Introduction of novel research on interfaces in extruded HVDC submarine cable systems

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Aim

The aim of this presentation is to present the influence on ramping speed on electric field distribution for testing cable peelings with limited width.

About cable peelings

- Insulation strips cut from full-sized XLPE cables.
- Normally cut in the angular orientation.
- Polymer orientation and crystalline structure identical to that of a real cable.
- Limitations with regards to width and accurate control of thickness.

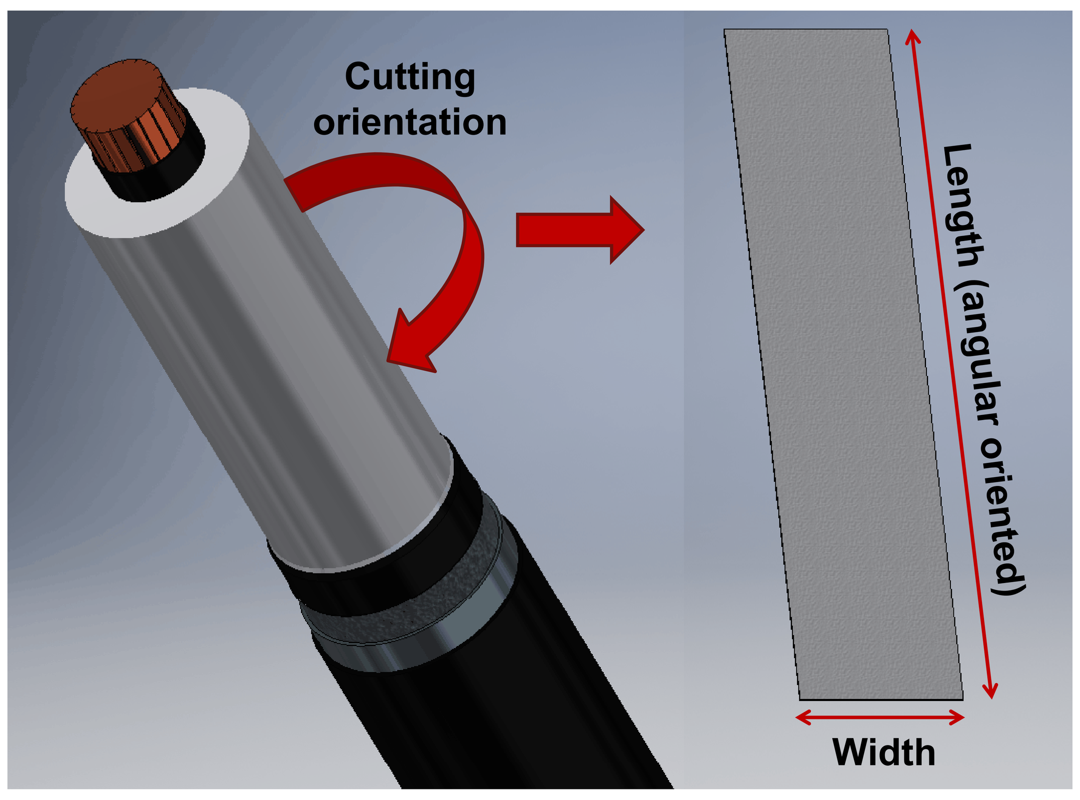

Figure 1. Illustration of cable geometry (right) and a surface cable peeling (left) with identical surface structure as found in HV accessories

