Silicones in HV Cable Accessories – a Success Story for AC and Existing Challenges for DC

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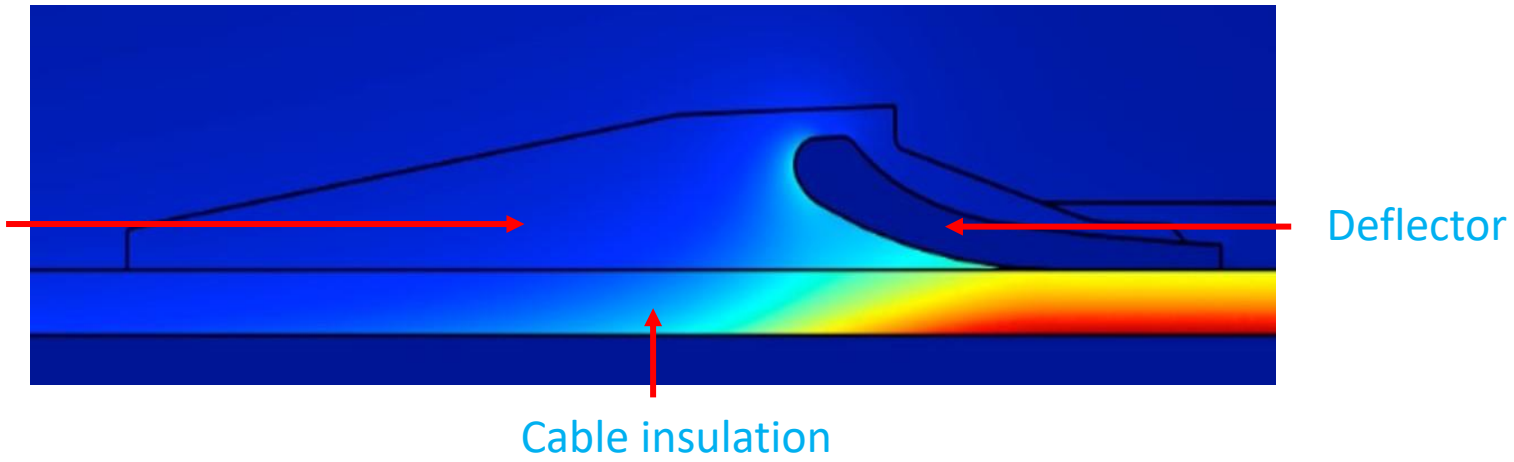
Applications and Properties of Silicones in HV Cable Accessories

- Silicone materials are widely used in HV cable accessories
  - Excellent dielectric properties
  - Excellent outdoor performance (UV resistance, hydrophobicity)
  - Very good mechanical properties (e.g. high flexibility)
  - Well established processing technology

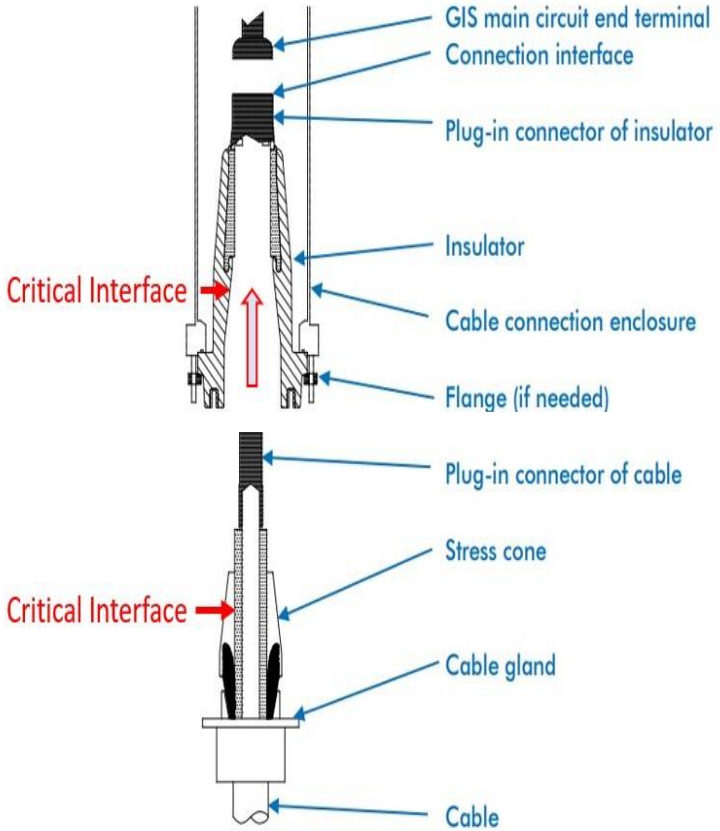
Example: Stress Cone in an Outdoor Termination



