Cable Research Testing

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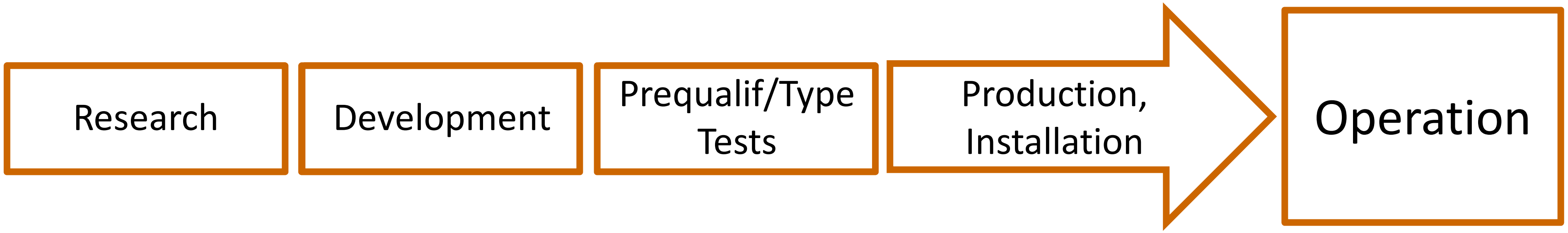
HVDC Extruded Cables



Electrical

Understanding material behavior
Chemical
Design parameters

Demonstrate satisfactory performance and characteristics
Extract parameters for modeling and design
Thermal

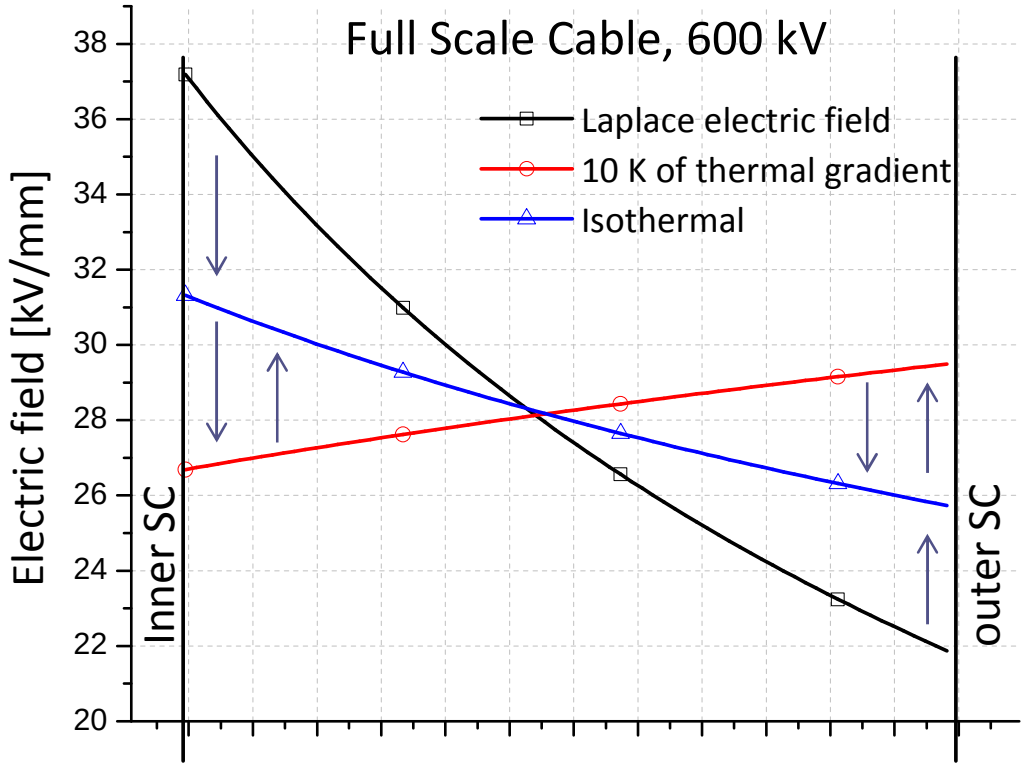
Ranking of materials and configurations
Mechanical

