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Practical experience and modelling of the corrosion behaviour of the Aluminium metallic cable sheath

In this study we investigated the impact of corrosion behavior of aluminum sheaths in HVAC power cable systems. Our main question to answer was: "What are the degradation mechanisms and should the frequency of the maintenance sheath tests change?"
The Netherlands has a high ground water table. To protect directly buried cables against water ingress, it has an aluminum water barrier. Approximately 10 years ago, the transition from using metallic cable sheaths of lead to smooth aluminum started. The main reasons for change was, reduction of cable weight, increase of conductivity, increase of mechanical strength and decrease of environmental impact.
Aluminium is more vulnerable than lead to electrochemical and electrolytic corrosive action. No cases of the metallic sheath degradation have been reported up to now in the Netherlands, when using aluminium welded metallic sheath (referred to as "AluWeld"). Nevertheless, because of (i) the large installed assets base, (ii) the required work force to install and to maintain all the future forecasted cable projects, it is necessary to get more insight on the AluWeld actual corrosion risk and associated corrosion kinetics. To ensure good quality cables over lifetime, it was decided to further study the degradation of the AluWeld sheath.

We started our research with a literature study. Main parameters for corrosion and experience from around the world have been identified from literature[1]. This provided an overview of e.g. important pH levels and current density thresholds, that may lead to corrosion degradation for our installed cables.

Based on the literature study we defined two experimental studies, a practical site experiment and a leakage current laboratory experimental setup. The results will also contribute to developing knowledge rules for site condition assessment of the installed base.
In the in-field test, cables samples with artificial prepared sheath faults were buried in an aggressive soil condition on a location in the Netherlands. From the literature study we identified peat as a more aggressive type, due to its low pH and high moisture content. Samples were buried in peat and sand in order to compare findings, see Figure 1.

The following tendencies are identified in literature about the corrosion behaviour of aluminium in soil:
- pH in most of the soils is considered to be between 5.5 and 8, which corresponds to the passive/passivation zone of aluminium
- No corrosion is reported in sandy (good aerated) and well drained (dry) soils
- Moderate pitting occurs in moist and marshy soils, even with low chlorides concentrations. After 5 year the max pitting depth measured is about 1 mm
- Very aggressive corrosion can occur in contaminated soils

[1] Understanding and mitigation of corrosion is provided in [1]

Figure 1 Arrangement of the samples in backfill, before covering and compaction

Yearly, a set of samples are dug up and investigated on degradation. The site tests are still ongoing. Results after 1 year have shown no evidence of corrosion and negligible weight loss.

In the second study we performed a leakage current laboratory experimental setup. First, modeling of a sheath fault was done to verify the leakage current with respect to the sheath fault. The model indicated the relation between various electrical conductivity and the leakage currents. Further information on modeling is provided in the paper.

As the influence of AC on the kinetics aluminium can be appreciable, a laboratory set-up was developed in order to assess the impact of AC on degradation of the sheath AluWeld. The experimental set-up provides thus insight on the degradation mechanism, its kinetics and the threshold current value to initiate corrosion.
Results of the of the laboratory test in sand and peat (similar as the in-field test) are shown in Figure 2. Three voltage tensions were exposed to the prepared cable samples: 10, 40 and 80V.

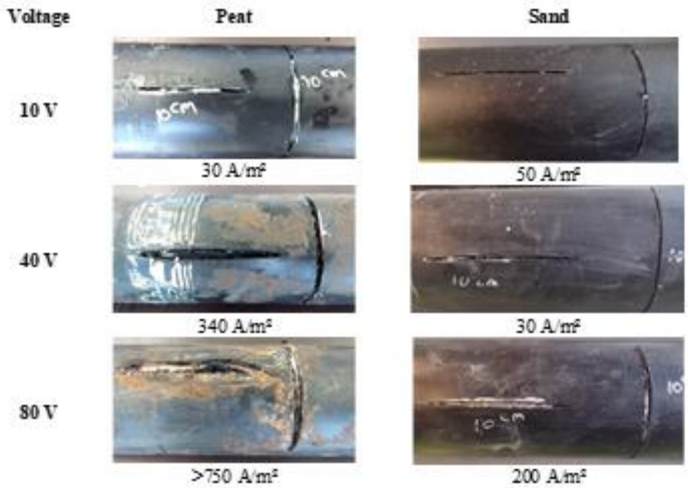

Figure 2 Degradation on the longitudinal defects after 3 months days, in function of the voltage applied on the aluminium sheath

The corresponding leakage current is given at each picture. The relation between voltage and leakage current provides insight in the failure mechanism. For increasing voltage and leakage current the artificial cut pushed up the aluminum and widened the cut. The aluminum perforated and propagated under the PE outer sheath. We concluded that earth leakage currents below ~<40A/m2 are not likely to affect the sheath properties.

Further conclusions taken from the investigations are:
- *Risk of degradation of Al sheath is unlikely if covering is not compromised*
- *Good inert aluminium property impedes possible corrosion*
- *In case of covering rupture: corrosion rate strongly depends on leakage current (Figure 2)*

In our study we focused on HVAC cables. HVDC cables were not studied. Nevertheless, conclusions drawn from the practical soil aggressiveness study may also hold for the HVDC cables in case of similar protection covers over the AluWeld.
As for the HVDC cable we can state that: if the jacked is not compromised, the risk of degradation on the AluWeld over its lifetime can be considered low. For punctured protection layers it can be concluded that aluminium is in general hardly affected by corrosion in neutral and aerated soils.
Exposure of chemical agents directly to the PE should be avoided since it could lead to early degradation of the PE. Similar as, organic solvents, oil or other specific chemicals can weaken the rigidity of the polymer structure by swelling and softening of the material.

The induced voltage in the HVDC cable system should be determined using affecting parameters. The voltage in the cable AluWeld sheath is induced by voltage ripple and other ac voltage waves profiles that can be active during operation. And the cable section lengths are longer in comparison to cable AC sections. These are one of the differences for Alu Weld corrosion in HVDAC cables and HVDC cables and should be identified.

The effect on stray currents represent an additional potential risk if the PE sheath is damaged. As mentioned before, the main corrosion parameter is the current density through the fault, which increases for decreasing soil resistivity.
Literature explains that AC leakage current impact on aluminium is ~50% compared to DC leakage current [2].
In order to scientifically verify the impact of the leakage current in DC situation, a similar approach of our research experiment could be performed using input parameters suitable for DC systems. Up to now site sheath failure experience is limited. It is therefore advised to analyze possible future failure cases, in order to build up knowledge towards condition indicator knowledge rules.

[1] Cigre brochure 765: “Understanding and mitigating corrosion”, April 2019
[2] S. Goidanich. “Influence of alternating current on metals corrosion”, PhD thesis, Politecnico di Milano, 2005