- Electrical stress below the deflector is as high as the dielectric stress in the cable insulation below the insulation screen and can reach values above 7 kV/mm.
- The stress cone has to withstand these electrical stresses for the expected life time of the termination (more than 30 years).

Example: Interfaces at Plug-In GIS Termination

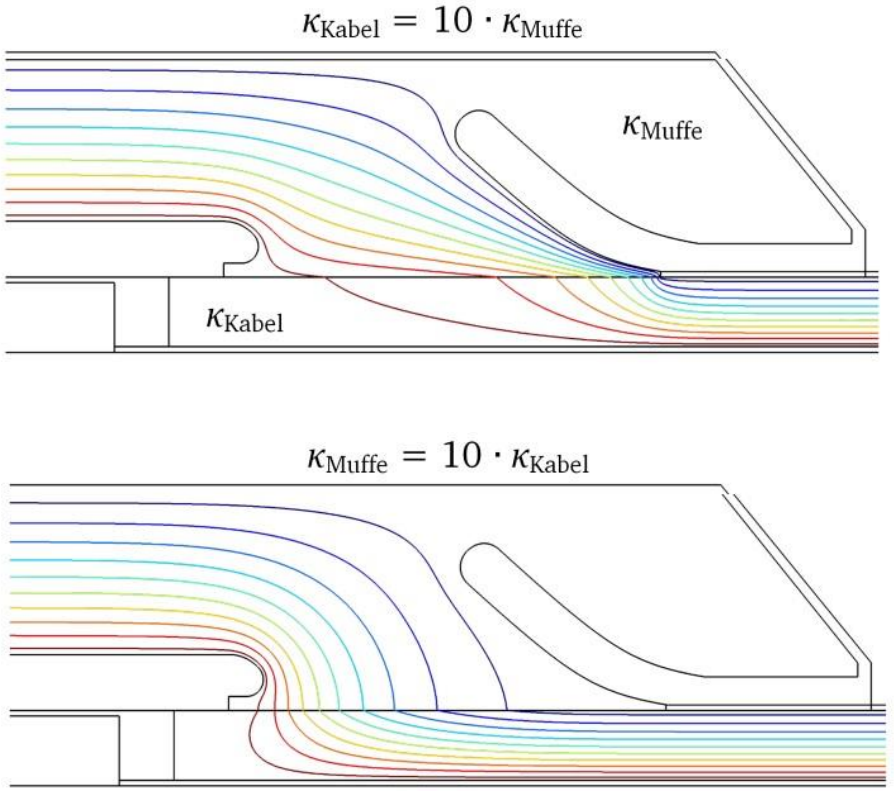
- At plug-in GIS terminations two critical interfaces exist:
  - Interface: stress cone – insulator
  - Interface: stress cone – cable insulation
- Dielectric strength of the interface depends on the mechanical pressure.
- To guarantee high dielectric strength throughout the service life of the termination, the mechanical properties of the silicone stress cones must remain virtually constant for decades.



Differences and Challenges at DC

- At DC the distribution of the electrical field depends on the conductivities of the joint insulation and the cable insulation.

