

CIGRE JWG D1/B3.57: Dielectric testing of gas-insulated HVDC-systems

Summary of achievements,
pending issues

Workshop: HVDC GIS PROMOTioN work package 15
DNV-GL Arnhem,
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JWG D1/B3.57

Scope

- Clarification of fundamental phenomena in electrical gas-insulated systems under DC and transient voltage stress taking into account the properties of the involved materials.
- Development of testing strategies for gas-insulated HVDC systems (e.g. HVDC GIS/GIL). This will include the parameters and procedures for type test, routine test and on-site test.
- The pending question about necessity of prequalification tests (long-term tests) will be addressed and the relevant test procedure will be defined if applicable.

Subjects discussed and covered in the Technical Brochure

1. Voltage and overvoltage stresses of gas-insulated HVDC systems
2. Basic phenomena and insulation properties at DC voltage and overvoltage stresses
3. Typical defects and their PD characteristic
4. Dielectric testing for proving the capability to withstand the phenomena in gas-insulated DC systems
5. Recommendation for dielectric testing of gas-insulated HVDC systems (Type test, routine test, onsite test, prototype installation test)
6. Superimposed voltage test, prototype installation test: Test equipment and test procedures

Subjects discussed and achievements (1)

- **Voltage and overvoltage stresses of gas-insulated HVDC systems**

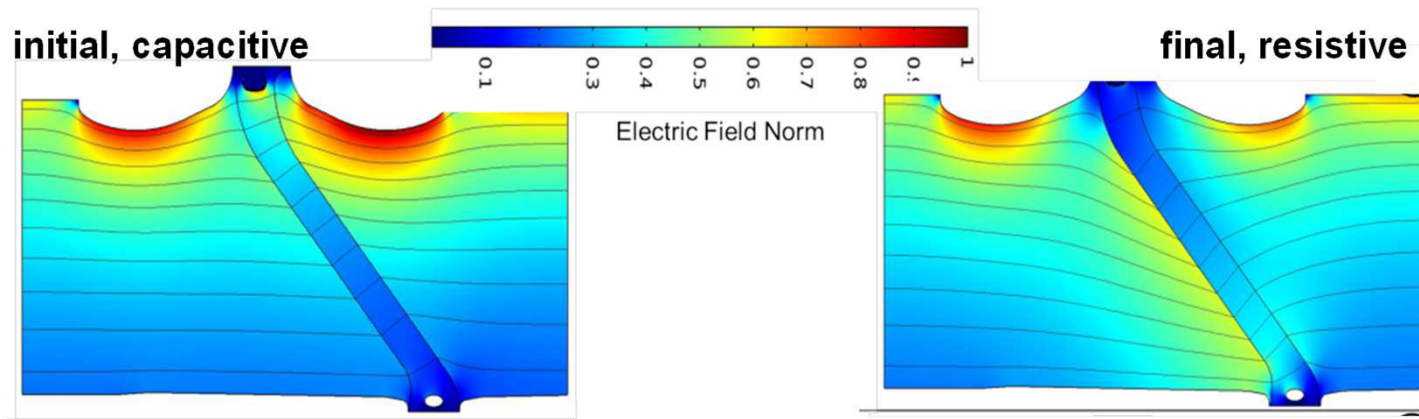
- A distinction of stresses having the origin either in the transmission line or at the converter are considered based on basic schemes of different DC links taking into account different converter technology.
 1. Slow Front Overvoltages at fault location, converter terminal and GIL-OHL interface caused by earth faults at different fault locations, line length 400 km
 2. SFO at converter terminals caused by earth fault at the DC side or AC side
 - SFO ≈ 2 pu to be considered for IC
 1. Fast Front Overvoltages at fault location, converter terminal and GIL-OHL interface caused by lightning
 - FFO ≈ 2.1 pu to be considered for IC assuming adequate arrester ratings

Subjects discussed and achievements (2)

- **Basic phenomena and insulation properties at DC and overvoltage stresses**
 - Gaseous dielectrics, charge generation and charge movement in gaseous insulation, discharge development and breakdown properties of insulating gases
 - Insulating materials and gas-insulator interfaces; effects at gas-insulator interfaces, surface charge accumulation; influencing factors on insulation properties, measures to control charge accumulation, impact of superimposed voltage stress
 - Simulation models and tools, verification of simulations
 - Particles and particle motion

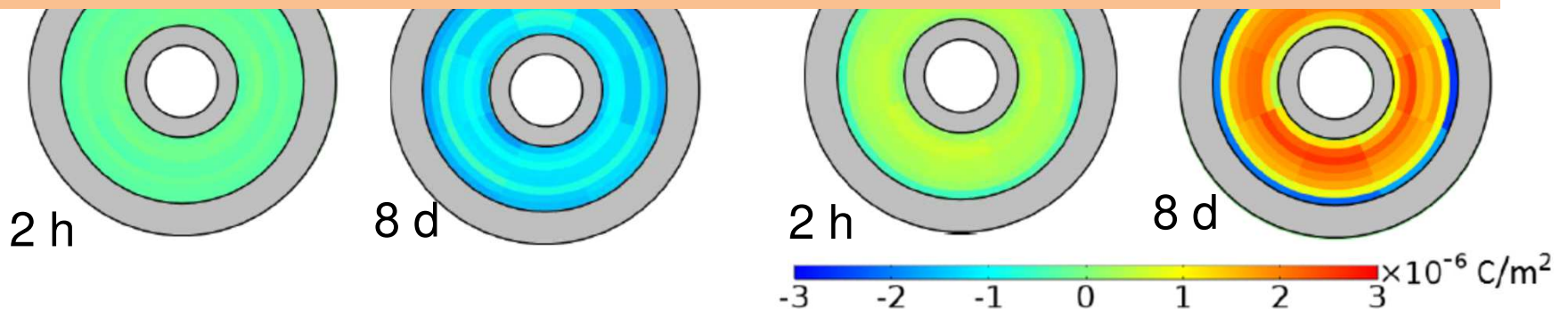
Charge accumulation

- When energized with DC voltage → field configuration from capacitive field to resistive at DC steady state status