Types of samples

	Dielectric Thickness	Manufacturing duration	Degassing duration	Test preparation	Occupied area during test
Plate	≈ 1.5 mm	< 1 h/plate	1 day	< 5 h	< 3 m²
Model Cable	≈ 6 mm	> 3 days	< 1 week	> 1 day	< 20 m²
Full Scale Cable	> 15 mm	> 3 days	> 1 week	> 1 week	> 40 m²

Tests on Full Scale Cables present technical challenges

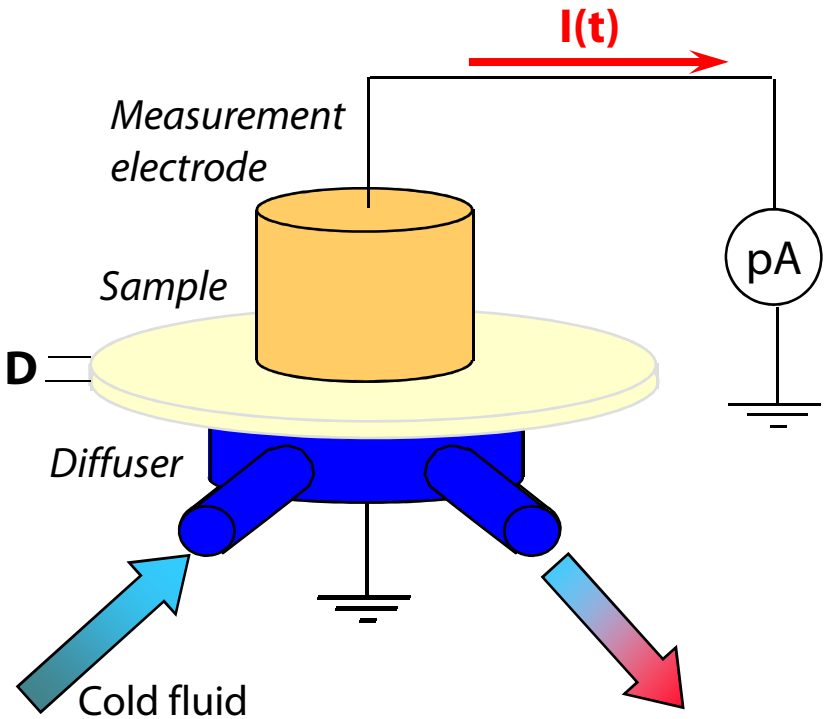
Electric Fields in HVDC XLPE Cables

