13. Symposium Energieinnovation, 12. -14. February 2014, Graz

Compact Systems for HVDC Applications

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Agenda

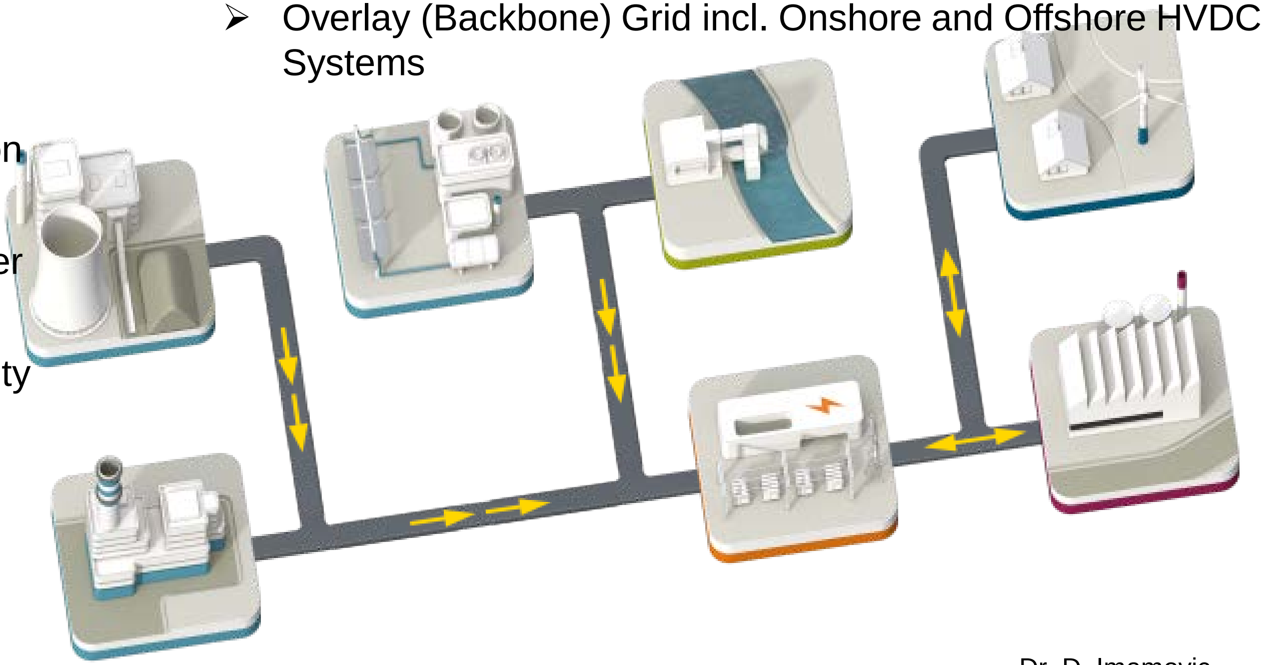
Compact Systems for HVDC Applications

Main drivers today:

- Requirements on space reduction
- Interconnection of Standardized HVDC Offshore Transmission Installations
- ENERGIEWENDE → Shutdown of nuclear and fossil power plants in Germany
- That means:
  - Increasing of transmission capacities
  - Efficient transmission over long distances
  - Increasing the grid stability with new generation structure

HVDC Solutions:

- Point-to Point connections for strengthening of grid and transmission of RES
- Onshore applications in a Hybrid Transmission System (OHL, underground Transmission)
- Offshore Multiterminal HVDC System
- Onshore Multiterminal HVDC System
- Overlay (Backbone) Grid incl. Onshore and Offshore HVDC Systems



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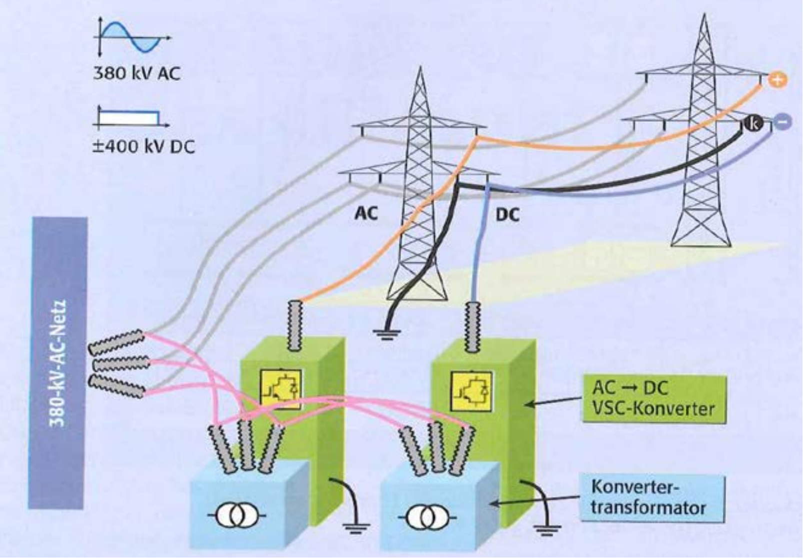
Prospects and Research for VSC Overhead Line Transmission