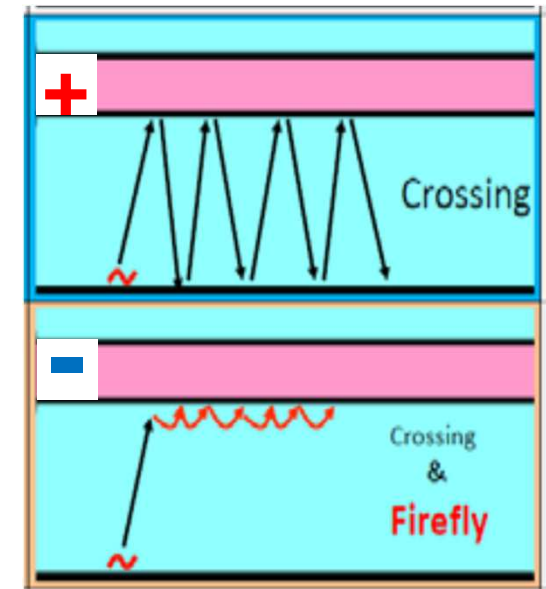
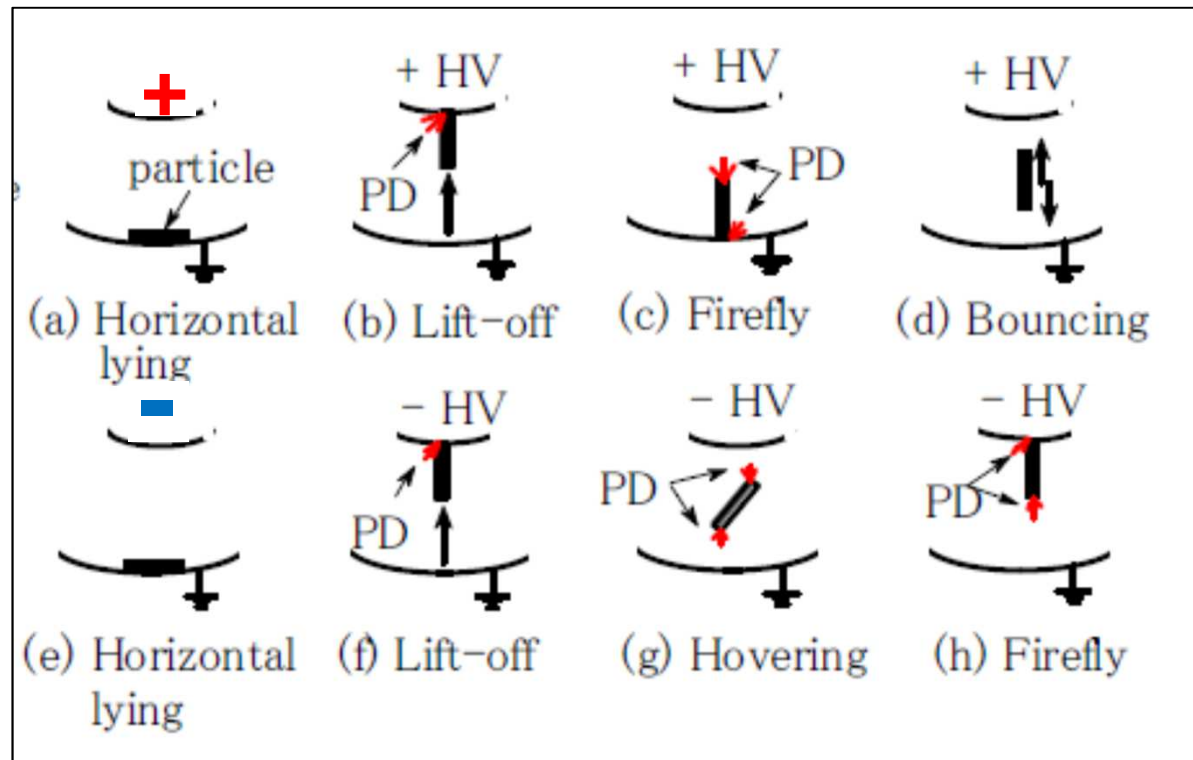


- During this process → charge accumulation on insulator surface

Insulator to be able to withstand DC stress, but also transient stresses (overvoltages) coming from system under real service conditions

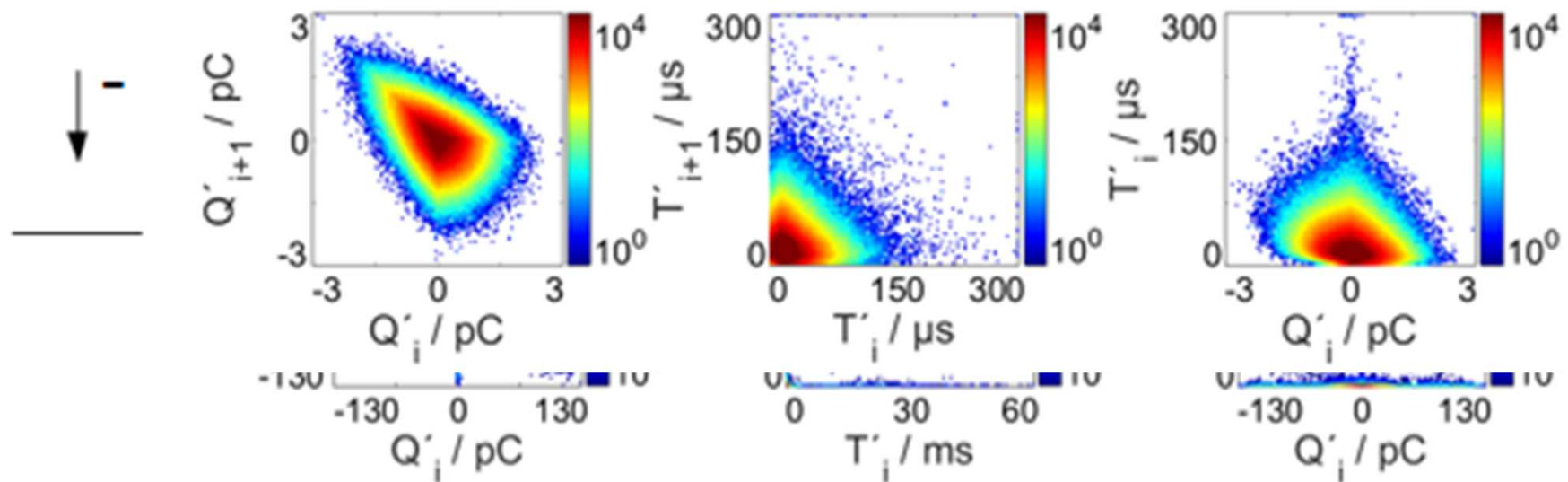


Particles and particle motion



Subjects discussed and achievements (3)

- **PD defects & PD testing of HV DC gas-insulated systems; test procedure, visualization of test results**
 - Presentation of PD characteristic of the typical PD defects (moving particles, protrusion, floating electrode, void, particle on insulator under DC voltage.
 - Influence of testing procedure and pre-stressing
 - Visualization: No correlation to phase angle => presentation as statistical distribution, e. g. NODI* pattern



Subjects discussed and achievements (4)

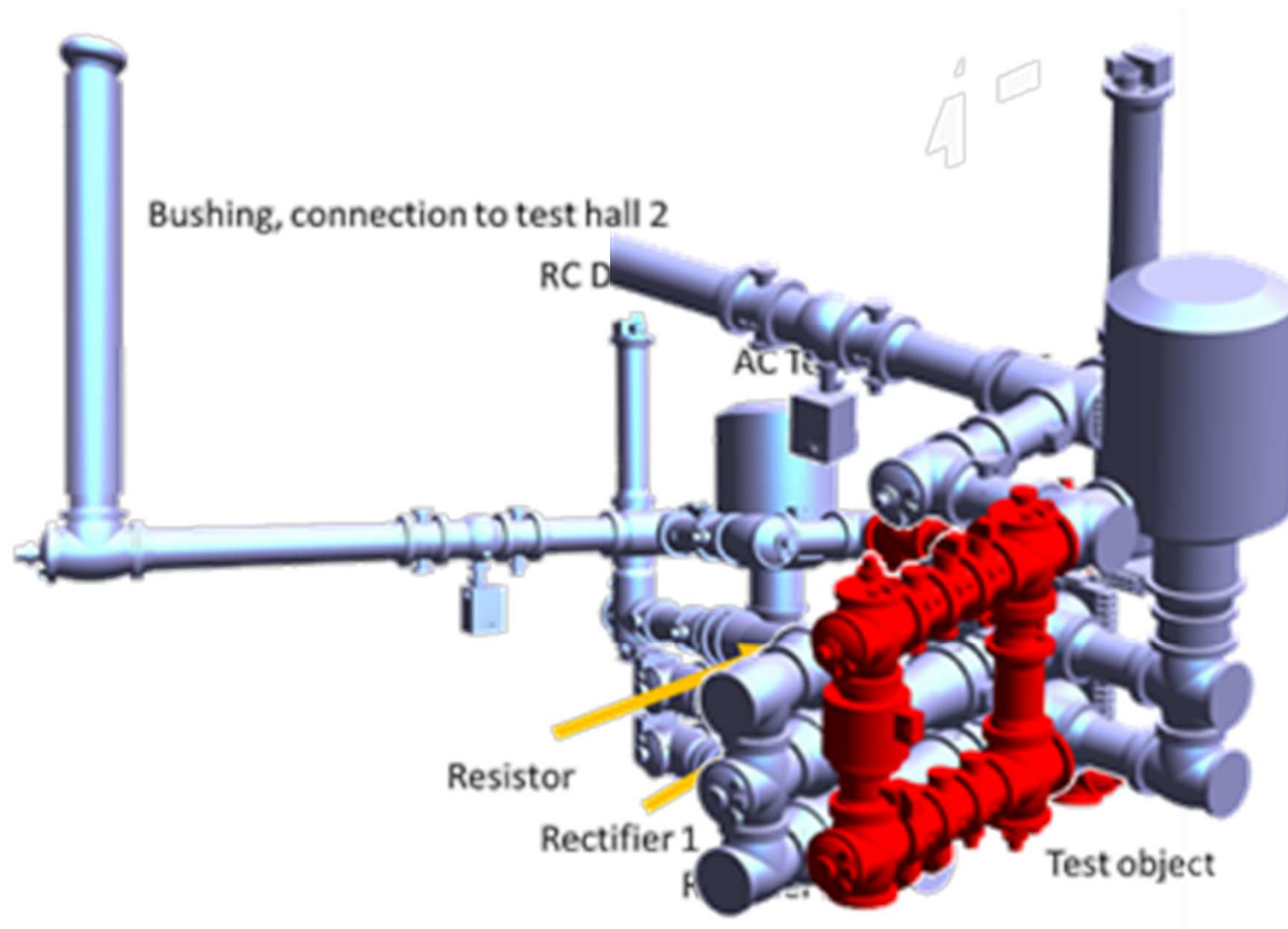
- **Dielectric testing of gas-insulated HVDC systems to cover DC-related phenomena**
 - In particular adequate testing of the insulators taking into account the charging processes and subsequent voltage stresses by superimposed impulse voltages => “insulation system test”
 - Impact of the particle phenomena, necessity of remedial measures, e. g. particle traps, but no test procedures to prove effectiveness. In responsibility of manufacturer.
 - Long-term test of insulating material
 - Prototype Installation test to confirm long-term capability of this type of HV DC equipment

