Partial Discharge testing of XLPE cables for HVDC: Challenges and opportunities

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The number of HVDC circuits using XLPE cables is steadily increasing. A number of questions are posed by this situation. How to ensure cable system reliability after laying? Can PD tests provide meaningful information? Is it reasonable to use AC instead of DC? The problems arising when HVDC cables are tested for PD can be summarized as follows:

1. Using DC sources, PD detection might be challenging due to external noise and corona. Also, these tests might not be fully representative of the conditions during service, as they are performed on cold cables. The impact of lightning surges should also be considered.
2. Using AC sources, the tests will be simpler. However, depending on the defect type, the field distribution within the cable might differ noticeably from that in DC.

The approach that we propose to investigate these points is the following. First, focus is made on the most common defects, i.e., those associated with human errors: (a) misalignment of resistive grading system (not in contact with the cable screen), (b) knife cuts caused by improper stripping of the screen.

After having decided defect geometries (e.g., distance between screen and grading system), the electric field at the defect site is estimated for both AC and DC supply using FEM software tools. Temperature profiles are considered, while space charge injection is not. These defects are created purposely in cable terminations. Then, PD measurements are carried out first under AC voltages, then under DC voltages, at room temperature and by inducing a temperature gradient inside the insulation. As a last step, the voltage is raised till breakdown, and a post-mortem analysis is performed.

For defect (a), FEM calculation did provide the following results. Under AC conditions (Vac=15 kV) the field is 10 kV/mm. Under DC conditions (V_{DC}=140 kV), the field is below 1 kV/mm, and around 3 kV/mm at room temperature and in the presence of temperature gradient (conductor temperature: 70°C), respectively. Tests did qualitatively confirm these evaluations. In fact, under AC voltage, PD incepted around 21 kV (peak). The PD pattern shows that the phenomenon is typical of discharges occurring on a dielectric surface, i.e. at the interface between the insulation and the termination sealing. Under negative DC, PD could not be detected up to 150 kV (except corona), independently of the temperature profile of the cable.

Eventually, the DC voltage was increased in steps of 30 kV, each lasting 5 minutes till breakdown, which occurred at 330 kV. Post mortem analysis showed that tracking started at different points of the screen, directed towards the grading system. At the border of the grading systems the discharge found a weak point and created a tree-like channel in the insulation that propagated towards the conductor till breakdown.

Thus, for this specific defect, FEM calculations and PD measurements provide results that are in agreement. Moreover, AC testing seems a viable alternative to DC testing (which proved to be very complicated due to corona with high repetition rate). At the time this abstract is written, tests are under way for the type (b) defect.