Challenges	On-going and Planned System Innovations
Exposure to atmospheric conditions with high probability of temporary short circuit faults require **fast fault detection, clearing and recovery**	➢ Bipolar VSC transmission solutions with similar or even better performance compared to HVDC Classic and AC systems ➢ Application of Full Bridge VSC for DC fault current control, extremely fast recovery and variable DC voltage control
Combined AC and DC towers may allow inter system faults (AC-DC) jeopardising operational security of the HV AC system	➢ Application of Full Bridge VSC for reliable fault current blocking (no additional device necessary, like a possible DC Breaker)

Full Bridge VSC is the most effective solution for VSC overhead line transmission providing:

- most reliable and fast blocking of all internal and external short circuit faults
- fast and smooth DC transmission restart with power transmission already during voltage ramp up
- extreme robustness due to unlimited duty cycles
- fast reduction of DC voltage to increase security e.g. under bad weather conditions
- future-prove solutions considering integration into possible extended HVDC grids



Source: Elektrizitätswirtschaft (ew), 112 (2013), issue 3, page 53

Amprion Ultranet

Reliable HVDC Grids need more than a Breaker

Short circuit faults spread at the speed of light (in case of overhead lines) and will affect the entire DC grid (DC voltage will be close to Zero during the fault)

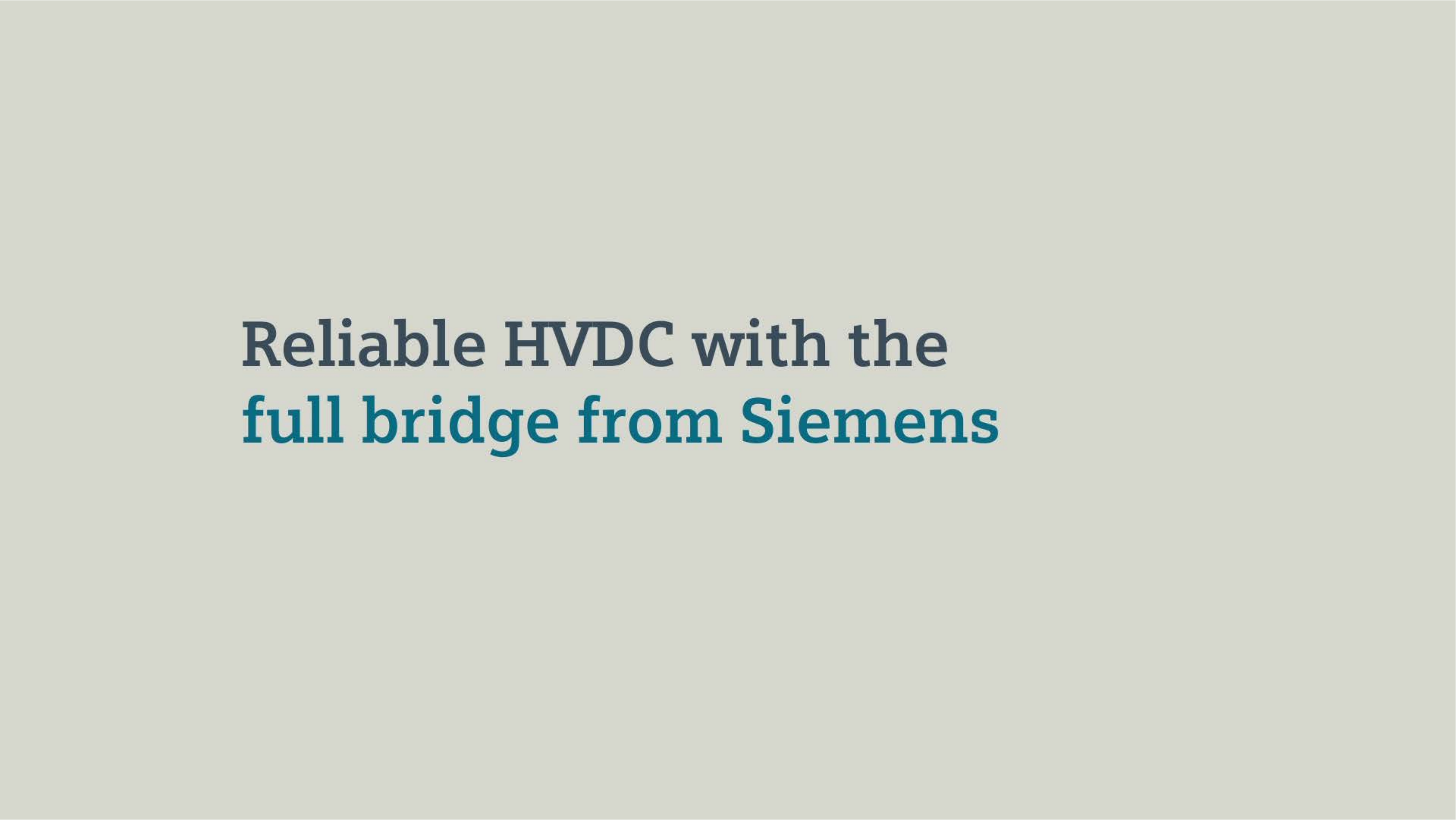
→ Possible solutions include **electronic DC Breakers, Hybrid DC Breakers in combination with large reactors, Full Bridge VSC in combination with Fast Switches**

Fault handling has <u>4 components</u>, all are needed and are related to one another:

1)	Fault detection and localization	➢ algorithms distinguishing normal transients from faults ➢ protection relays/functions ➢ methods identifying the fault location w/o communication (if possible)
2)	Fault current interruption	➢ highly reliable solutions minimizing interference with AC systems or the other DC pole ➢ backup systems
3)	Fault isolation	➢ high speed (ultra fast) switches
4)	System recovery	➢ fast and reliable recovery of remaining system ➢ high repetition capability

Future HVDC Grids will be build step by step.
Smaller systems comprising a few stations will be integrated into larger HVDC Grids.
→ This requires standardisation of HVDC Grid design and operating principles.