Insulation System Test

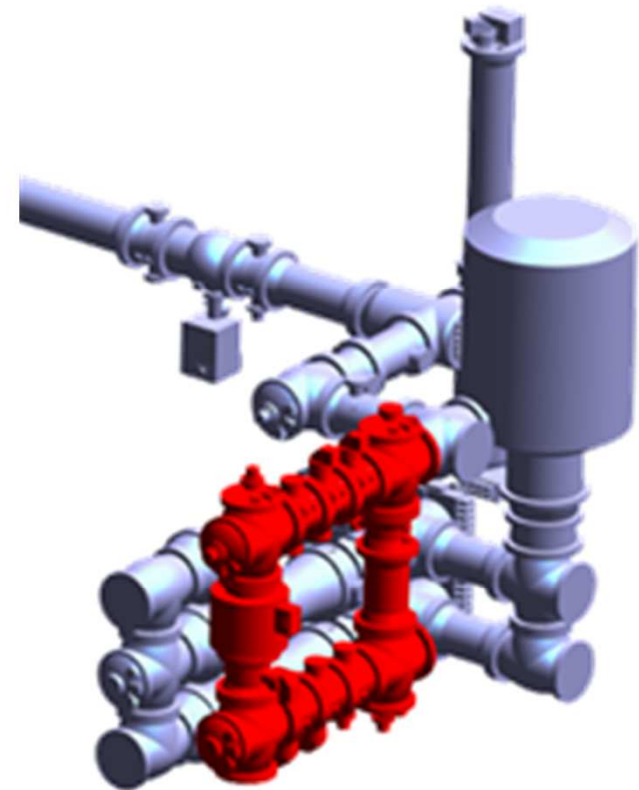
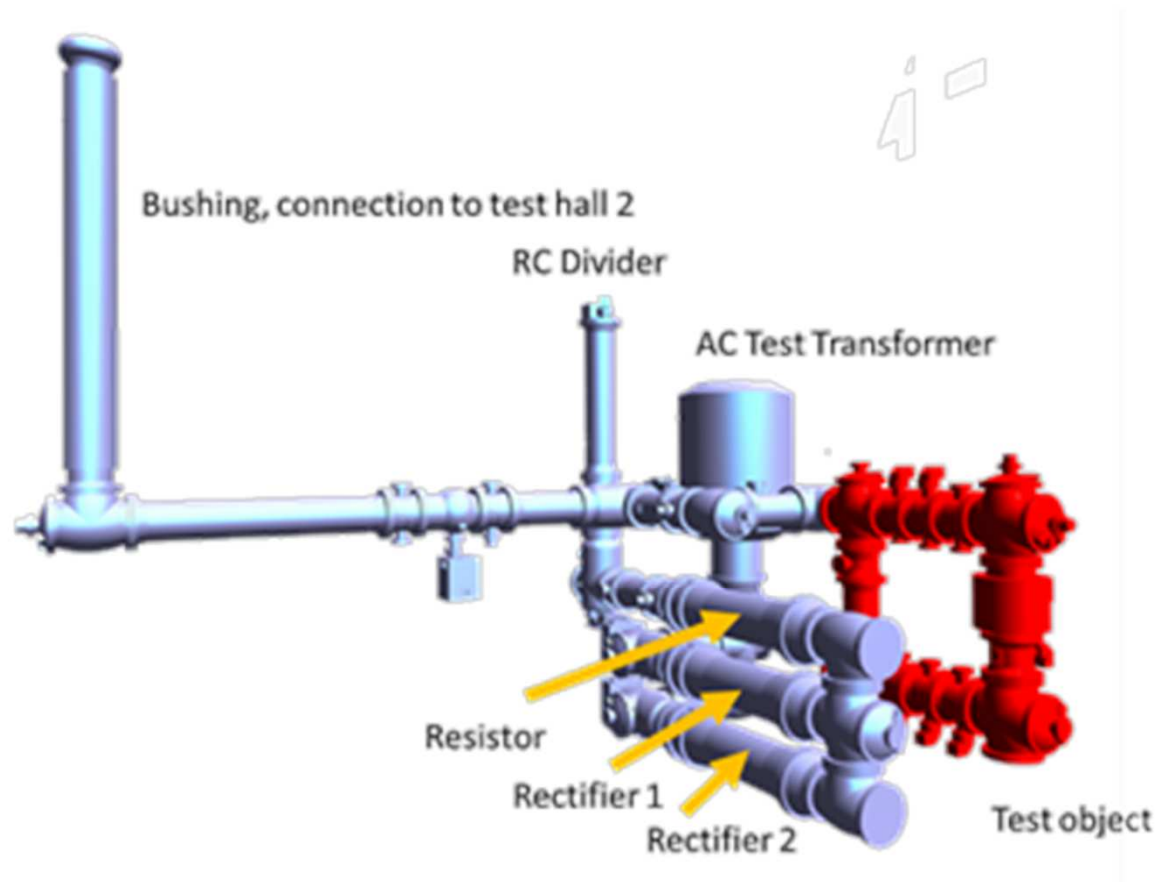
Test	Conditions		
	Test Values	Load	Remarks
Pre-tests	Heating Dielectric Pretests		
Long duration continuous DC voltage test	Max. continuous operating DC voltage (-)	HL	duration $d_{DC}^{*})$
Superimposed LI voltage tests (bipolar and unipolar superposition) Superimposed SI voltage tests (bipolar and unipolar superposition) (Polarity reversal)	Rated values	HL	
Long duration continuous DC voltage test	Maximum continuous operating DC voltage (+)	HL	Duration $d_{DC}^{*})$
Superimposed LI voltage tests (bipolar and unipolar superposition) Superimposed SI voltage tests (bipolar and unipolar superposition)	Rated values	HL	

*) time duration to reach 90 % of the DC steady state field at each location of the insulator surface

