned in Ireland in the coming years. The logistics of employing the large number of RTS units could be unfeasible, so alternative testing strategies such as testing the circuit in stages will have to be considered.

Currently there are several issues with using PD Testing as a long-term monitoring strategy for use on the Irish Transmission system. There are several reasons for this such as the identifying of alarm thresholds for PD alerts during cable operation. This factor will hopefully drive increased learning across other countries to help derisk the issue and make this PD Testing approach more common.

The adaption of PD testing on HVDC cable systems is yet to be fully evaluated due to the size and nature of the Irish transmission system. Potentially HVDC PD testing applications are to become more frequent with more offshore and interconnection projects being progressed.

Following lessons learned, there is a greater emphasis on online PD testing going forward for future projects. This application will help to identify any potential issues around workmanship, installation environment and assembly instructions. The unique nature of online testing will help facilitate the required testing of installed cables while not requiring any transmission outage. This feature and various others is a huge positive due to the complexity of granting transmission outages during times of close operational margins.