VSC full bridge



Reliable HVDC with the
full bridge from Siemens

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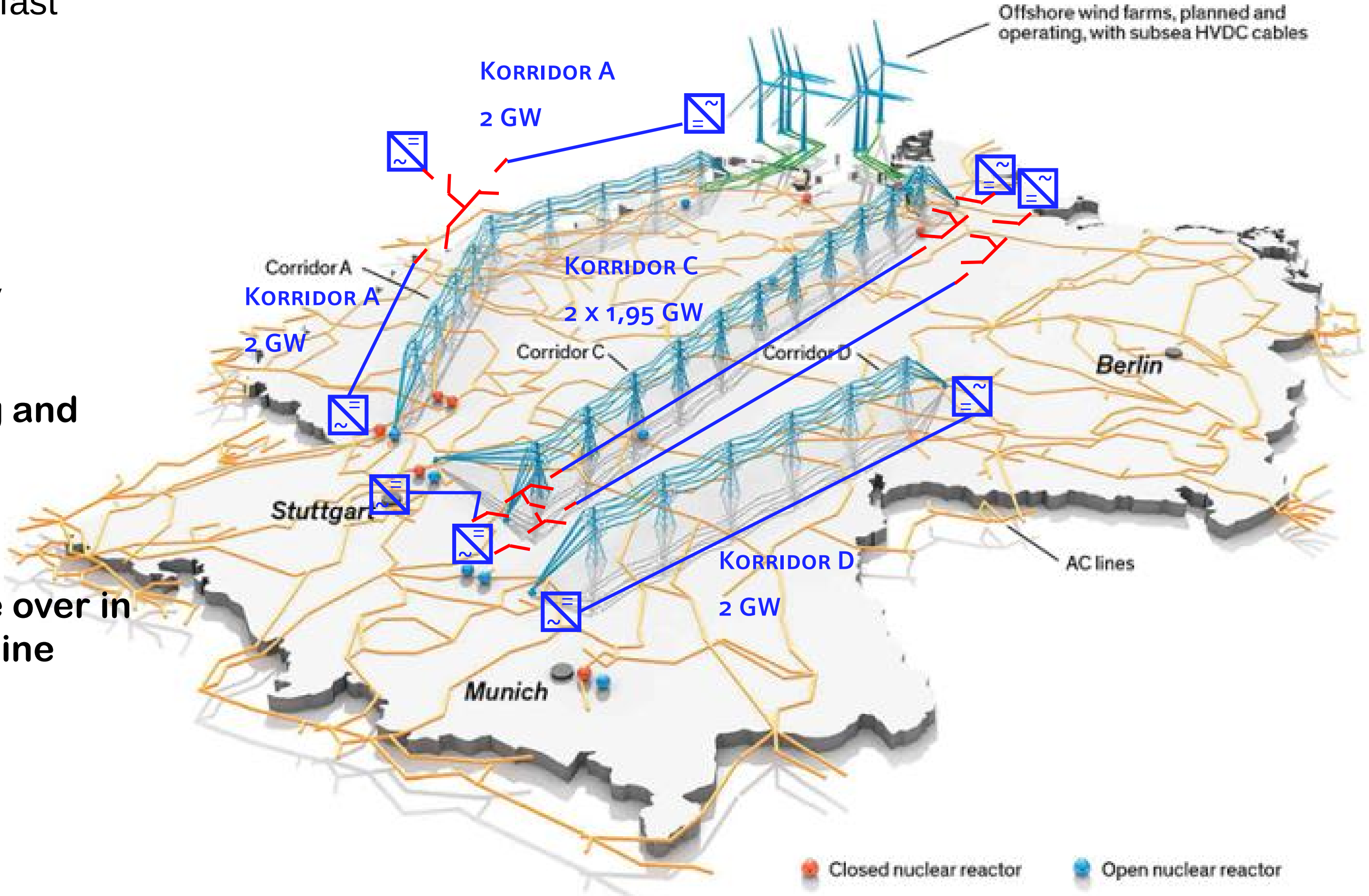
Towards a first DC Grid in Germany

— Multi-teminal links using full bridge converters and fast DC switches

Highest availability

- **In corridor A:** **selective fault clearing and fast recovery**
- **In corridor C:** **parallel operation of two lines with fast take over in case of a fault on one line**