Insulation System Test; test arrangement



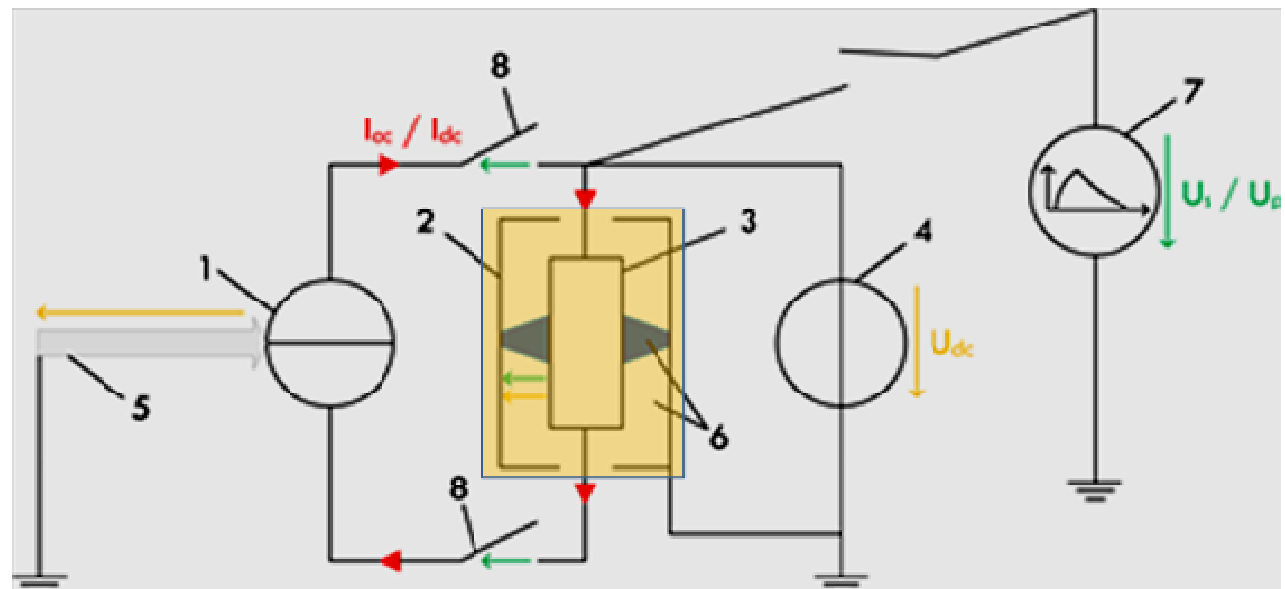
Insulation System Test; test arrangement



Prototype Installation test to confirm long-term capability of this type of HV DC equipment

- Necessity of long-term tests on gas-insulated HVDC systems
- Cons & Pros; most convincing Pro: Lack of experience with this new technology

- Basic structure of prototype installation test
- Test levels and test procedure
- Basic structure of Basic test circuit



1 Current Source
2 Enclosure
3 Inner Conductor
4 DC Voltage source

5 Power transmission for 1
6 Gas insulated system
7 Impulse voltage source
8 Switches (optional)

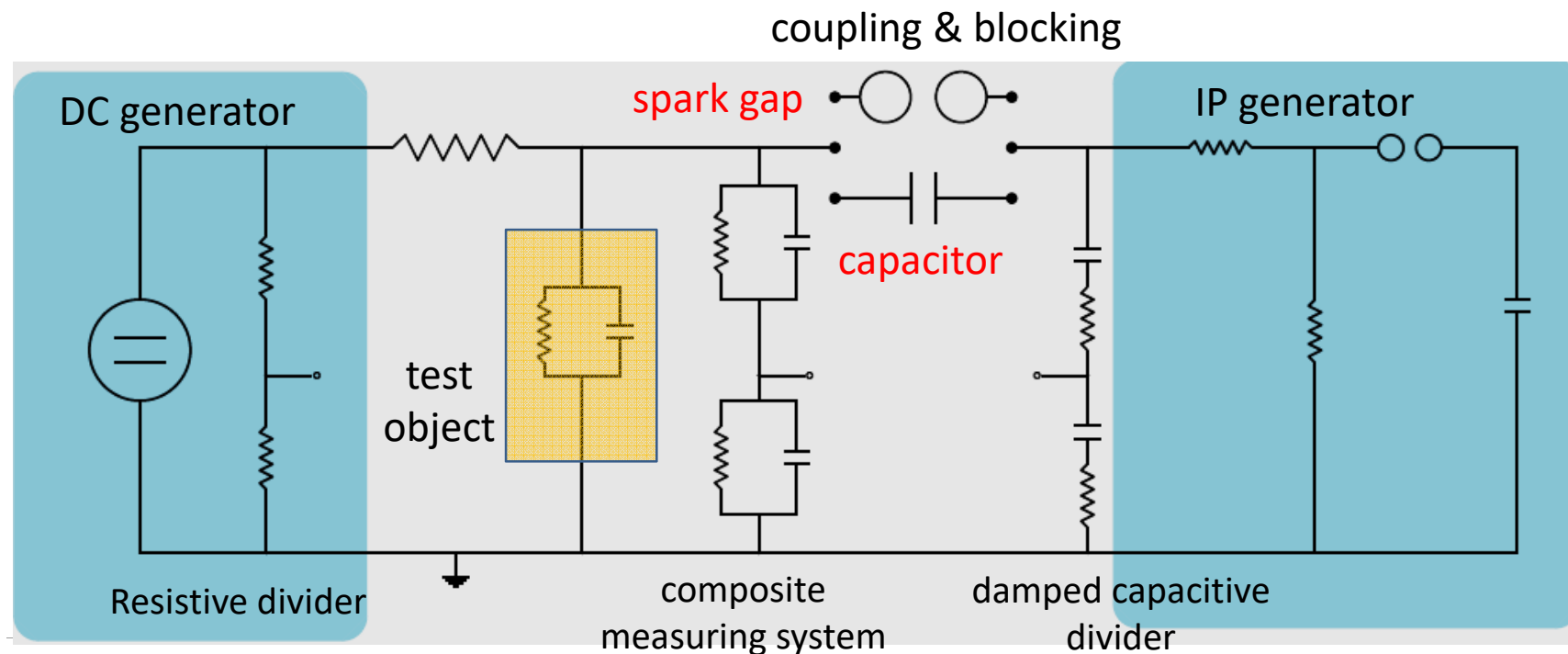
Subjects discussed and achievements (5)

- Basics testing of HVDC systems (type tests, routine tests, onsite tests, prototype installation test)
- Draft “Recommendations for testing of gas-insulated HVDC systems”
 - Test voltage levels have been agreed upon
 - Test with superimposed voltages: Basic test procedure & acceptance criteria have been agreed upon => no flashover across insulator surface permitted
 - PD testing at AC voltage recommended.

Subjects discussed and achievements (5)

Superimposed impulse voltage tests, prototype installation test

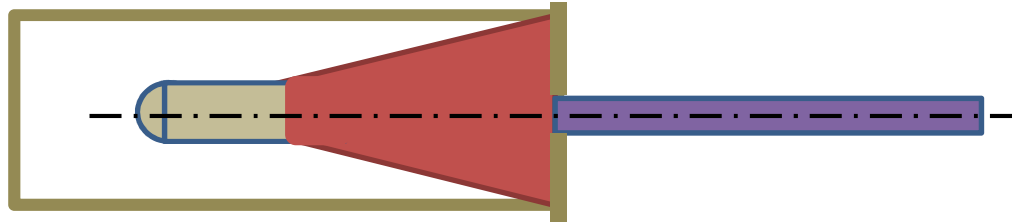
- Test equipment & test arrangements, effect of different blocking & coupling methods, impact on testing parameters, acceptable tolerances; measuring devices; testing experience & recommendations



Subjects to be discussed

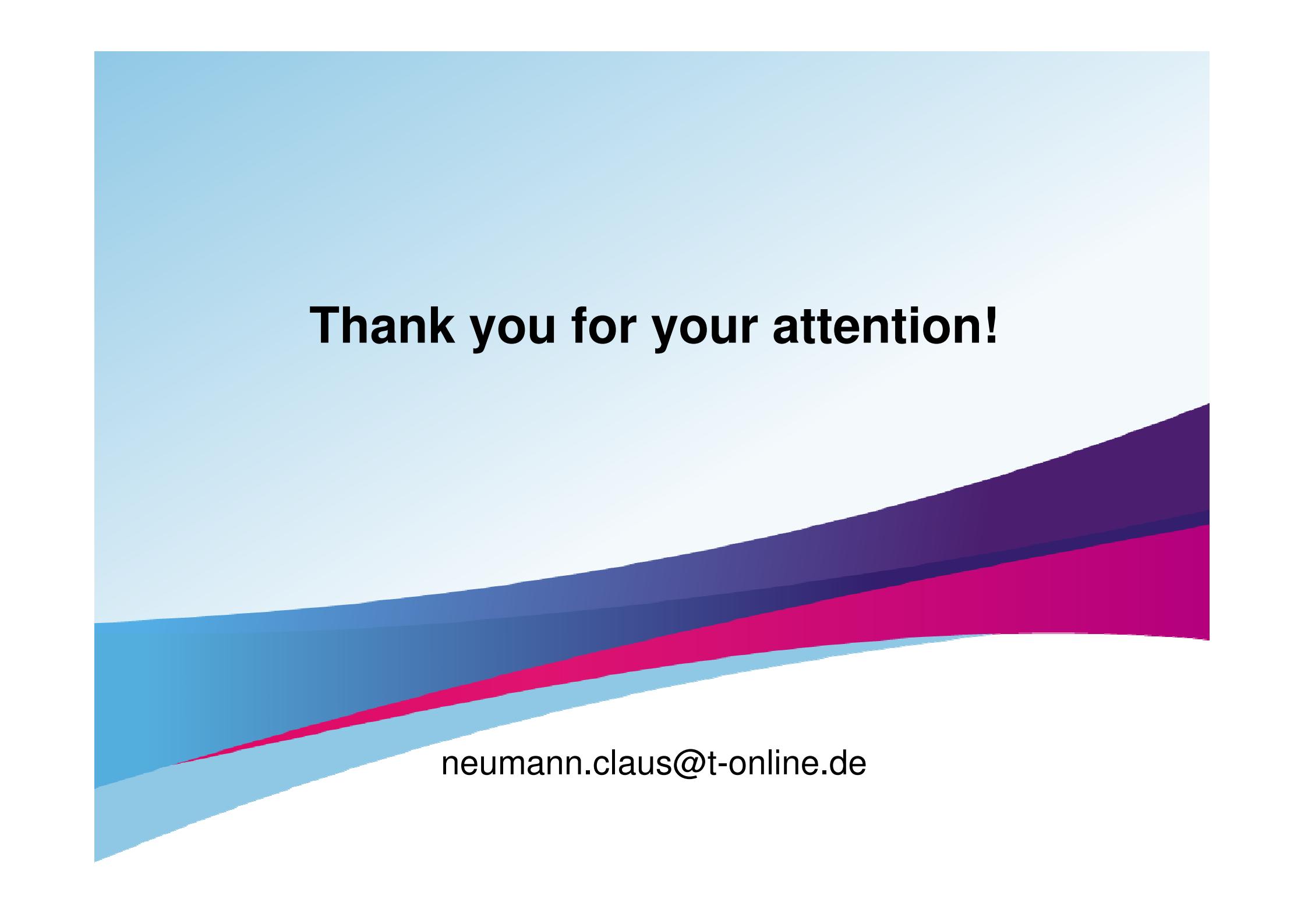
- Testing of gas-insulated systems in combination with cables. Testing procedure to cover cable as well as GIS/GIL requirement.
- Differences in testing philosophy & testing procedure
 - Insulation system test, prototype Installation test

Testing of metal encapsulated cable termination



- Gas-insulated cable termination without any other GIS/GIL component to be tested according to the cable test requirements (TB 496), because field distribution is affected by metal enclosure of the DC GIS & different from outdoor termination.
- Type test: $U_T = 1,85 U_0$; $U_{P1} (LI) = 2,1 U_0$; $U_{P2,s} (SI) = 2,1 U_0$; $U_{P2,o} (SI) = 1,2 U_0$
- PQ test (long-term): $U_{TP1} = 1,45 U_0$; $U_{P1} (LI) = 2,1 U_0$; $U_{P2,o} (SI) = 1,2 U_0$
- Gas-insulated cable termination, in particular the cone as a GIS component to be tested according to the insulation system test
- DC voltage U_0 to be applied for t_{90} ; subsequently to be subjected with superimposed LI & SI voltage, immediately without rest period; LI & SI test level corresponding to cable specification; polarity corresponding to GIS/GIL spec.

✓ ?



Thank you for your attention!

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Back-up

Prototype Installation Test

Test sequence (1)

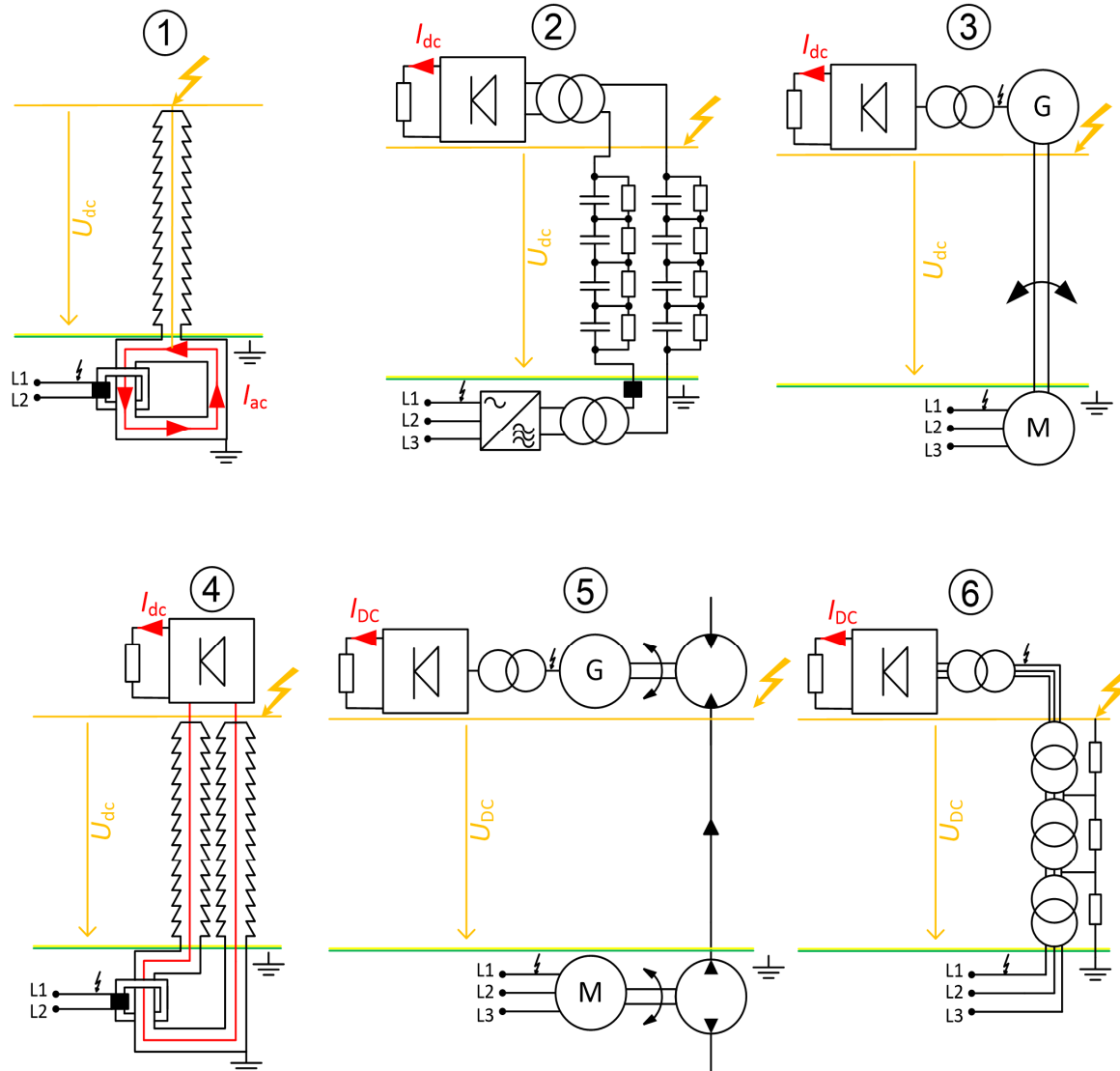
Test		Test conditions	Load	Remark
1	Thermal-mechanical pre-stress	Heating up to defined temperature ± 5 K	high	Thermal calibration
2	Cooling down	12/24 h	no	
3	2 repetitions of test step 1 & 2			
4	Dielectric pre-test	PD test with AC or DC test voltage	zero	Test voltage acc. to type test
5	Superimposed LI & SI test (bipolar & unipolar)	superimposed to rated DC voltage, pos. & neg. polarity	zero	3 impulses, no flashover

Prototype Installation Test

Test sequence (2)

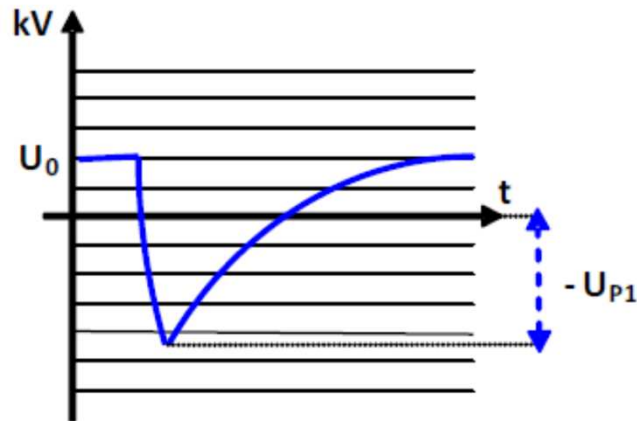
6	Long-term-test with DC voltage	U_T negative polarity	high	Test duration 30 days
7	Superimposed LI & SI test (bipolar & unipolar)	U_{SiT} , U_{UT} superimposed to rated DC voltage	no	3 impulses, no flashover
8	Long-term-test with DC voltage	positive polarity	high	Test duration 30 days
9	Superimposed LI & SI test (bipolar & unipolar)	U_{SiT} , U_{UT} superimposed to rated DC voltage	no	3 impulses, no flashover
10	Repetition of test step 6 to 9;		Long-term test duration:150 days	
11	Cooling down	48 h	zero	
12	Superimposed LI & SI test (bipolar & unipolar)	U_{SiT} , U_{UT} superimposed to rated DC voltage	no	3 impulses, no flashover

Prototype Installation Test, current injection circuits

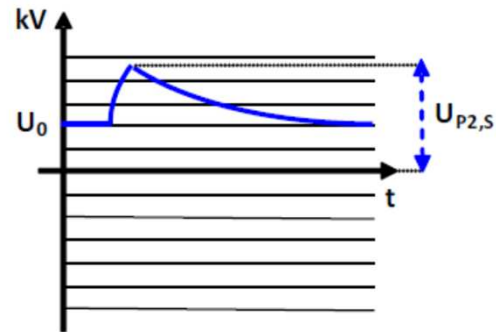


CIGRE JWG D1/B3.57, PROMOTiON
Meeting in Arnhem 20-09-2018

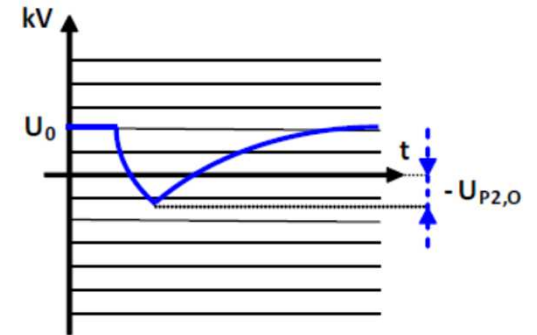
DC Cable, superimposed voltage test after at type testing



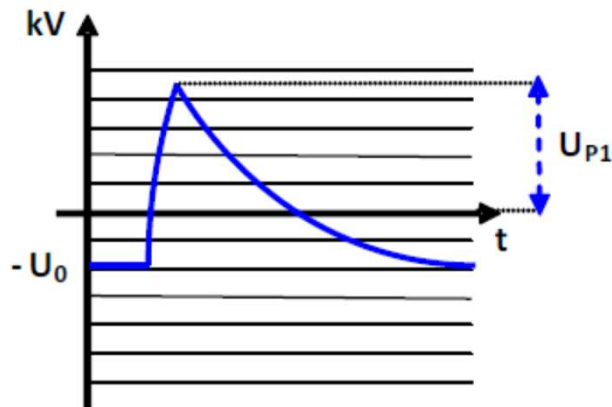
$$U_{P1} = \pm 2.1 \times U_{dc}$$



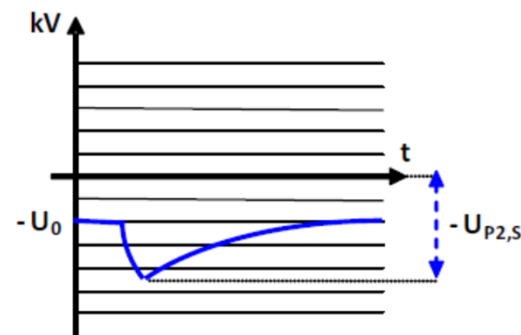
$$U_{P2,S} = 2.1 \times U_{dc}$$



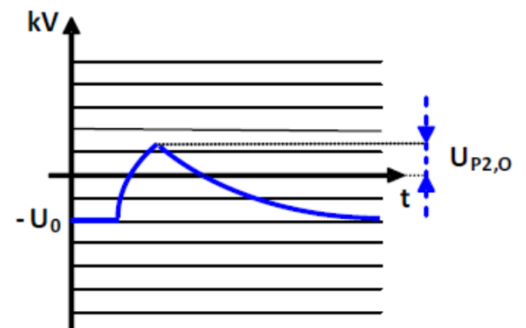
$$U_{P2,O} = 1.2 \times U_{dc}$$



LI



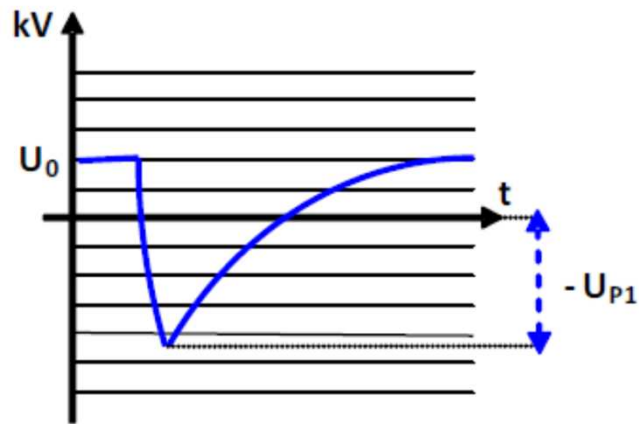
SI



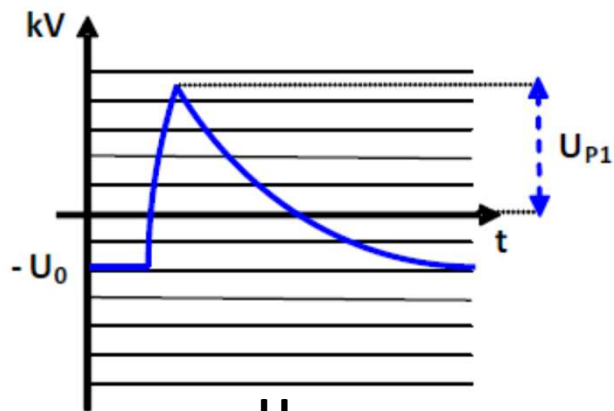
Voltage level in accord. to a proposal of a German ad hoc WG dealing with standardisations of test voltages

DC Cable, superimposed voltage tests after longterm-testing

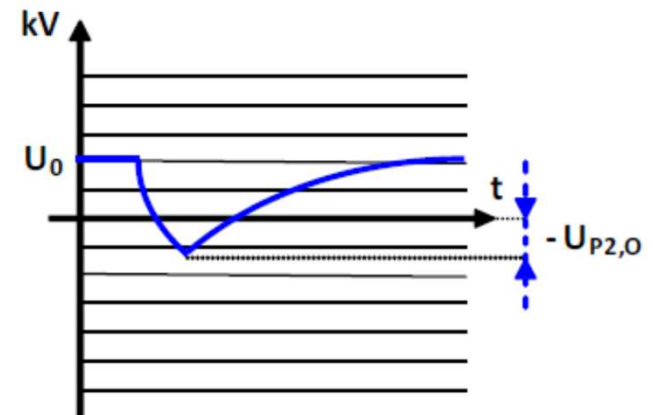
Accord. to TB 496, chapter 3.4



$$U_{P1} = \pm 2.1 \times U_{dc}$$



if required



$$U_{P2,O} = 1.2 \times U_{dc}$$