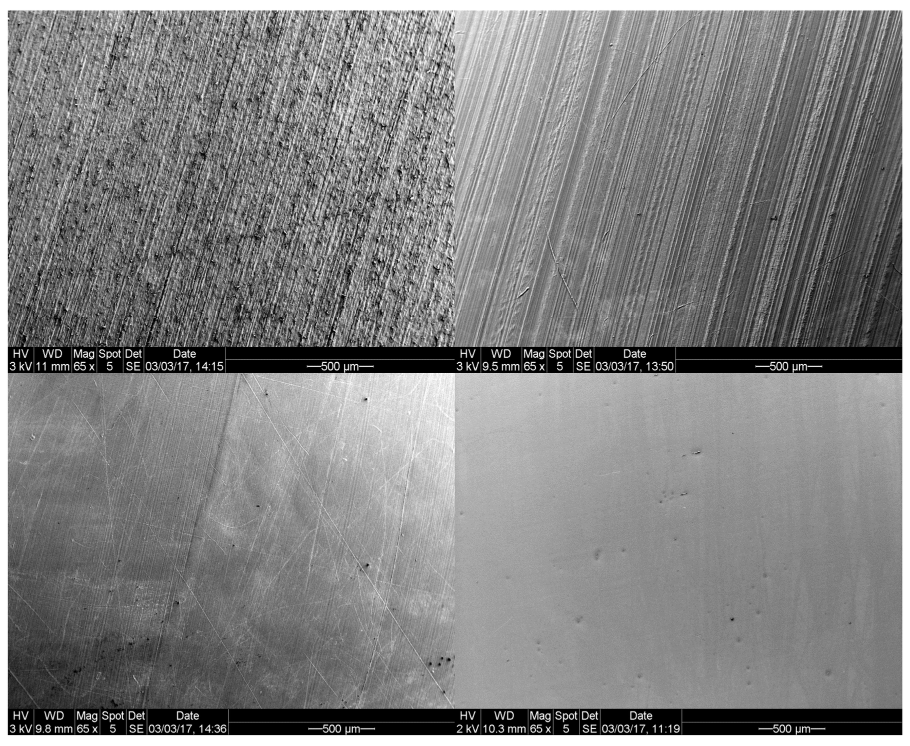

Figure 2. SEM characterization of surface structure at 65 times magnification. The surfaces are abraded (top left), roughly cut (top right), cut (bottom left) and remolded (bottom right).

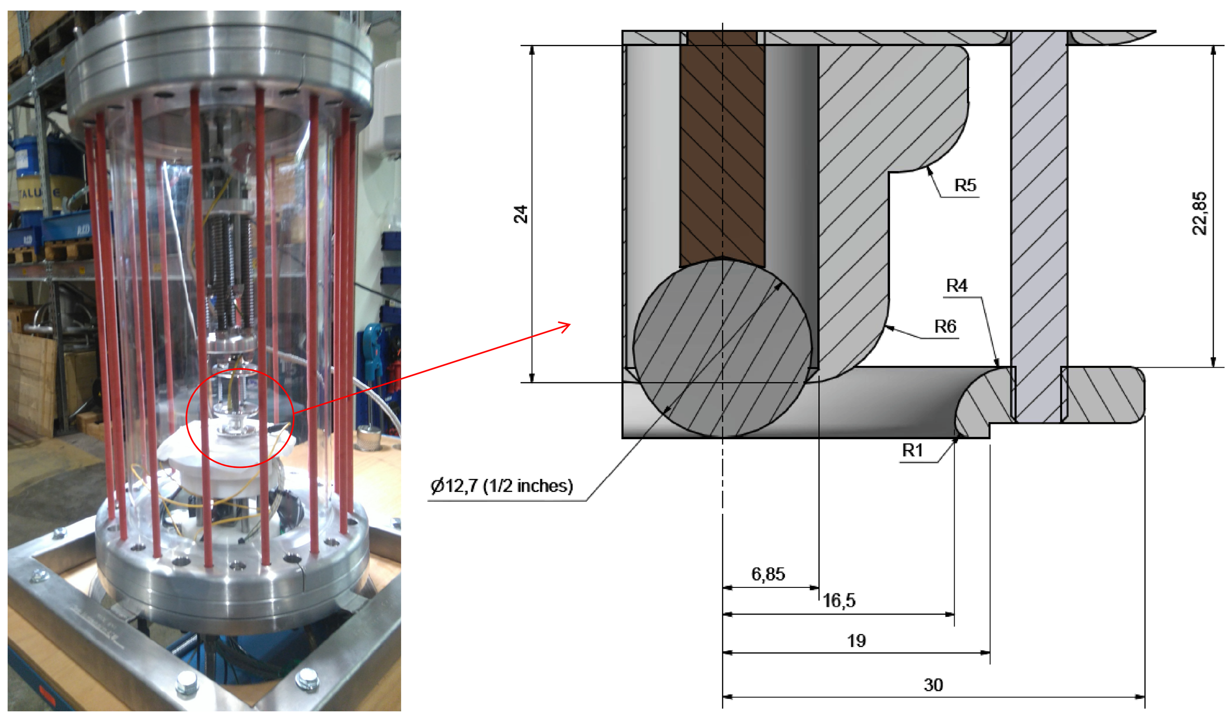

Figure 2. The Designed test cell with it's ball bearing electrode and removable guard ring.

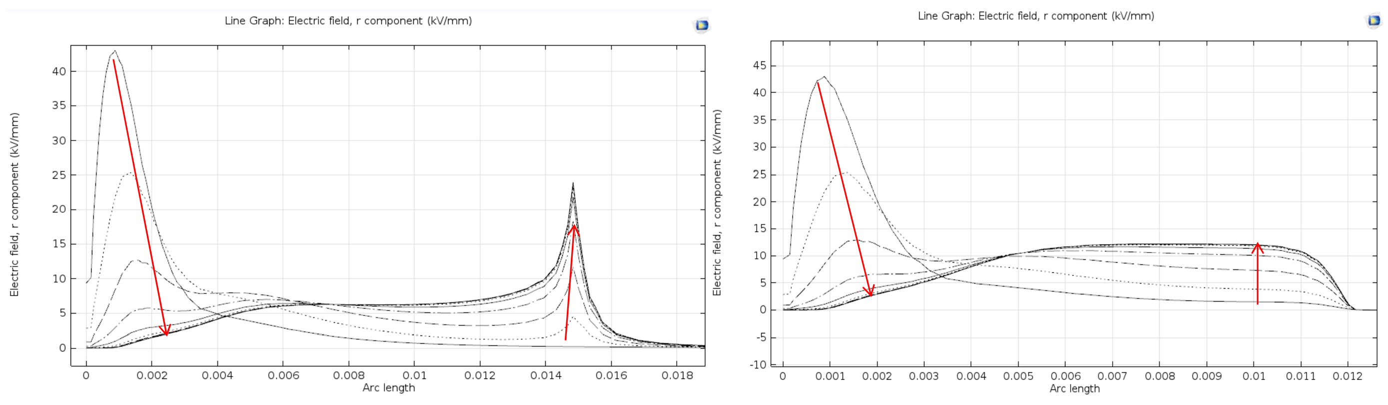

Figure 3. Conductivity sweep simulation (a decrease of conductivity is indicated with the arrows) of rod-plane geometry without (right) and with (left) a grounded guard ring. The radial electric field is displayed as function of radial position along the sample surface

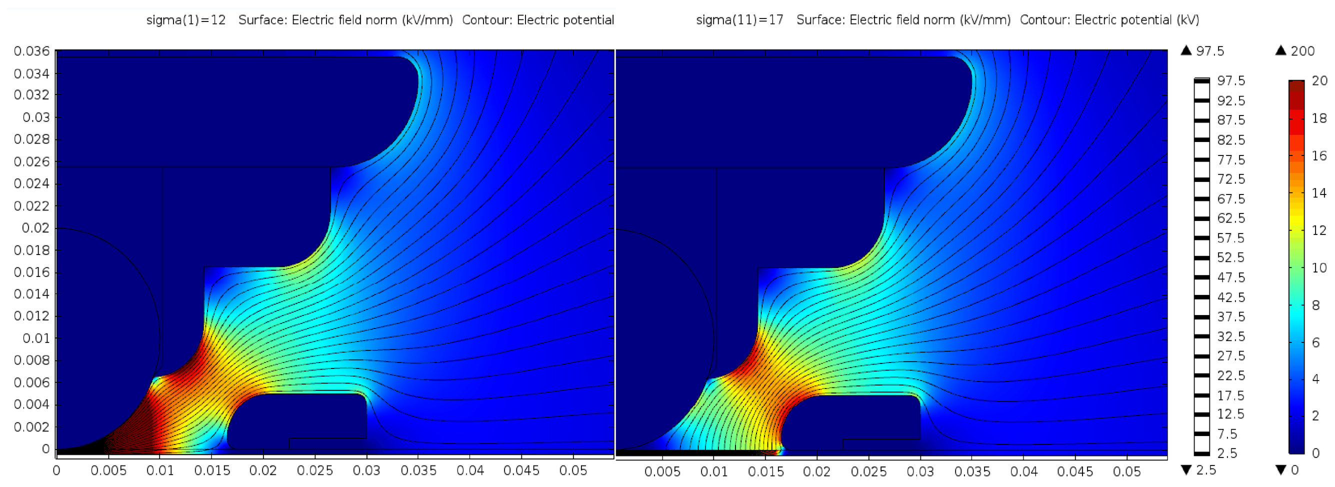

Figure 4. Electric field distribution in the setup with a more conductive sample (left) and a low-conductive sample (right). The applied voltage is 100kV.

Theoretical calculations

The MWS polarization of a parallel-plane geometry was calculated for stepwise and ramped voltage application.

$$\tau = \frac{b\varepsilon_a + a\varepsilon_b}{b\sigma_a + a\sigma_b}$$

$$E_a(t) = V\frac{\sigma_b}{b\sigma_a + a\sigma_b}\left(1 - e^{-t/\tau}\right) + V\frac{\varepsilon_b}{b\varepsilon_a + a\varepsilon_b}e^{-t/\tau}$$

$$V\theta(t) \rightarrow Laplace \rightarrow \frac{V}{s} \qquad V(t) = V * t \rightarrow Laplace \rightarrow \frac{V_r}{s^2}$$

$$E_a(t) = V_r\frac{\varepsilon_b}{b\varepsilon_a + a\varepsilon_b}\left(1 - e^{-t/\tau}\right) + V_r\frac{\sigma_b}{b\sigma_a + a\sigma_b}\left(\frac{t}{\tau} + e^{-t/\tau} - 1\right)$$

In order to test in DC, ramping speed needs to be limited for low-conductive samples.

Surface structure

Different orientation and magnitude of the surface texture was found for different surface preparation methods. Its influence on DC breakdown could be investigated using the presented test cell.

Simulation results

The rod-plane geometry is able to concentrate the electric field near the electrode for samples with higher conductivity.

For low-conductivity samples, an additional grounded guard ring is able to mitigate any edge effect caused by the short sample witdth.

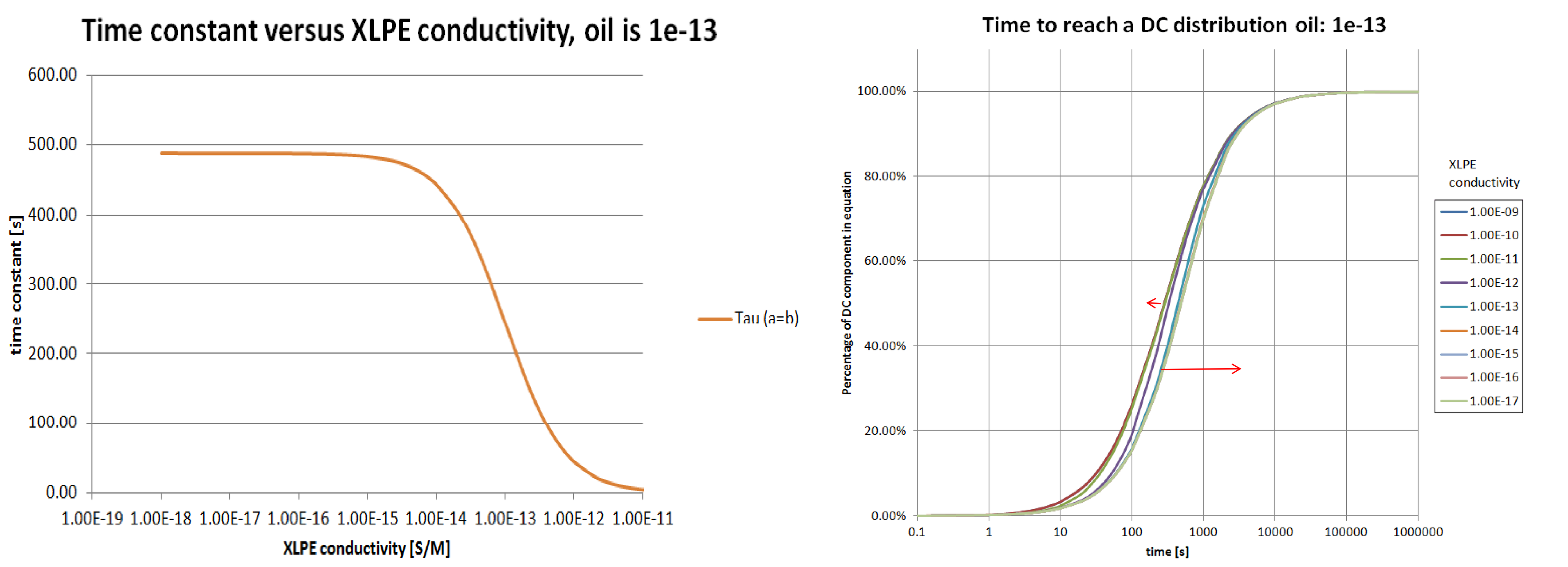

Figure 5. Variation of the time constant versus sample conductivity (right) and percentage of DC content versus sample conductivity for a ramped DC breakdown test. Red arrows indicate how the curves shift if the oil conductivity is lowered, resulting in a bigger spread among the displayed curves.

Conclusions

- The grounded guard ring should mitigate the edge effect at the cost of higher stress in the oil and a slight increase of the average field along the surface.
- A low enough ramping speed will be required in order to reach a DC field distribution.
- The peeling method will allow for small scale tests with exact replication of the surface structure from full-sized HV accessories.
- DC breakdown test will be commenced in order to see if previous breakdown results on cable ends can be replicated on the cable peelings with different surface structures.

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