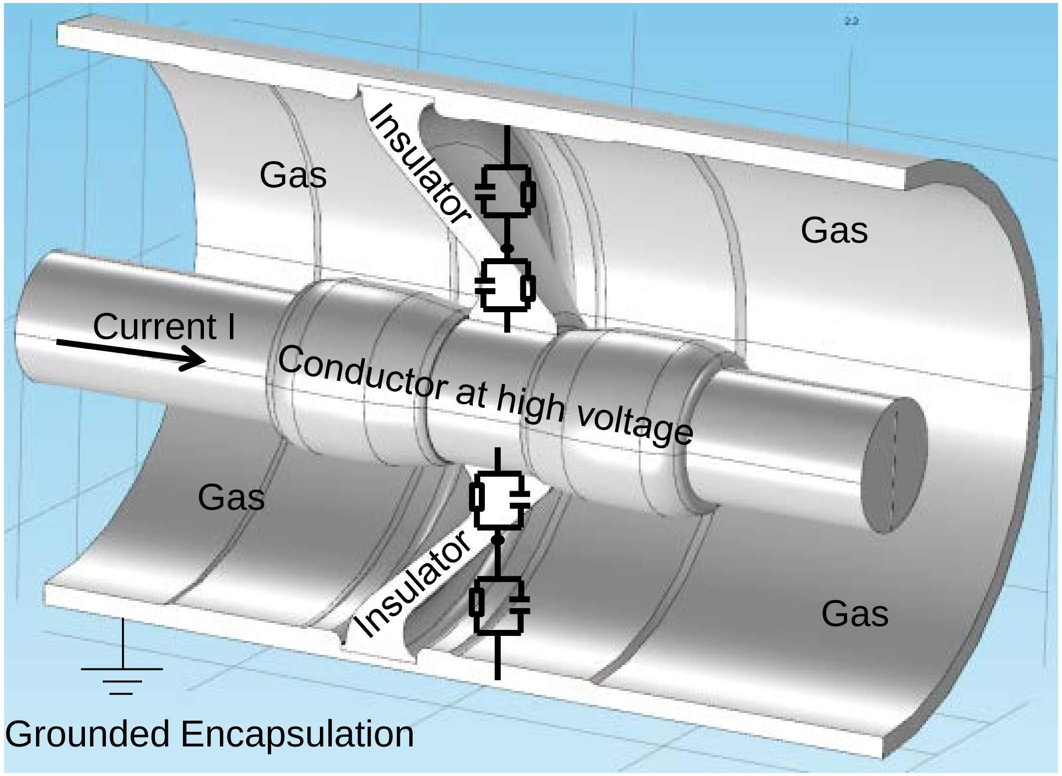
Initial Illustration: Bryan Christie Design. Source: www.entsoe.eu

Based on

Szenario B-2022 NEP 2012

Operational stresses in gas insulated systems

Why is it NOT possible to directly use existing AC systems for DC voltage?



Stresses of insulators in operation

Mechanical Stress

Chemical Stress

Thermal Stress

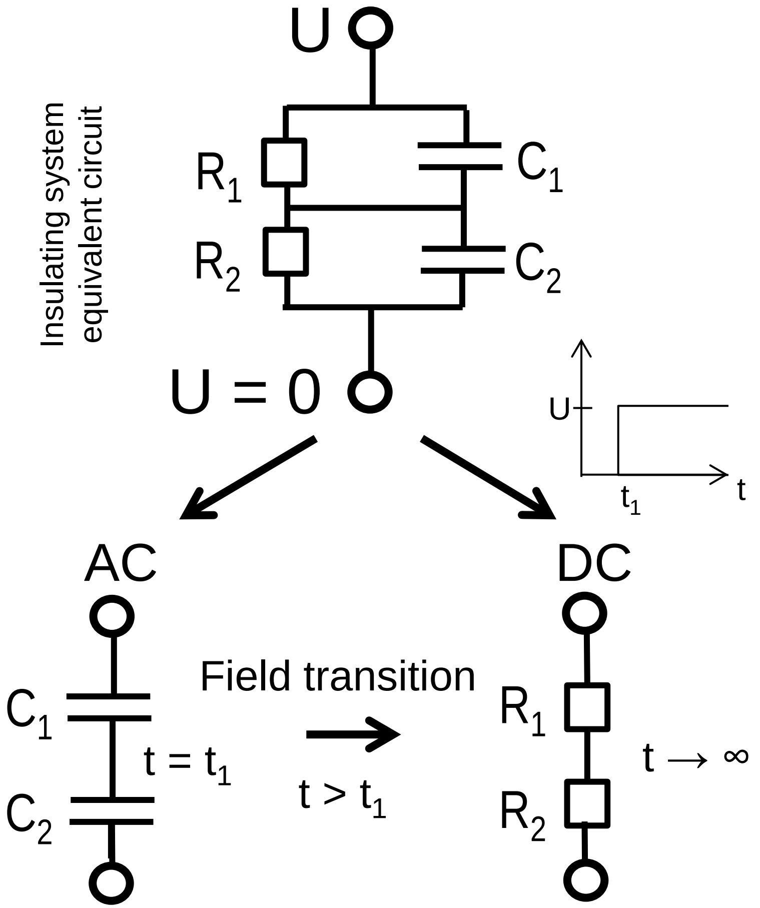
Impact on

Electric Stress

DC insulating systems must withstand different electrical stress compared to AC systems

Electric stresses on insulating materials

Why do we have different conditions under DC voltage?



AC Insulating system

Capacitance C determines voltage distribution
→ C hardly dependent on temperature
→ C hardly dependent on electrical field strength

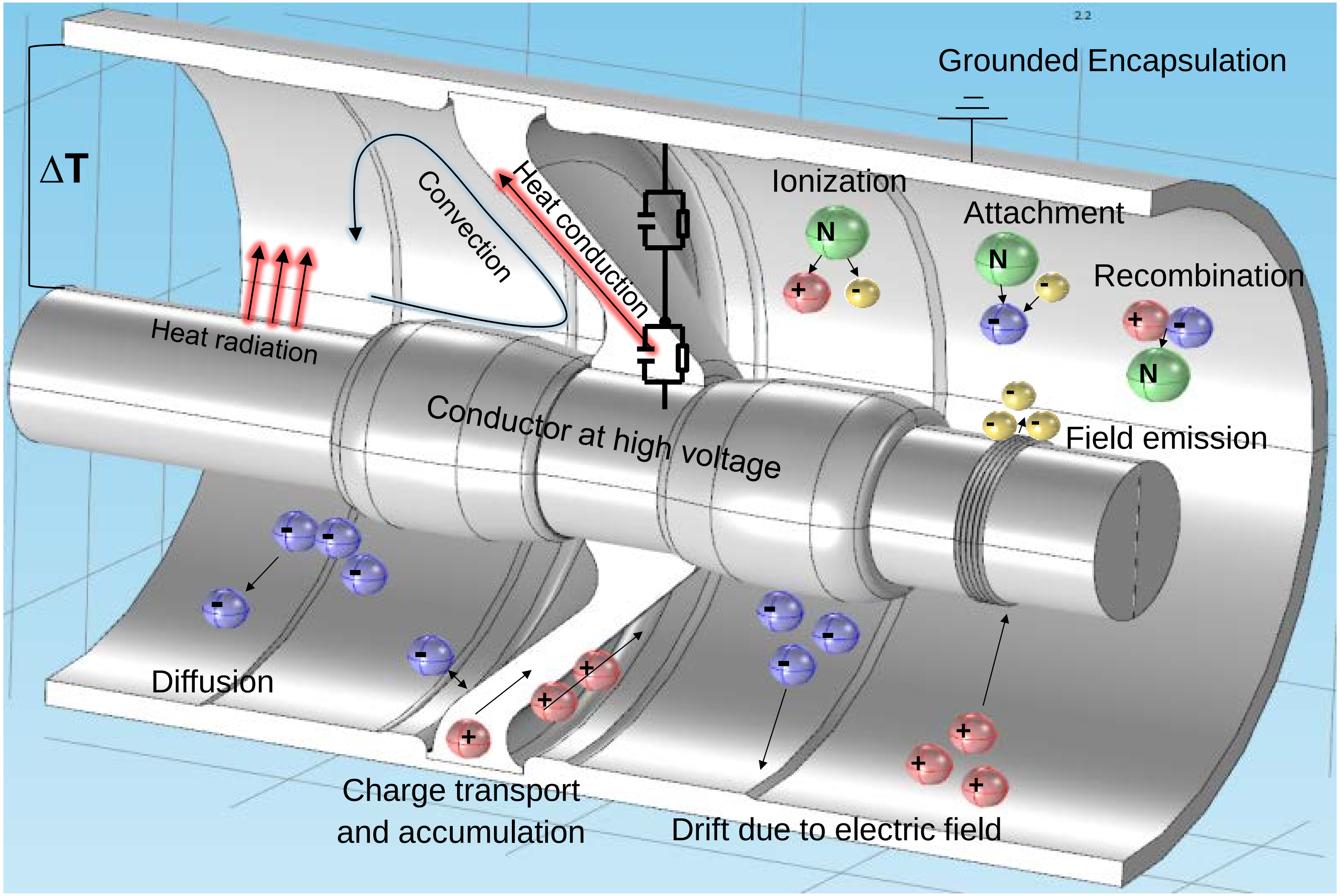
Stable AC voltage distribution in operation

DC Insulating system

Resistance R determines voltage distribution
→ R strongly dependent on temperature
→ R strongly dependent on electrical field strength

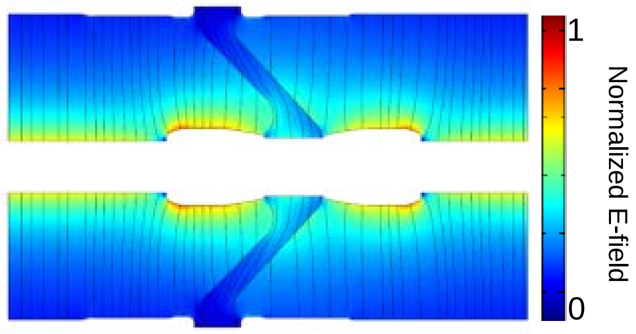
Time-dependent DC voltage distribution in operation

Physical Effects influencing electric stress

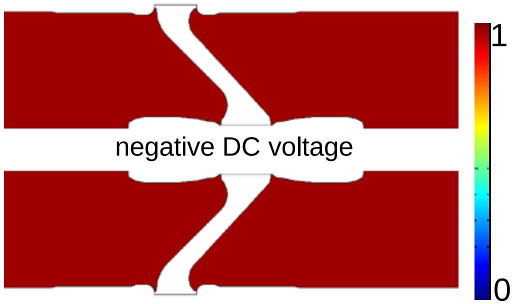


Transition from AC to DC electric field

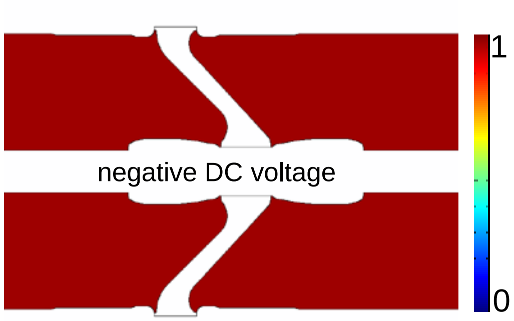
AC



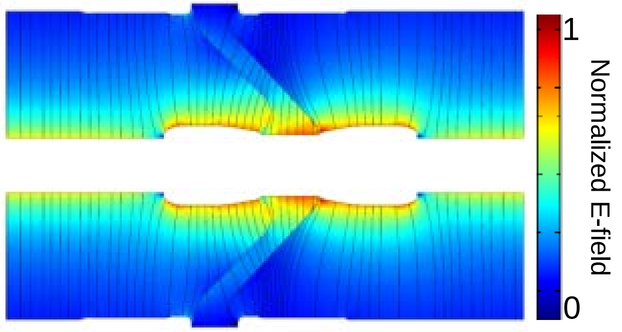
Negative space charge
density in gas



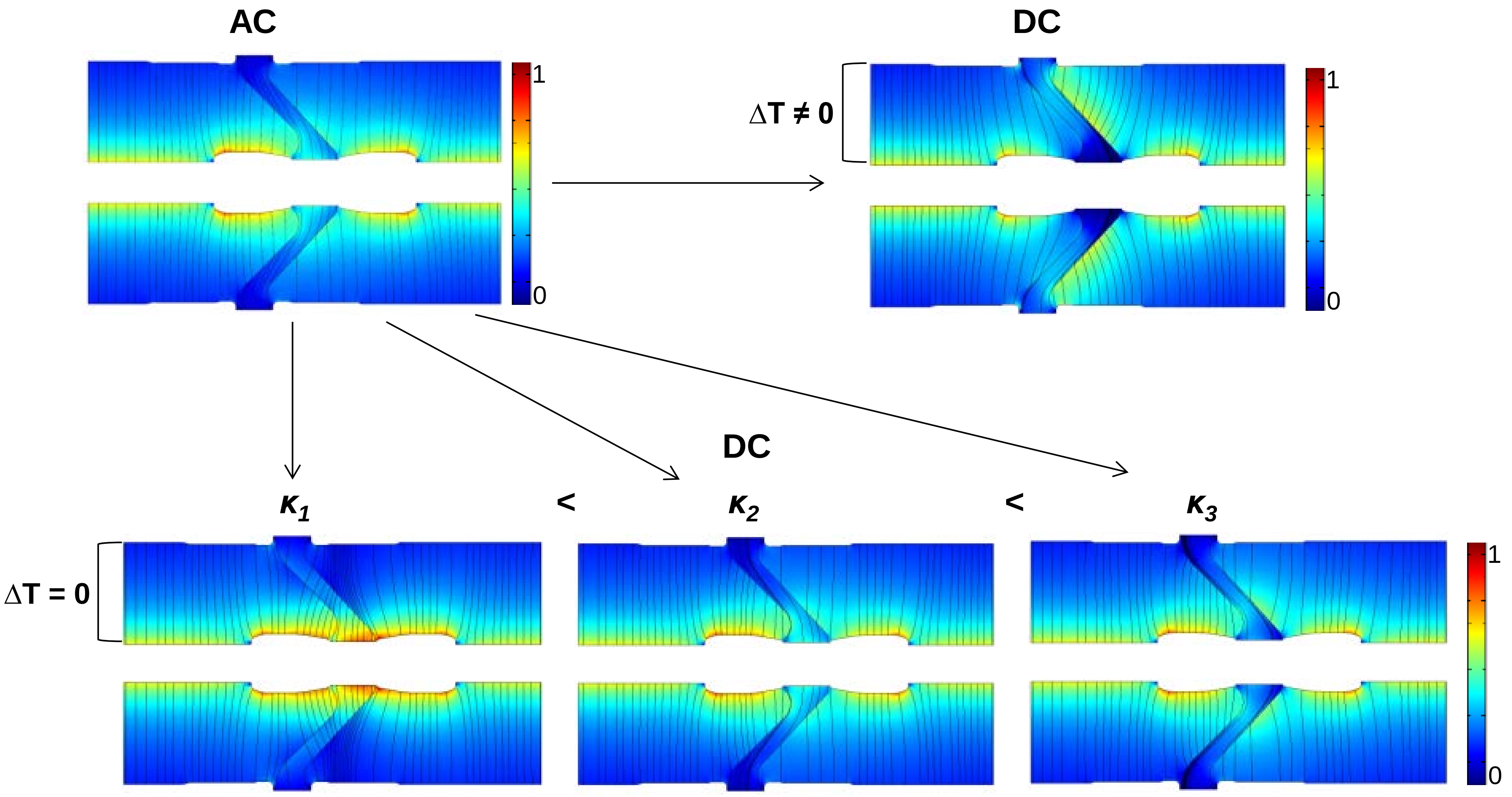
Positive space charge
density in gas



DC



Influence of conductivity κ and temperature T on DC electric field distribution



AC

DC