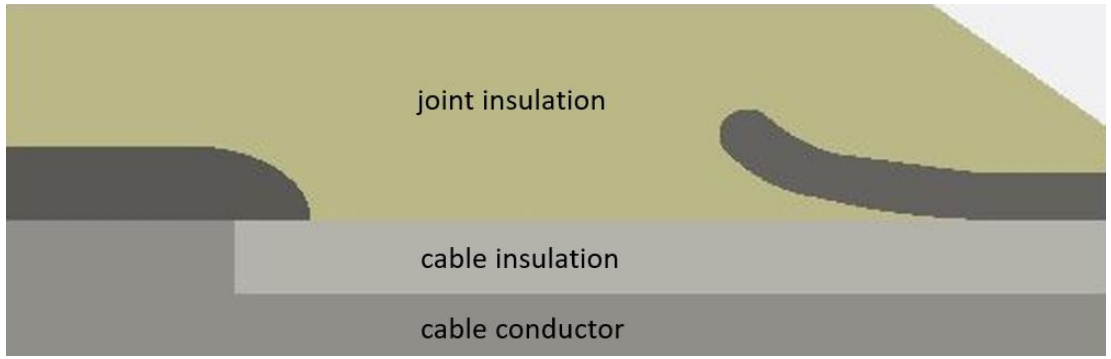
- The electric field distribution is only homogeneous if these conductivities are approximately equal (similar as at AC)



Source: PhD Thesis of R. Hussain, Tech. University of Darmstadt (2020)

Disadvantages of Classical Joint Design for HVDC

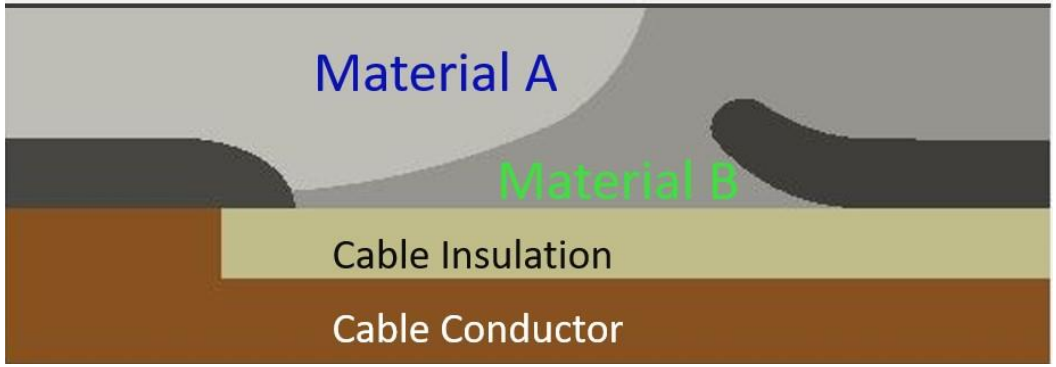
- Conductivity of involved insulating materials depends on temperature. This means that even if they are equal at a certain temperature, generally they will not be equal at another temperature.
- Conductivity of the involved materials can vary from batch to batch
- Conductivity of the involved materials depends on the processing parameters (e.g. degassing process of the cable core)



Classical Joint Design

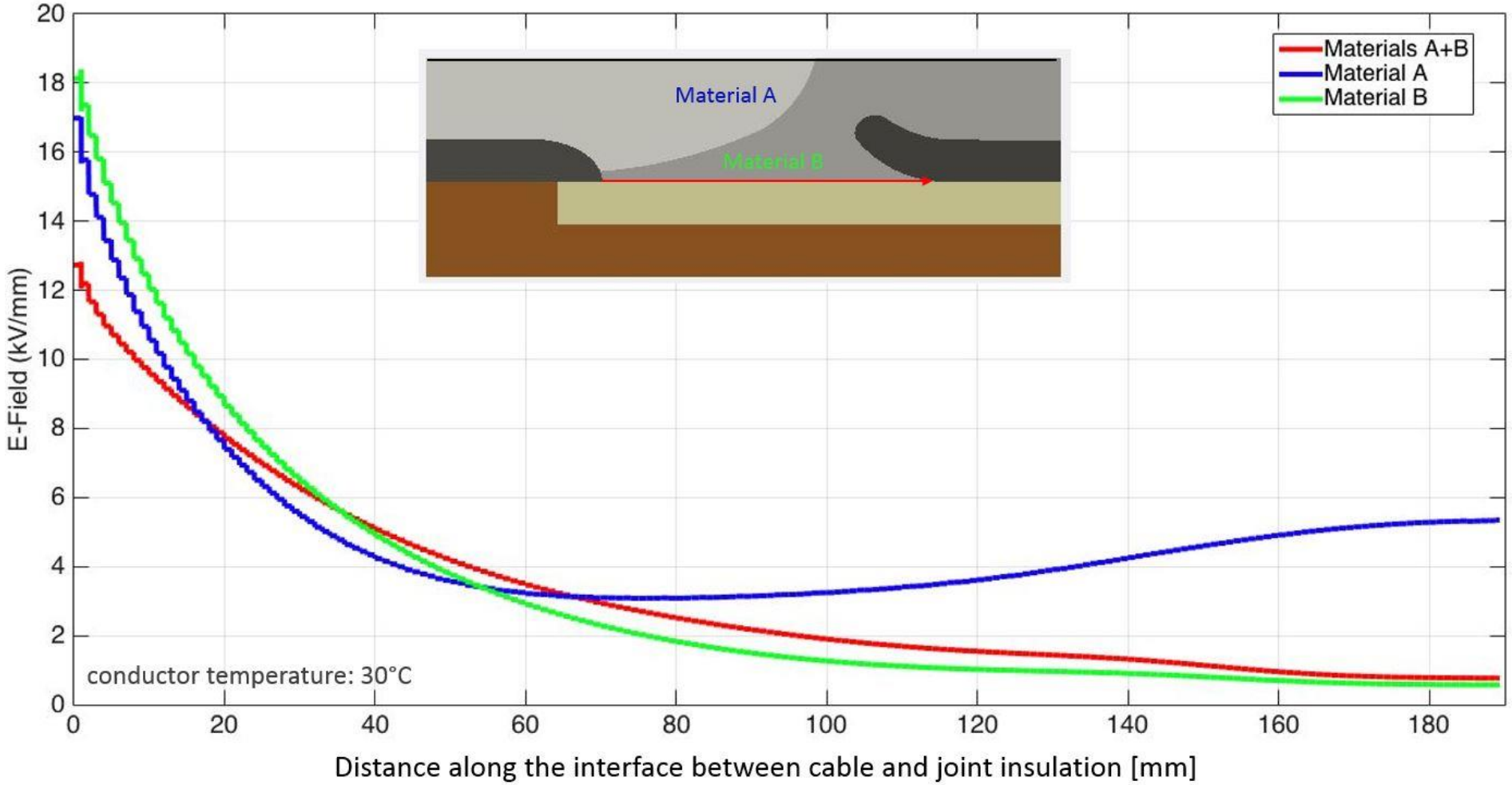
New Design Concept for HVDC Joints

- Using two insulating materials (A and B) with different conductivities in the joint body
- Each of the insulating materials must connect high voltage potential with ground potential
- Conductivity of material B must be higher than that of material A and also higher than that of the cable insulation (XLPE)

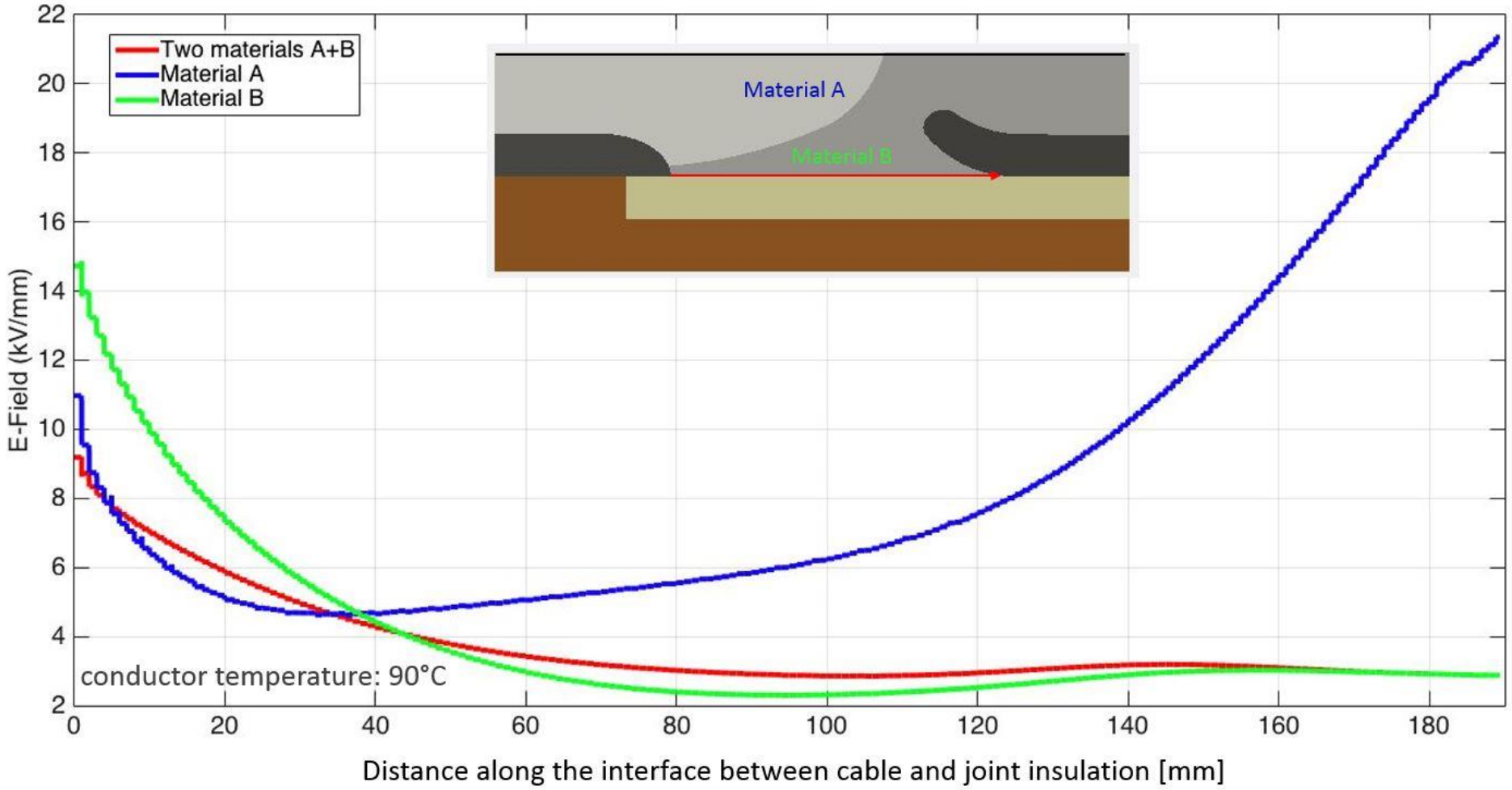


Gramespacher H: “Prefabricated sleeve body for connecting two high-voltage polymer cables for direct current”, Patent EP334201B1, (2021)

Electrical Field Distribution with New Joint Design (1)

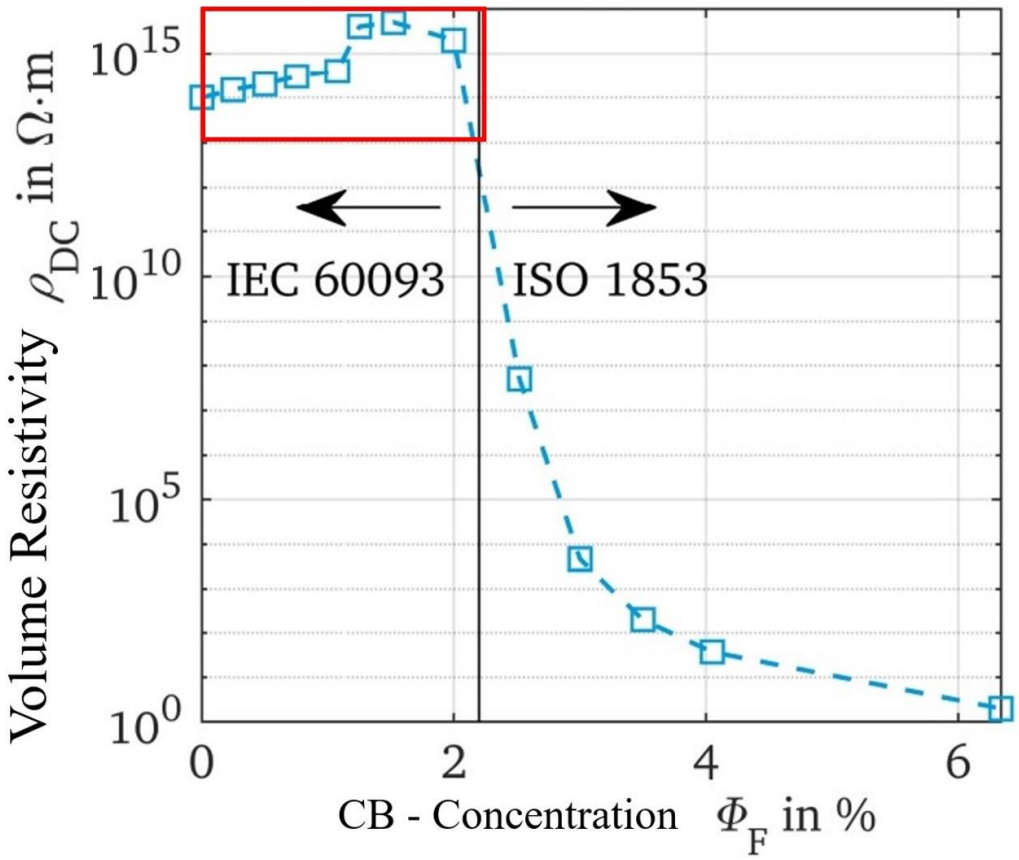


Electrical Field Distribution with New Joint Design (2)



Adjusting the Conductivities of Insulating Silicone Elastomers

- Using carbon nanoparticles as a filler below the percolation treshold increases the resistivity of the silicone elastomer.
- It is possible to increase the resistivity by about two orders of magnitude.
- Unfilled silicone could be used as material B, filled material could be used as material A in the new joint design.



Source: PhD Thesis of R. Hussain, Tech. University of Darmstadt (2020)

Discussion of the New Design Concept

- “The interface between the two insulating materials may lead to space charges and therefore locally to high electrical fields.”

- But:
  - There is already an interface between two insulating materials in the joint body (between cable insulation and joint insulation).
  - The interface can be selected so that the largest component of the electric field runs (locally) parallel to the interface.
  - Caused by the fact that the interface connects ground potential with high potential, a current is flowing along the interfaces.

Proposal for Research Program

In practical applications there exists very often an electrical field parallel to the interface of insulating materials. This electrical field (current) might influence the distribution of space charges at the interfaces.

When space charges at insulating interfaces are investigated (e.g. with PEA –methods) the influence of an electrical field parallel to the interface should be also investigated.

Summary

- Silicone elastomers have proven their excellent performance at HV AC cable accessories since decades.
- Silicone elastomers are rarely used for HVDC cable joints caused by their resistivities in comparison to resistivity of the cable insulation.
- New design concept of HVDC cable joints allows - together with the possibility to adjust the resistivity of silicone elastomers - the use of silicone elastomers also for HVDC.
- At the investigation of space charges at interfaces also the presence of an electrical field parallel to the interface should be considered in future.

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Thank you very much for your attention