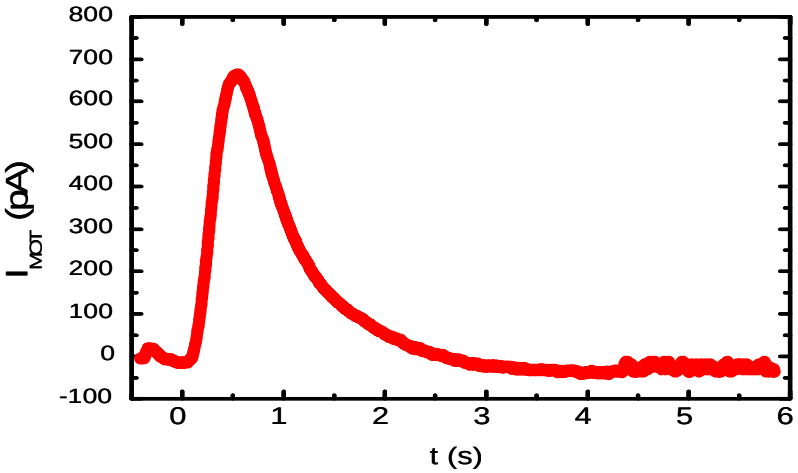


Space charge phenomena will induce field distortions

Need to determine electric field distribution in cables

Thermal Step Method



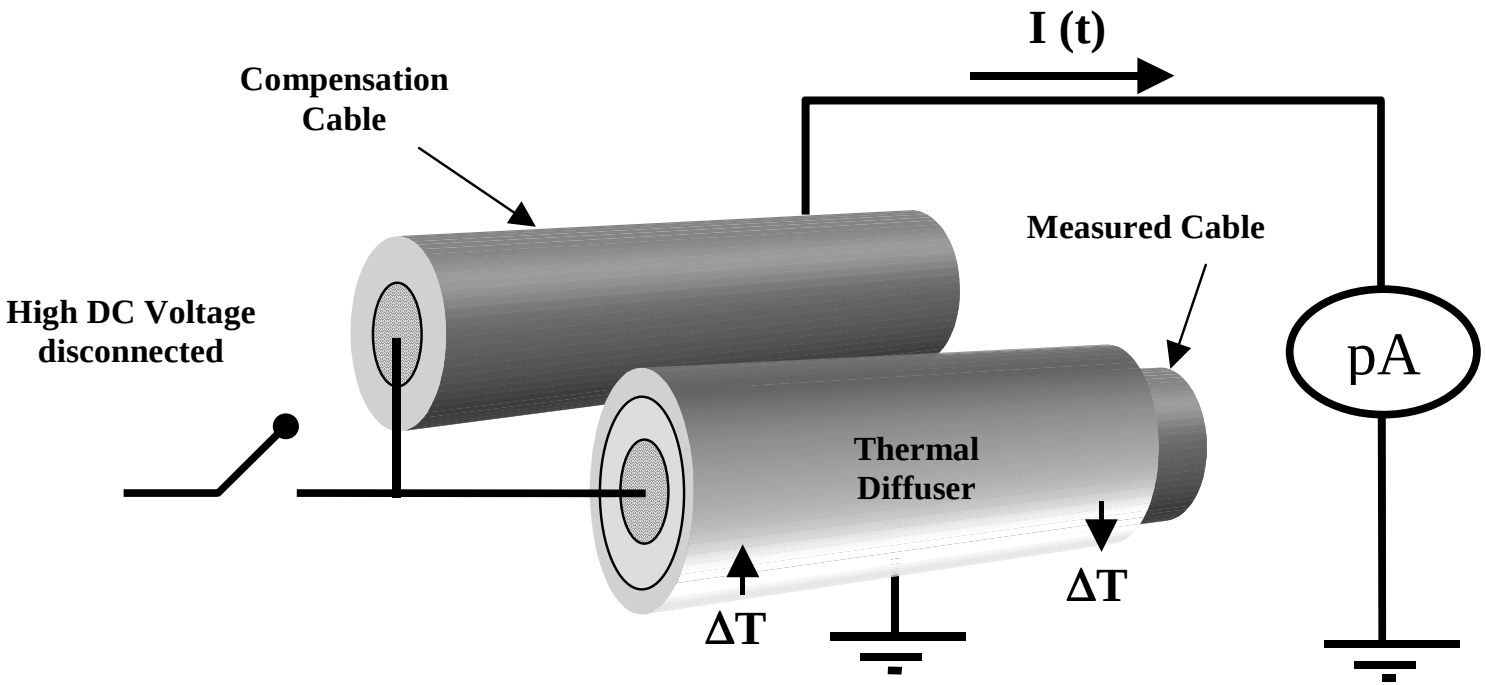


$$I(t) = -\alpha C \int_0^D E(x) \frac{\partial \Delta T(x,t)}{\partial t} dx$$

$$\alpha = \frac{1}{x}\frac{dx}{dT} - \frac{1}{\varepsilon}\frac{d\varepsilon}{dT}$$

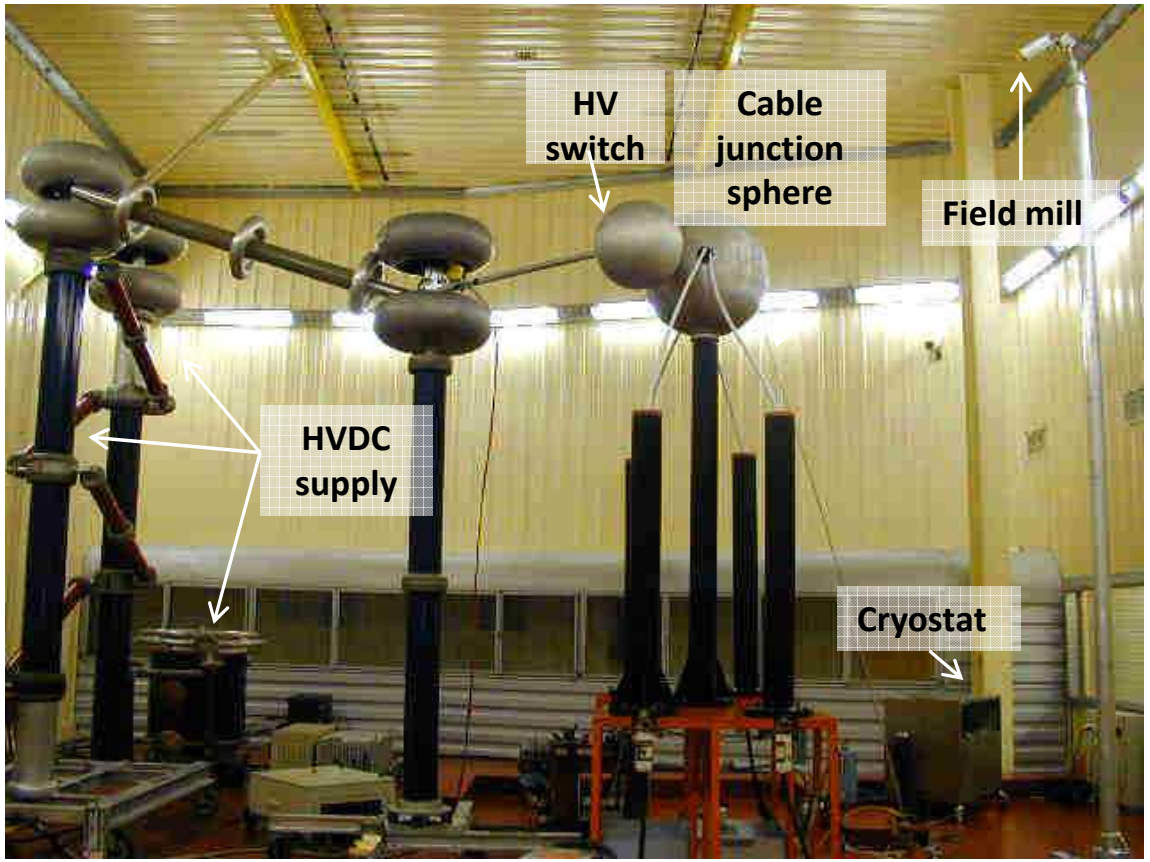
Calibration required to determine α

Double Capacitor Technique



Compensation of cable polarization and conduction current

Double Capacitor Technique Setup



Cable thermal condition must be in steady state

Electrical ageing is not interrupted during measurement

Calibration

$$I(t) = -\alpha C \int_0^D E(x) \frac{\partial \Delta T(x,t)}{\partial t} dx$$

Use of a known electric field distribution for calibration

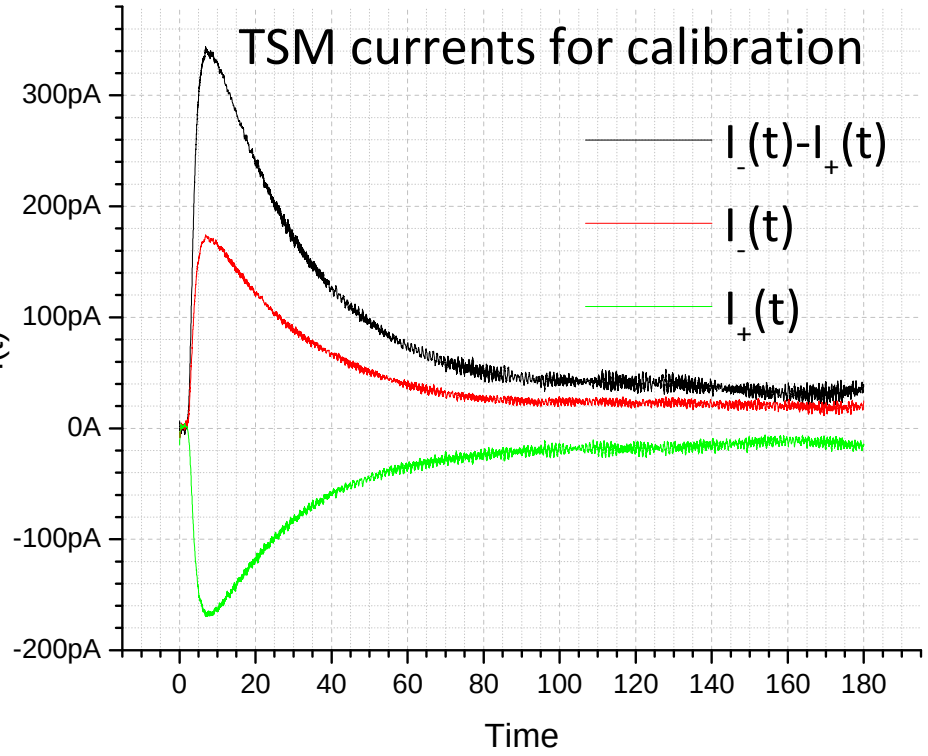
Low voltage application at both polarities

Calibration

$$I_-(t) = -\alpha \frac{C}{2} \int_0^D \left(-E_{Lap}(r) + E_r(r)\right) \frac{\delta \Delta T(r,t)}{\delta t} dr$$

$$I_+(t) = -\alpha \frac{C}{2} \int_0^D \left(E_{Lap}(r) + E_r(r)\right) \frac{\delta \Delta T(r,t)}{\delta t} dr$$

$$I_-(t) - I_+(t) = -\alpha C \int_0^D E_{Lap}(r) \frac{\delta \Delta T(r,t)}{\delta t} dr$$

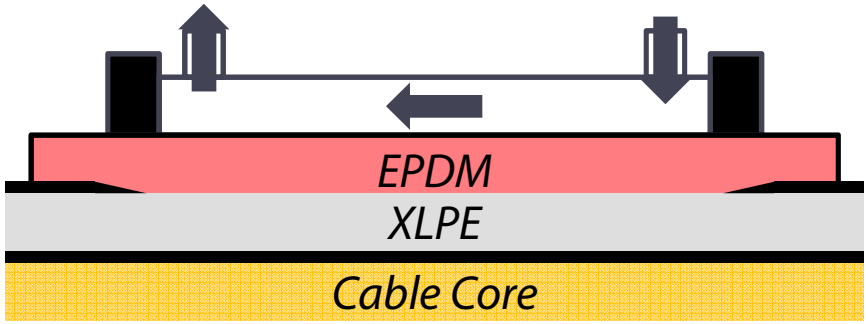


Can be performed either on unaged or aged cables

One calibration is sufficient to process measurements under ageing different conditions

Example of TSM measurements

V_{pol} = 50 kV; ΔT: 20 K



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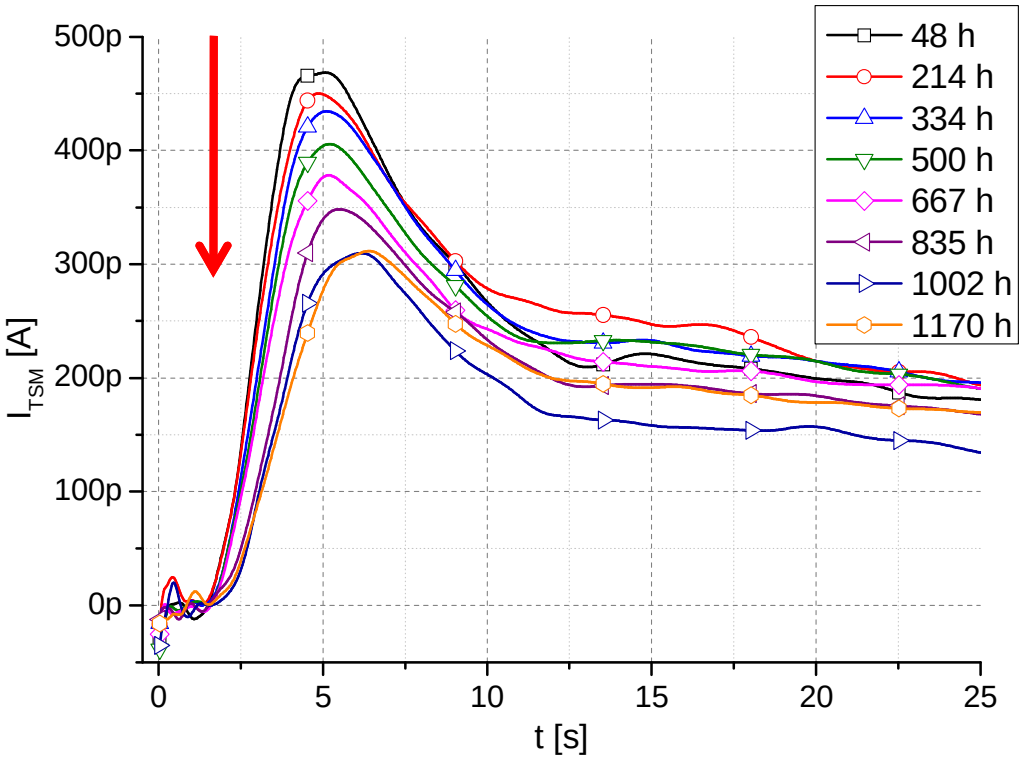
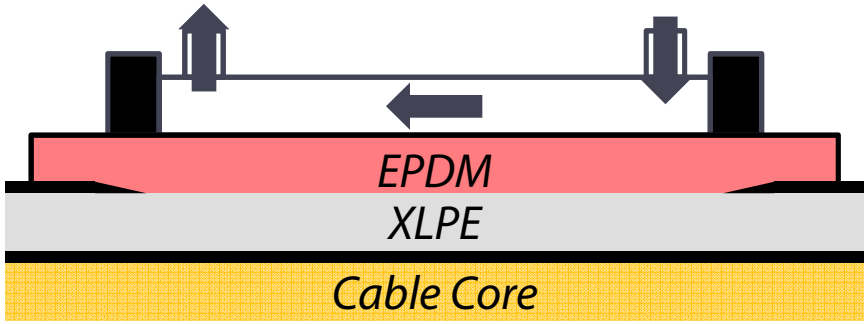
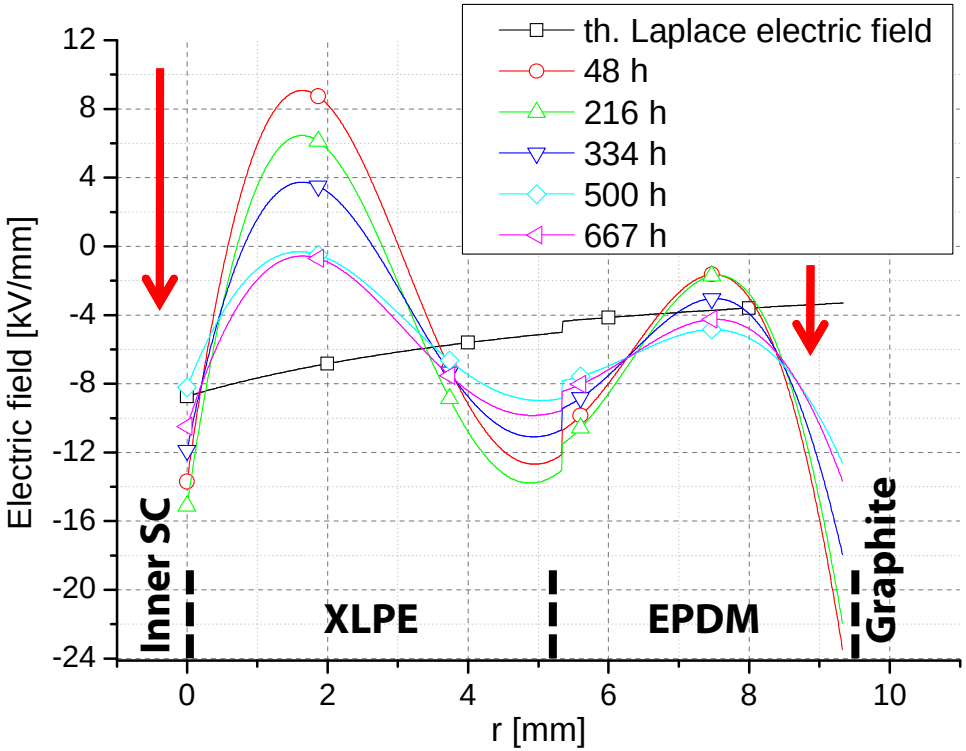


Decrease of TS current magnitude indicates a decrease of E field magnitude in the sample

Example of TSM measurements

V_{pol} = 50 kV; ΔT: 20 K



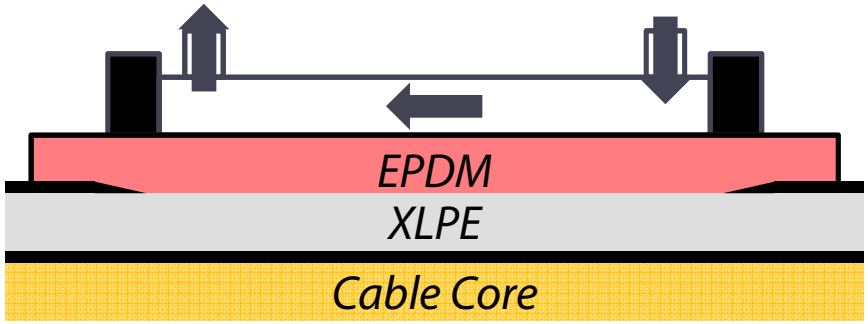


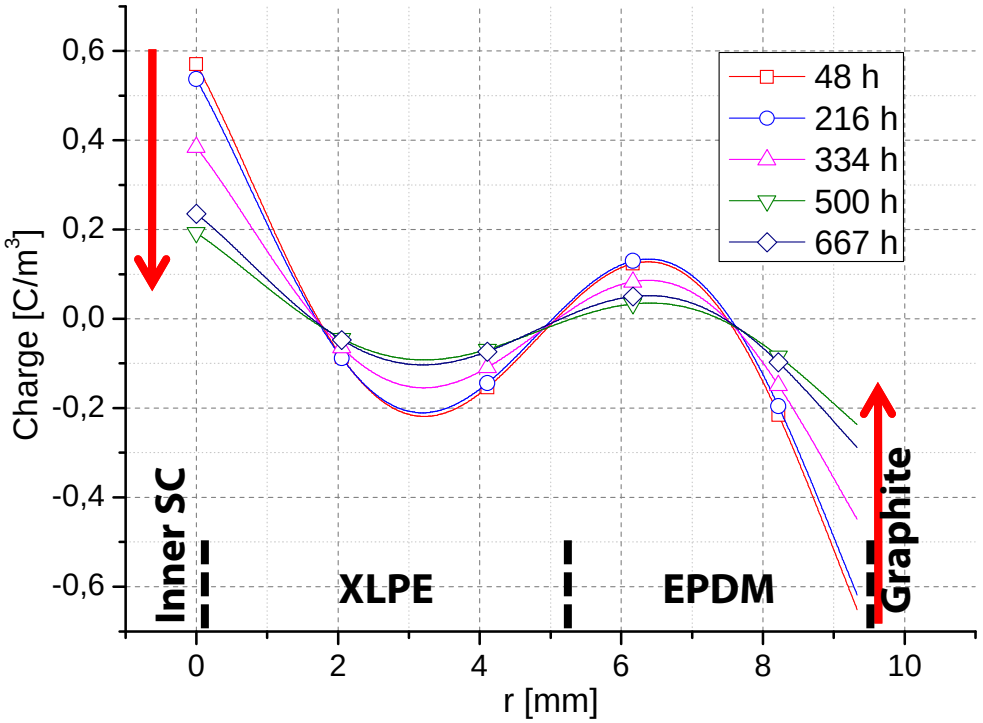
Field enhancement at electrodes indicates heterocharges

Decrease of E field magnitude in the sample

Example of TSM measurements

V_{pol} = 50 kV; ΔT: 20 K





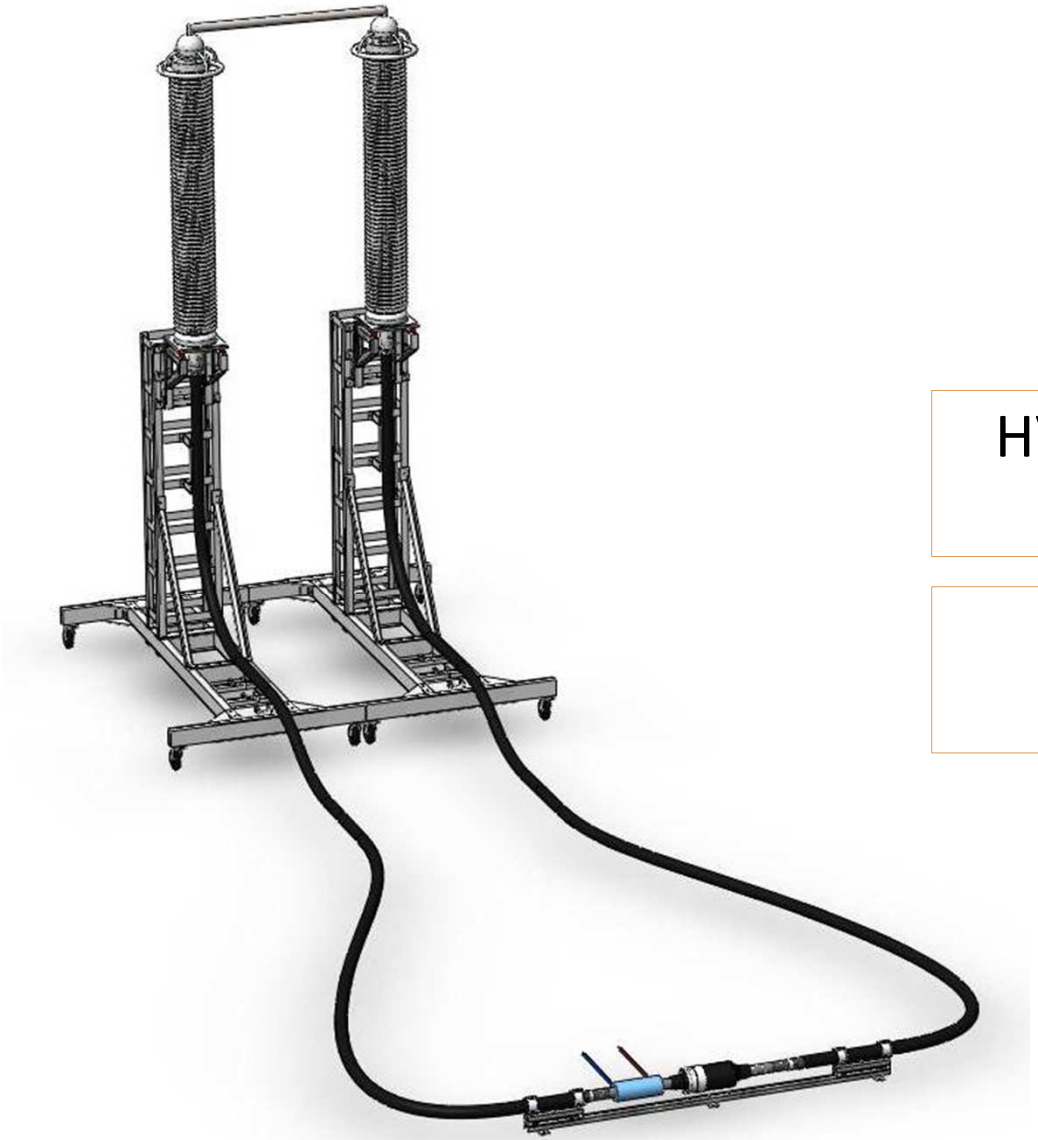
Decrease of heterocharges with ageing duration

Conclusion

Broad scale of samples are involved in cable research testing

Space charge characterization is of great importance for HVDC extruded cables

Characterization of full scale cable during ageing will provide valuable information for cable system developments



HVDC full scale XLPE long term ageing

TSM, PEA, TDDS