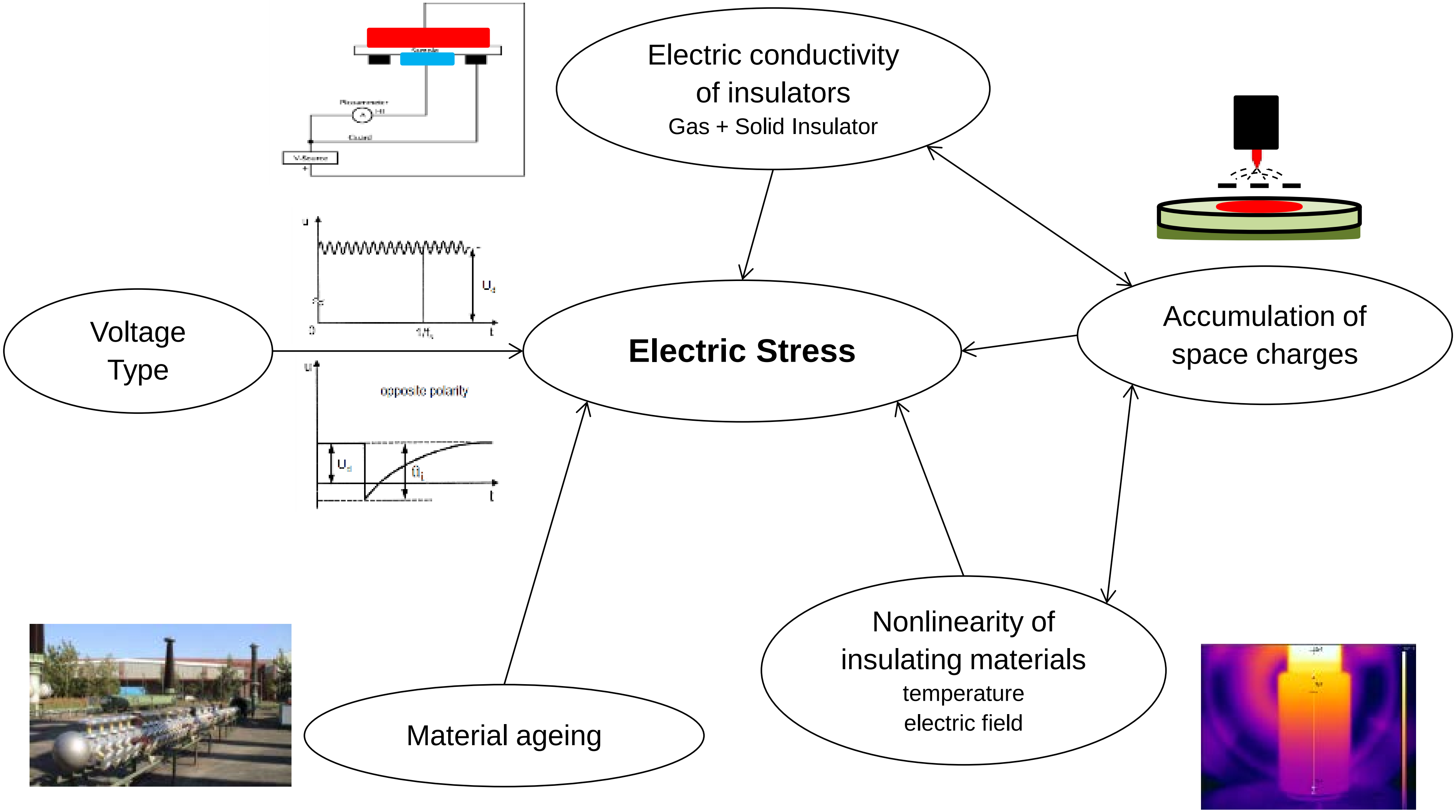
$\Delta T \neq 0$

DC

κ_1 < κ_2 < κ_3

$\Delta T = 0$

HVDC basic investigations
Factors of impact on electric stress in DC Compact Systems



Electric conductivity of insulators
Gas + Solid Insulator

Voltage Type

Electric Stress

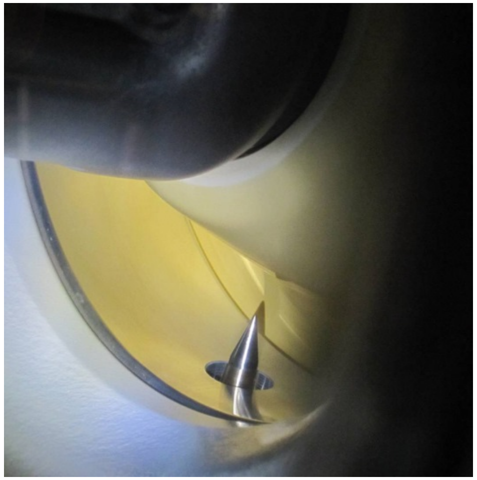
Accumulation of space charges

Material ageing

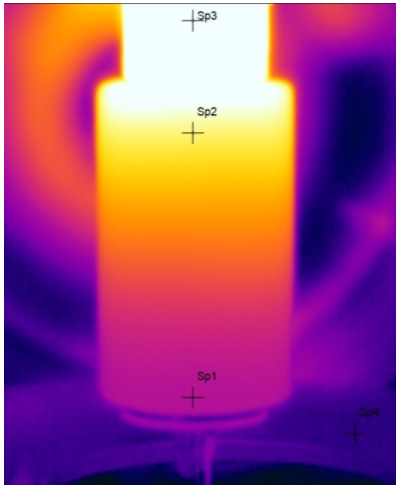
Nonlinearity of insulating materials
temperature
electric field

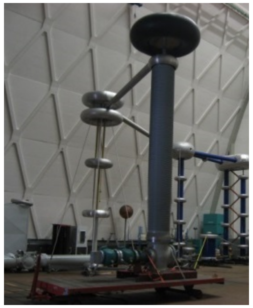
HVDC basic investigations
Exemplary test setups

Artificial protrusions

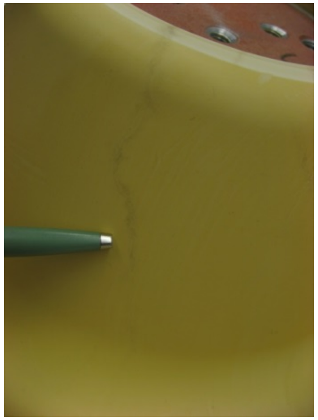


Temperature gradient





Dielectric limits



Surface effects

Long-term testing

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Technical challenges for DC insulators

- Development of insulator design allowing for control of physical effects, particularly charging effects

- Development of suitable insulating material for DC gas insulated systems

- Careful handling/drying of insulating parts and cleanliness during assembly

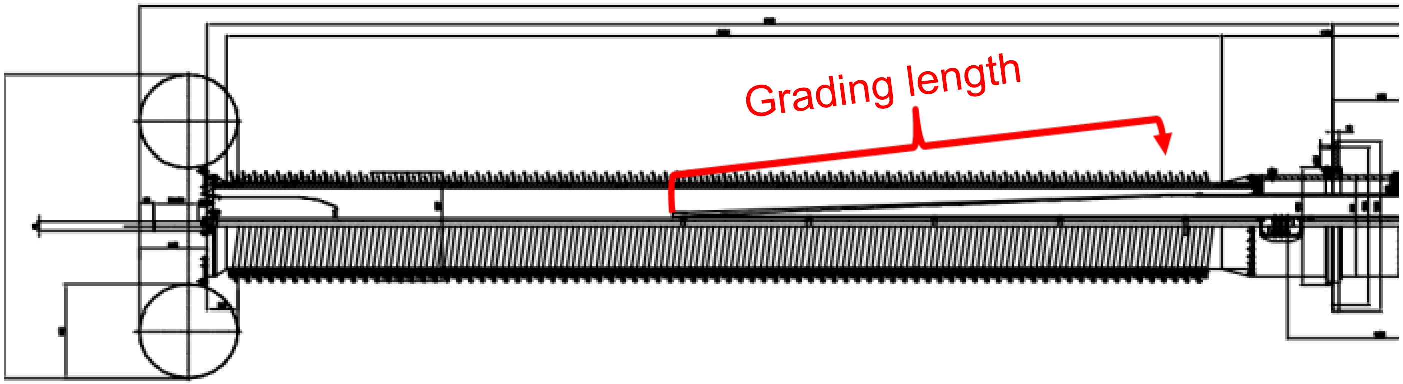
- Definition of “equipment-specific” high voltage testing procedures

Siemens Solution approach

Application of capacitively graded insulator based on RIP technology

Solution approach
Application of capacitively graded insulator

AC/DC bushing

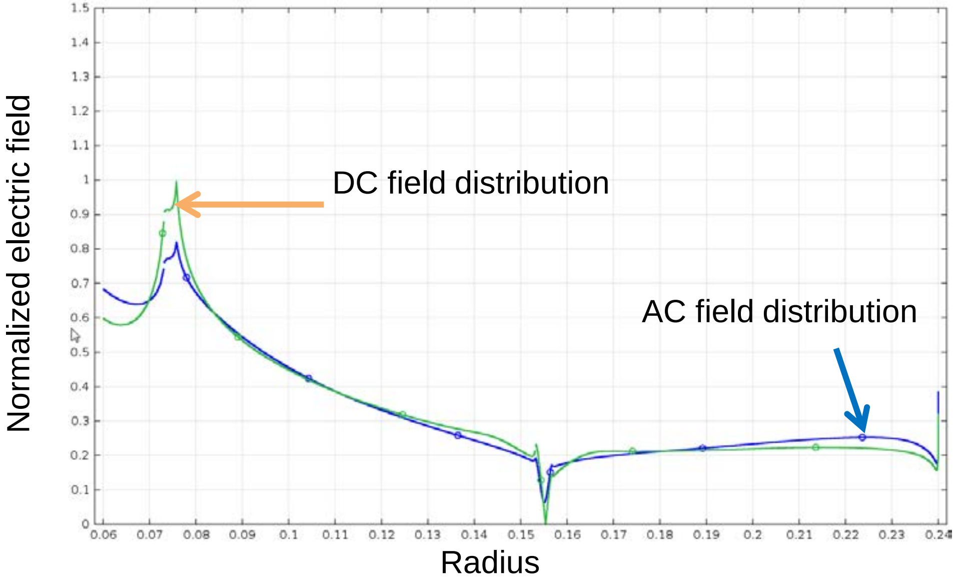


- More than 30 years of experience with RIP technology
- Application of RIP technology at DC voltage levels up to ±800 kV
- