Budapest University of Technology and Economics
High Voltage Laboratory

Time Domain Spectroscopy of Low Voltage Nuclear Power Cables Under Simultaneous Thermal and Mechanical Aging

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Agenda

- Background
- Objectives
- Dielectric Spectroscopy
- Concept of the Extended Voltage Response (EVR)
- EVR measurement setup & circuit representation
- Experimental work: Samples, combined aging, and experimental setup
- Results & Discussion
- Conclusion

Background

- According to Many international reports, the role of the nuclear power plants in the energy generation market is increasing day by day.
- NPPs supplies around 11% of the world's electricity and around of 25% of the electricity in OECD countries.
- The reliability and safety of these plants relies on many components and all these components should function properly during the normal operation conditions and the accident conditions.
- Cables in NPPs provides the link between the transducing, instrumentation and control systems that monitor these plants.
- Cables are not only subjected to high radiation levels but also, they suffers from electrical, mechanical and thermal stresses.
- These stresses affects the insulation integrity of these cables or in other words causing aging. Therefore, the insulation state of these cables must be monitored.

Objectives

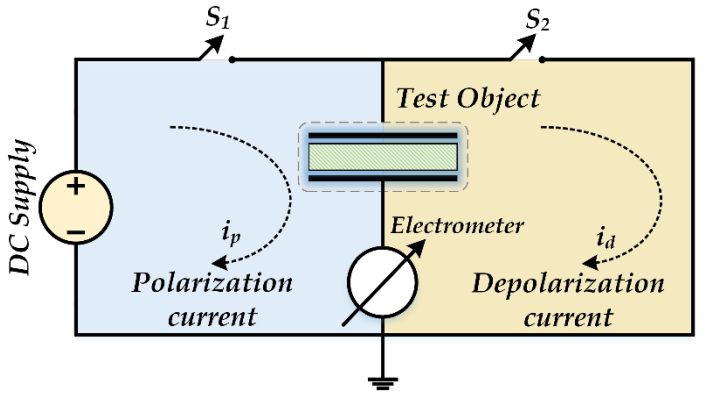
- Investigating the effect of thermal aging
- Non-Destructive condition monitoring
- Electrical testing, EVR “ Extended Voltage Response”
- Aging markers
- Insulation state

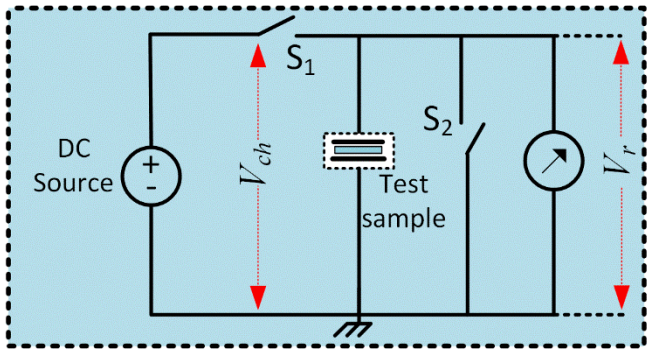
Elongation at Break (EaB)

Dielectric Spectroscopy

Time Domain Spectroscopy

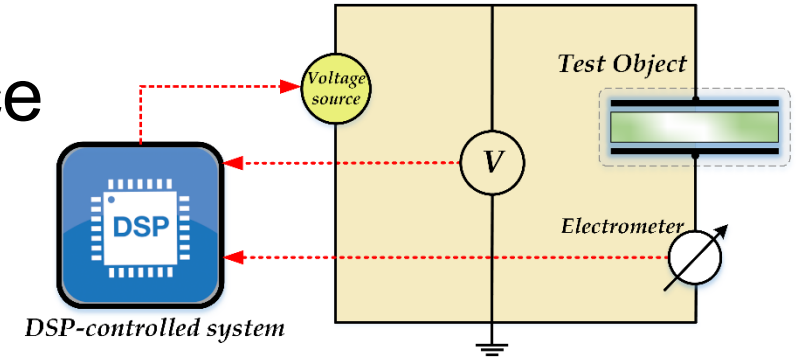
- PDC
- RVM
- VR
- EVR





Frequency Domain Spectroscopy

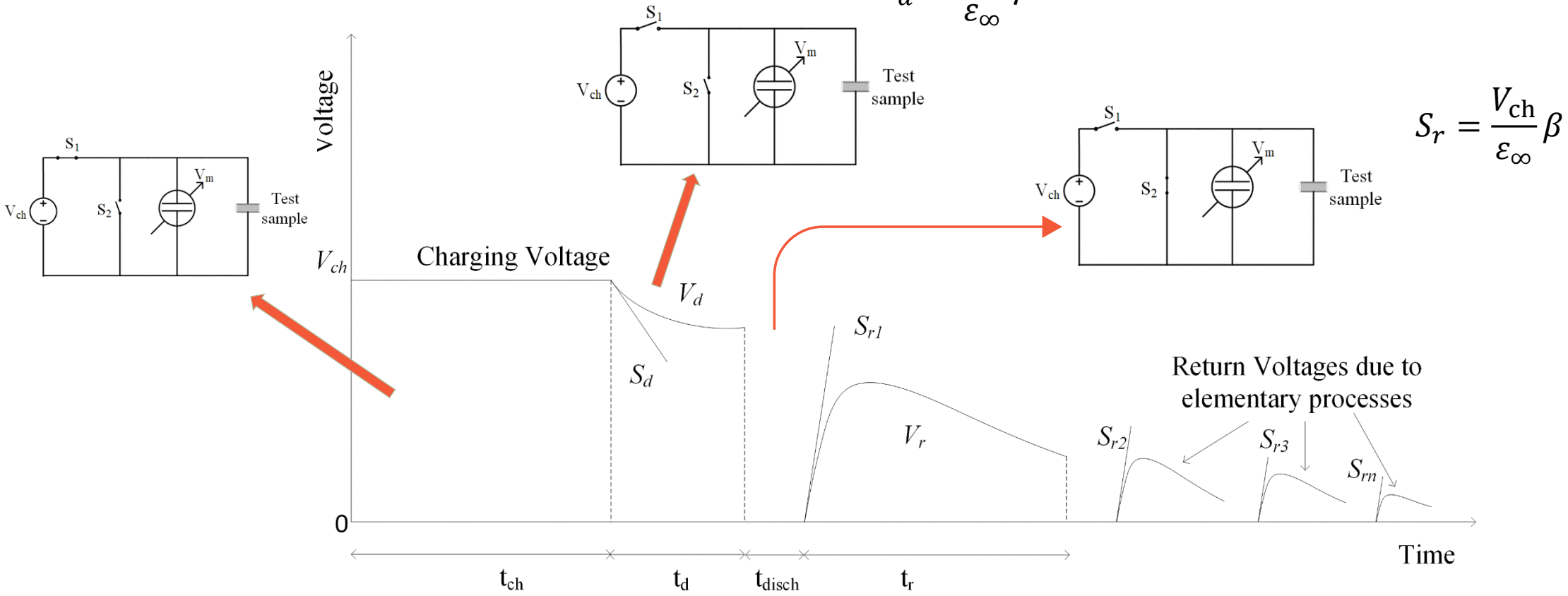
- tanδ
- Capacitance
- Impedance
- Permittivity



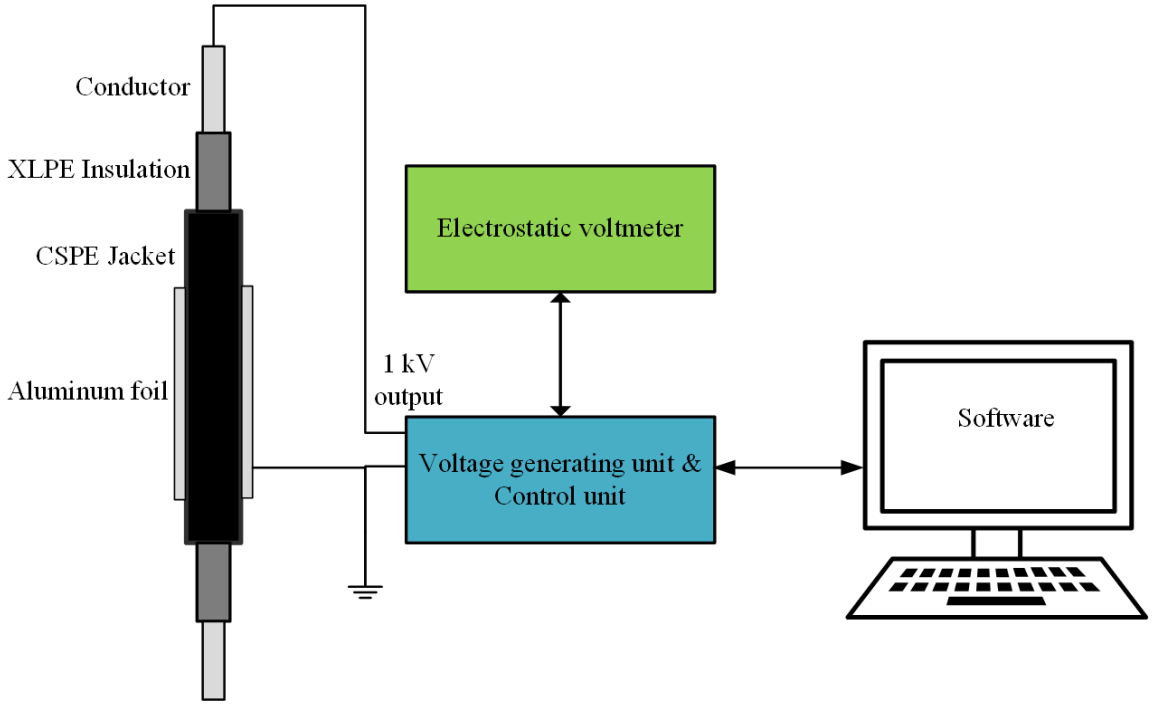
Concept of EVR

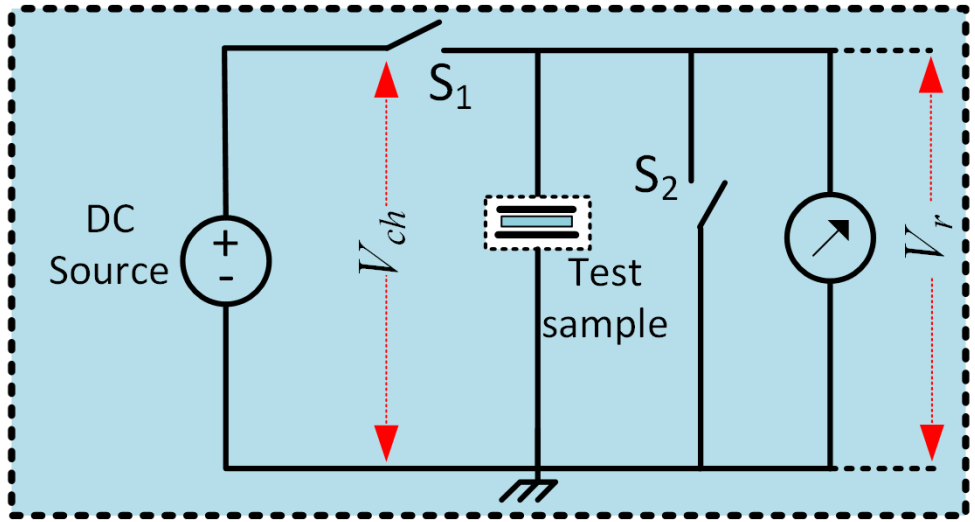
$$S_d = \frac{V_{\mathrm{ch}}}{\varepsilon_\infty}\gamma$$

$$S_r = \frac{V_{\mathrm{ch}}}{\varepsilon_\infty}\beta$$



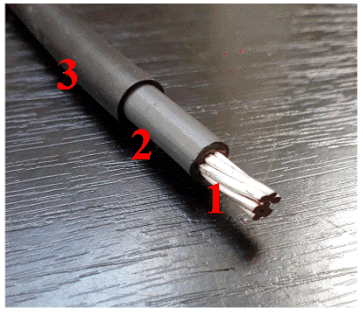
EVR Measurement Setup





Experimental Work

1. Specimens



1. Tin-coated copper conductor
2. XLPE core insualtion
3. CSPE outer jacket

- Rated voltage: 1 kV.
- Insulation thickness: 1.143 mm.
- Jacket thickness: 0.762 mm.
- Outer diameter: 8.636 mm.

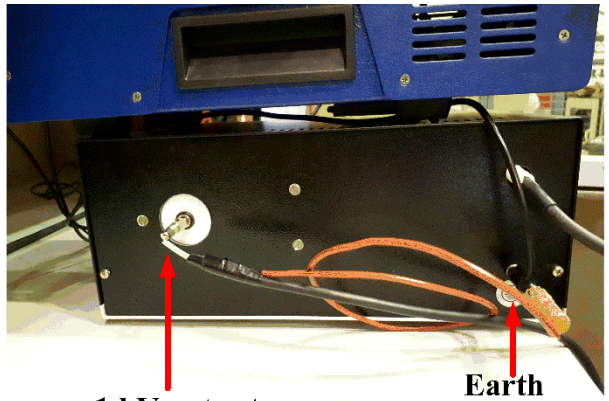
2. Accelerated Aging

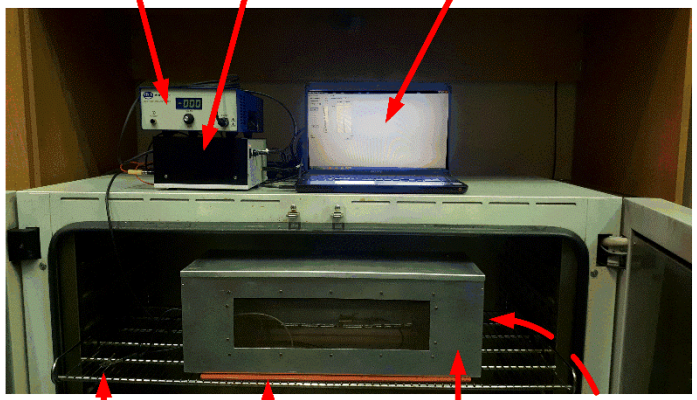
- Mechanical bending: IEEE 383.
- Mandrel diameter: 150 mm.
- Oven temperature: 120 °C.
- Combined aging: 779 hours.

Experimental Work…Cont.

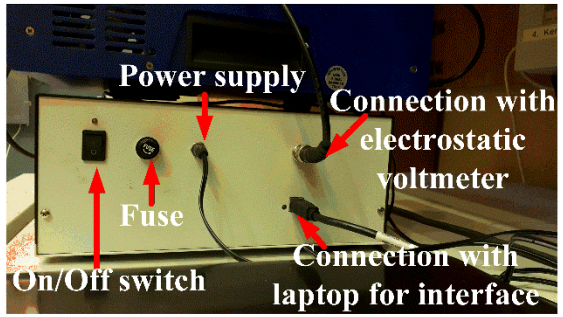
3. Experimental Setup

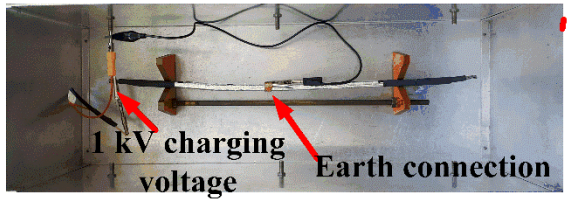
Left side view of voltage generation & control unit





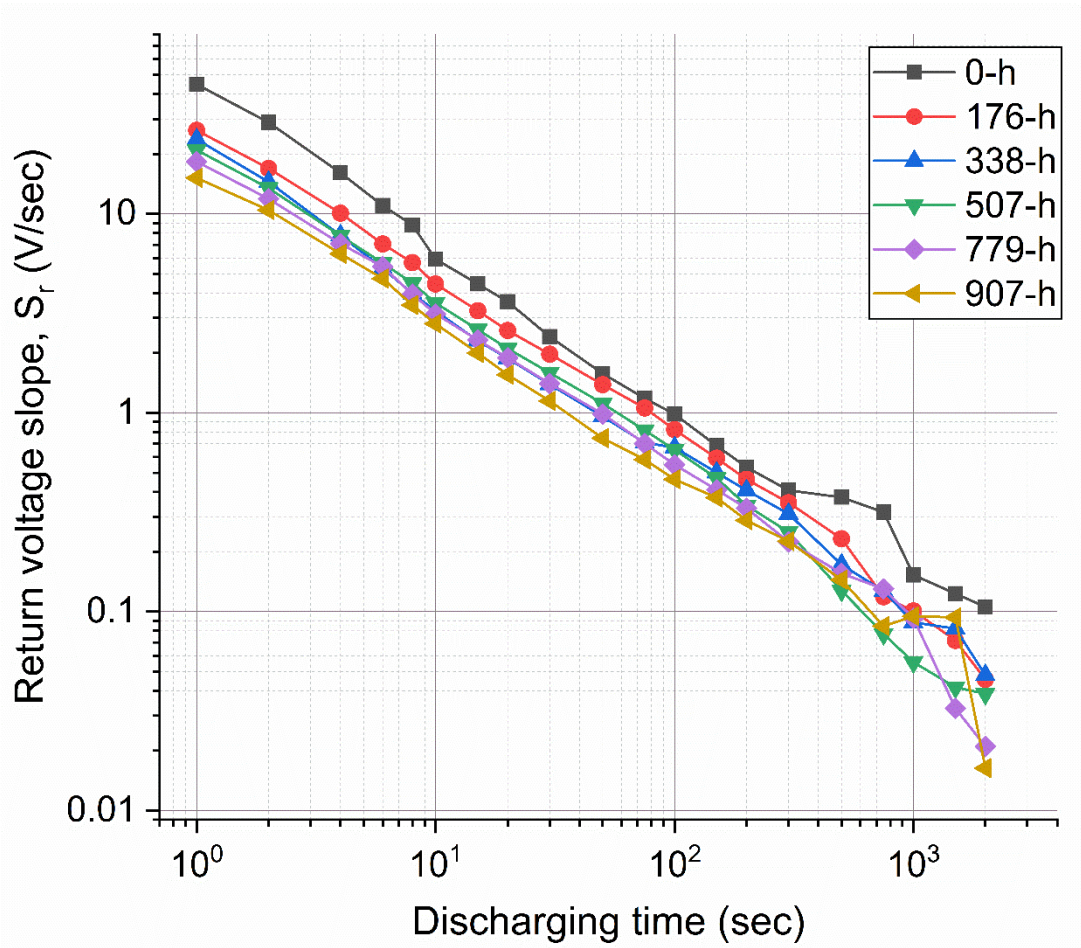
Right side view of voltage generation & control unit





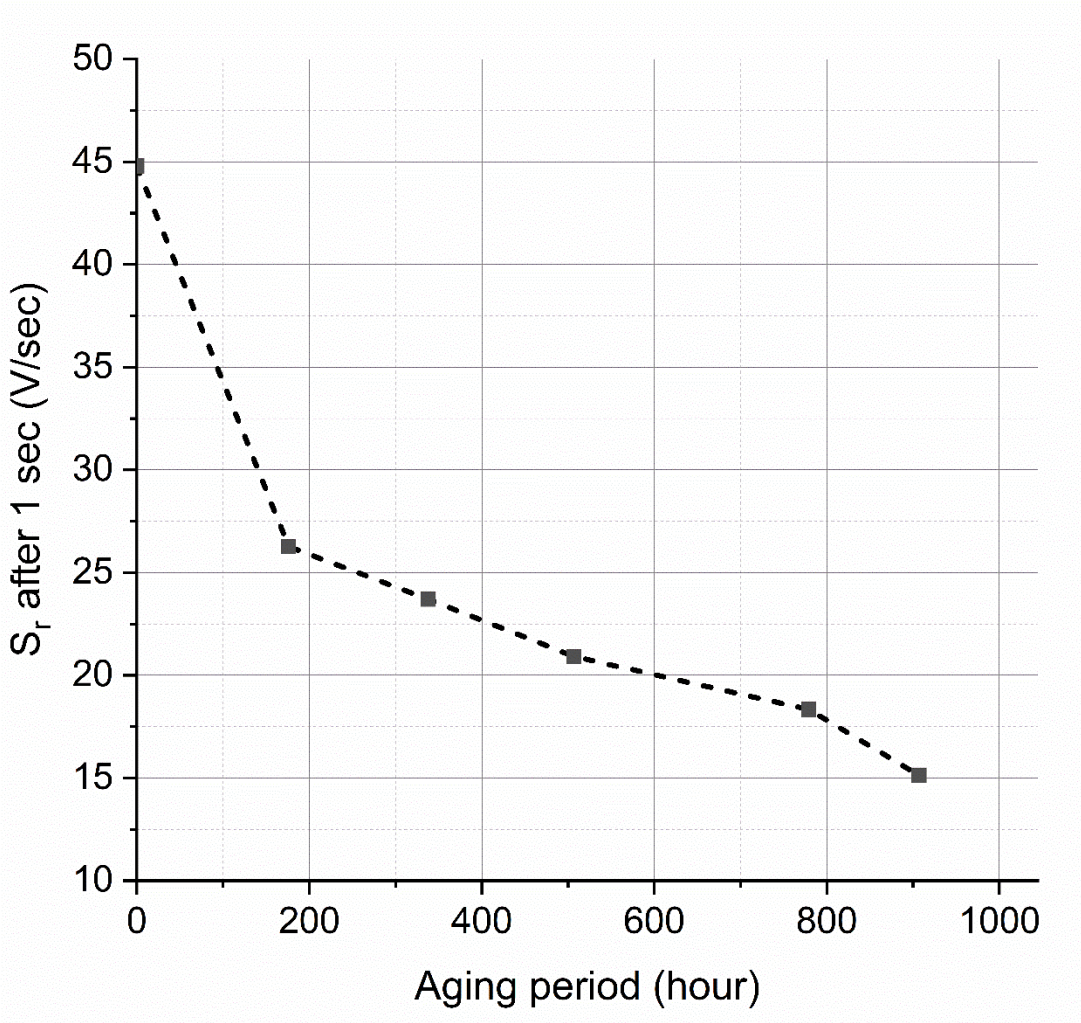
Results & Discussion

- **Charging voltage: 1 kV**
- **Charging time: 4000 sec**
- **Discharging time: from 1 to 2000 sec**



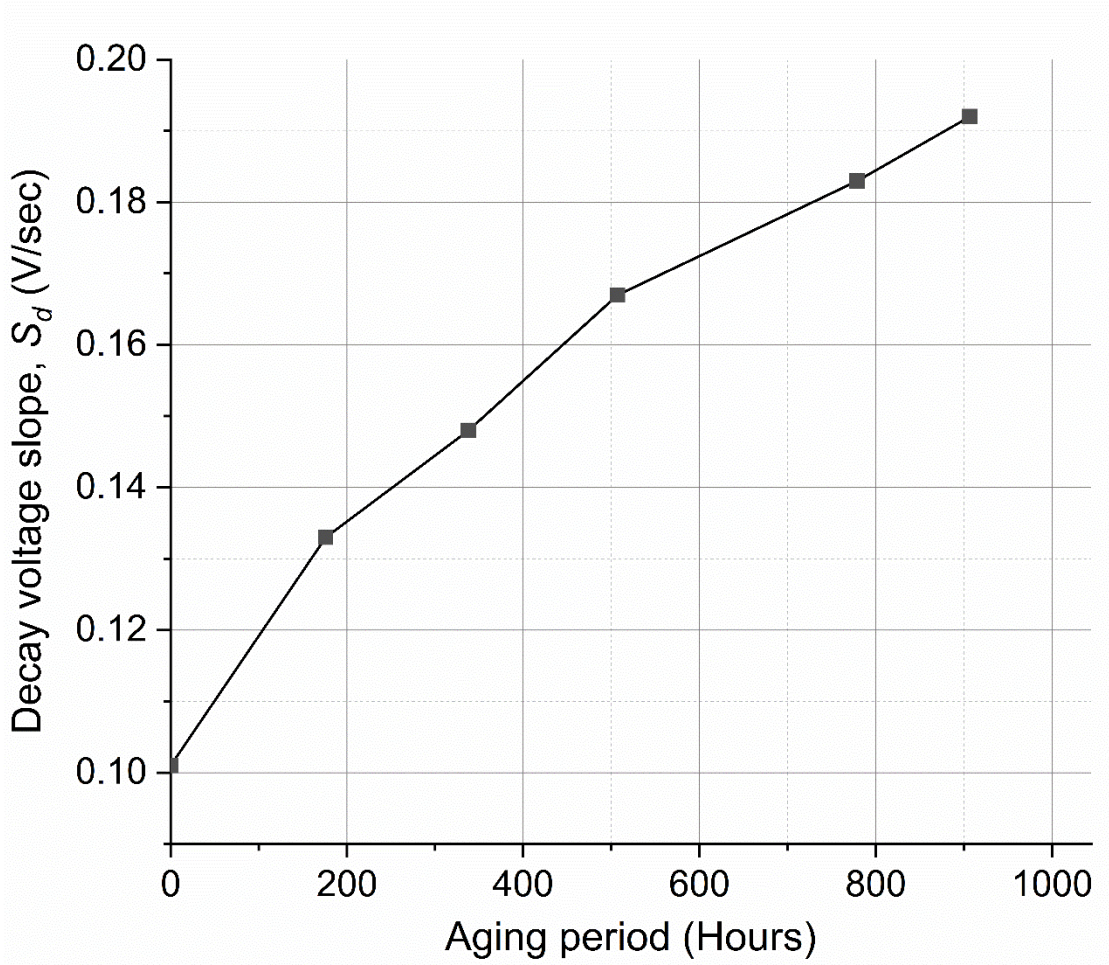
Results & Discussion …..Cont.

- The return voltage slope decreased with the aging time increased.
- The reduction in the return voltage slope suggest the domination of the cross-linking reaction in addition to the role of the compressive stress which tends to create duple bonds.
- In addition, the jacketing material undergo dehydrochlorination when subjected to thermal stress.



Results & Discussion …..Cont.

- The decay voltage slope slightly increased with the aging period increased.
- Due to the thermal stress, the generation of free radicals is enhanced.
- The free radicals tends to increase the conductivity of the dialectic material.
- This process was inhibited by the mechanical stress and the antioxidants.



Conclusion

- Chemical and physical changes have been occurred in the insulation due to thermal and mechanical stress
- Chemical structure: Re-Cross- linking & Dehydrochlorination
- Combined thermal - mechanical stress, ***S_r decreased & S_d increased***
- Polarization process decreased
- ***S_d*** and ***S_r*** could be used as ***Electrical Aging markers***

Thank you for your attention!

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