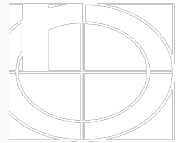
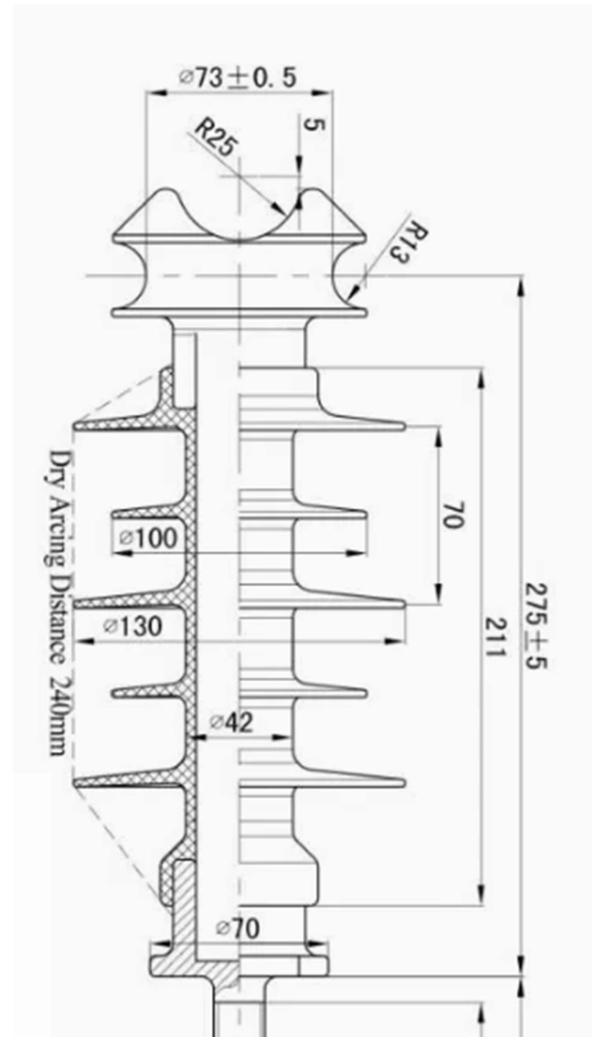


A proposal for the Dielectric Evaluation of the Condition of Composite Insulators

- Initial Experiences

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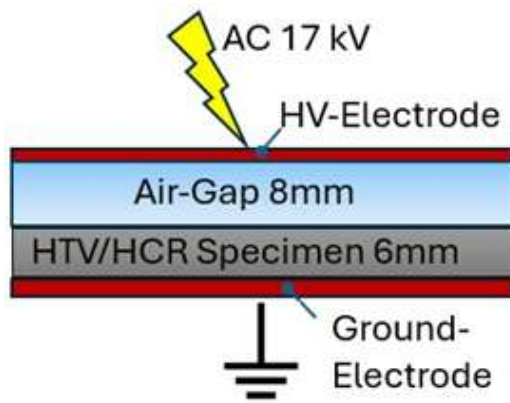


Non-Destructive Electrical Testing of Composite Insulators

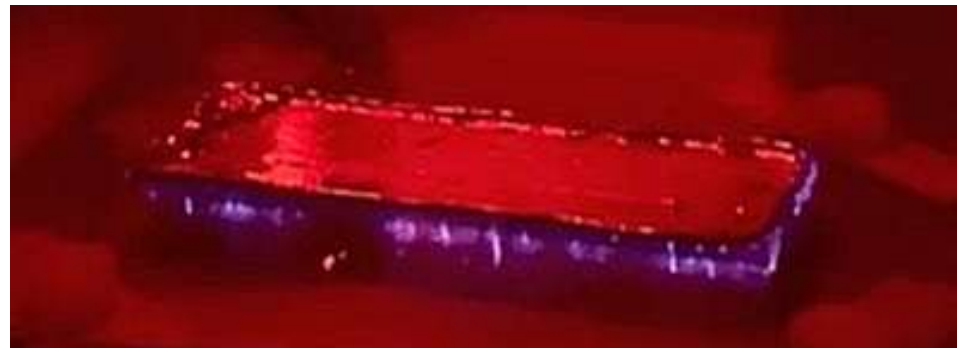
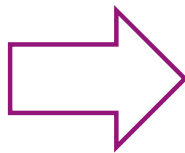
- Modified dielectric diagnostic setup that has earlier has been used for the purpose of evaluating the ageing state of insulator surfaces,
- Allows the detection of slight changes in dielectric properties, thereby enabling a more precise evaluation of material and insulator condition prior to the onset of visible damage.
- For validation, material specimens were exposed to artificial ageing stress over a range of durations.
- Subsequently, evaluation was conducted using the test setup.



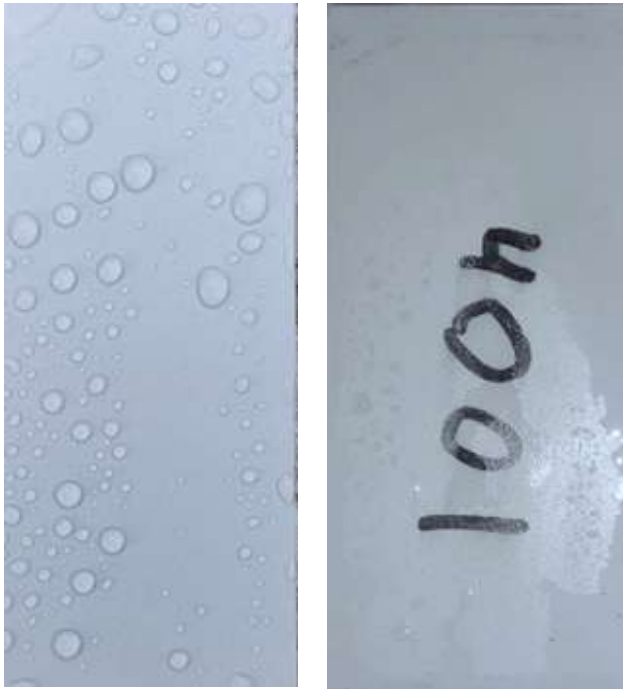
Material Specimens Testing and Results



Duration of treatment:
1h, 10h, 100 h



Material Specimens Testing and Results



O_3 and nitric acid are generated as by-products of the corona process in air.

Treatment leads to a loss of the hydrophobicity (as expected) due to deposition of charges, a loss of CH_3 -groups of the PDMS-structure accompanied with surface oxidation ($-CH_3 \rightarrow -OH$).

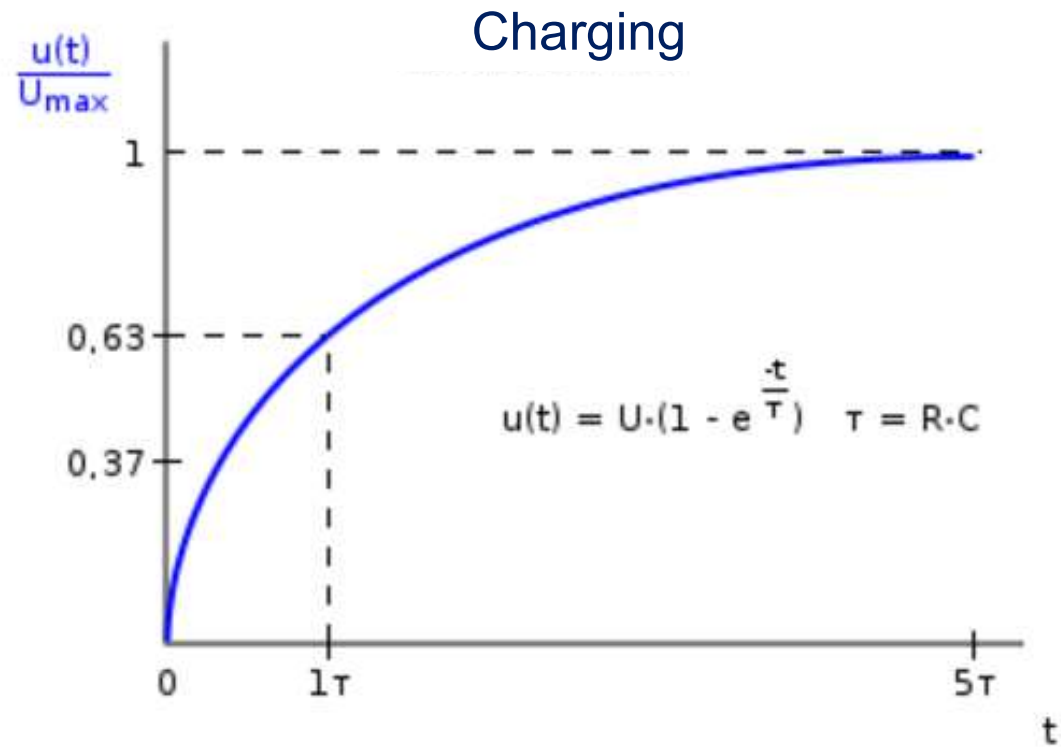
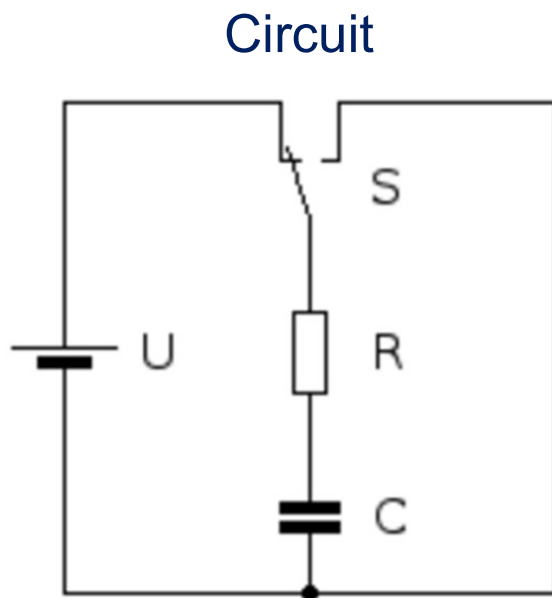
Material Specimens Testing and Results - Current Response

After the treatment a current response measurement was performed.

Megger S1-1568® testing device was used in the IR(t)-mode with an application of a step voltage of +15 kV DC.

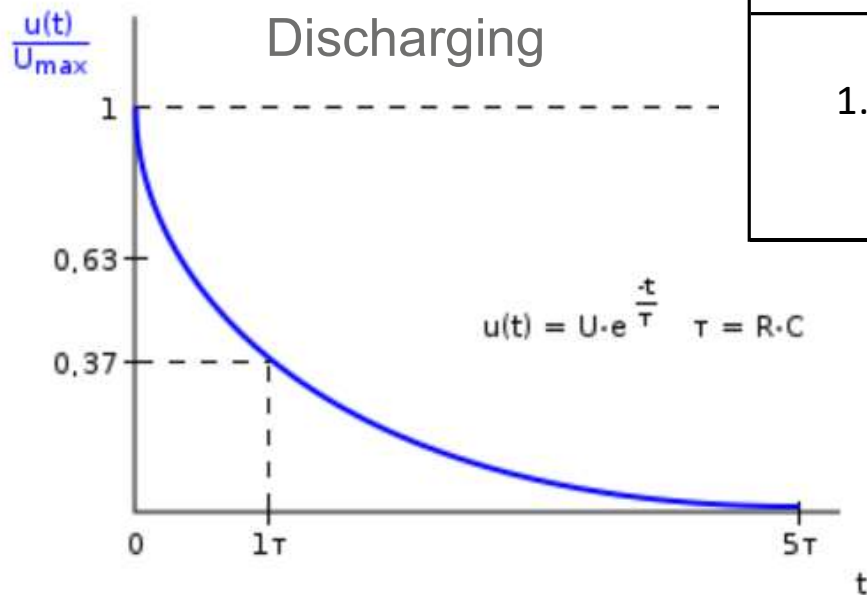


Excursus – Charging and Discharging of a Capacitor via Resistor

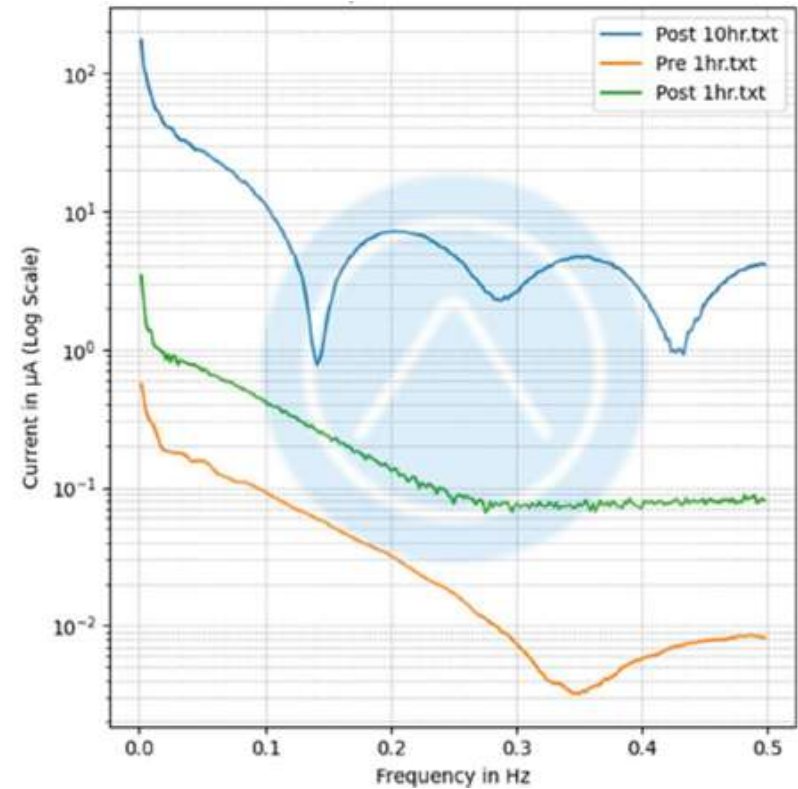
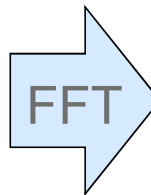
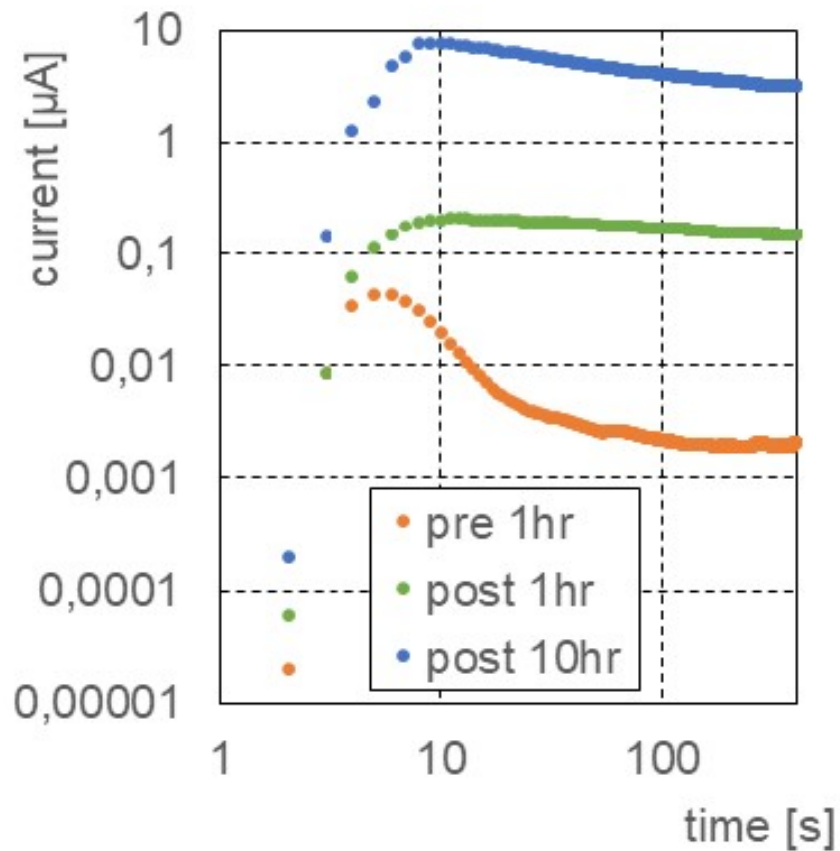


Excursus – Charging and Discharging of a Capacitor via an Resistor

Resistance	Capacitance	Time constant	Frequency
Ohm	Farad	Second	Hertz
$V A^{-1}$	$As V^{-1}$	s	$Hz (s^{-1})$
1.000.000	1,00E-03	1000	0,001
100.000	1,00E-03	100	0,01
10.000	1,00E-03	10	0,1



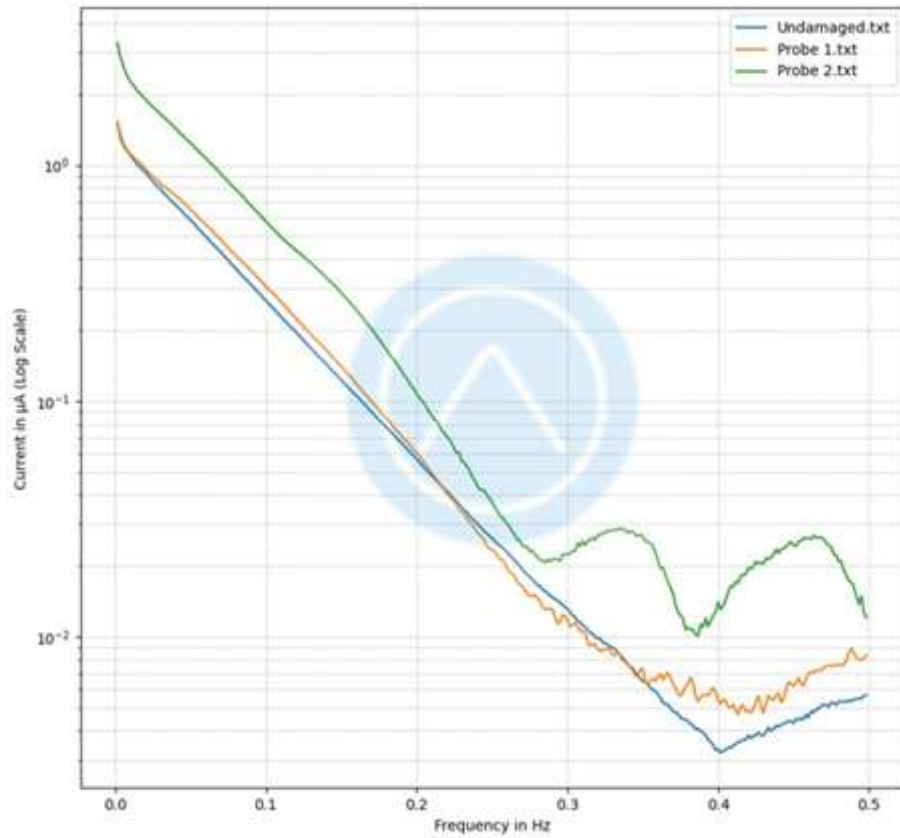
Material Specimens Testing and Results – Current Response



Material Specimens Testing and Results – Current Response

- Longer treatments (100 h) don't lead to further increase of the current,
- The effect may be explained by surface charging with a saturation after all charge acceptors in the material are filled up with charge carriers.
- A repetition after 48 days leads to the same results,
- While the hydrophobicity is recovered within 48 hours, the current response signal remains increased for long durations.
- This means that a longer lasting material modification was initiated by the corona discharges.

Insulator Testing and Results – Current Response



Green: Severe Degradation
Orange: beginning degradation
Blue: new insulator

Insulator Testing and Results - Isothermal relaxation current method (IRCM)

IRCM is measured in a second measurement.

Charging voltage was selected to be 5000 V.

In the discharge stage, the current is decreasing down to a constant value after the voltage is switched off.

The discharging (relaxation) current decays slowly with the given time constant of the specimen.

Megger S1-1568 is standardly applying a charging time of 30 minutes.

Megger procedure “DD” was applied in all cases:

$$DD = \frac{I_{1 \text{ min}}}{V \cdot C}$$

V	test voltage (5000 V standard settings))
$I_{1 \text{ min}}$	discharge current after 1 minute
C	capacity of the specimen in F (pF).

Insulator Testing and Results - IRCM

Sample	Condition
A	Sound (new) composite insulator from production line, no defects (blue)
B	Sample in beginning phase of decay-like fracture (orange)
C	Sample with severe interfacial degradation/ decay-like fracture (green)

Status of the insulation according to DD assessment for transformers, transformer bushings and MV cables

Very bad > 7
Bad 4 - 7
Suspicious 2 - 4
Good < 2
Homogeneous, sound 0

Sample C: DD > 2
Sample B: DD = 1-2
Sample A: DD < 1

Conclusions

- Investigated procedures are non-destructive diagnostic tools, capable to detect conductivity changes at both the surface and the interface of composite insulators.
- Results demonstrate that dielectric diagnosis in the very low-frequency range provides sensitive indicators of incipient aging processes.
- Current response at +15 kV DC reveals systematic shifts over the course of aging while frequency domain analysis might help to detect minor changes.
- For field applications, the isothermal relaxation current method and the Megger-DD indices distinguish sound insulators from units showing signs of incipient or advanced interfacial degradation.

Conclusions

To further solidify this approach, it is recommend to:

1. Use standardized setups with controlled environment and electrode/contacts,
2. Replicate and statistically analyze across specimens and stress durations,
3. Apply complementary surface and interface characterization (e.g. FTIR/XPS, micro-sections) to link electrical responses to chemistry and morphology; and
4. Define asset-class-specific DD thresholds (health index definitions) enabling decision-making for replacement or continued service.



Thank you very much for your attention!

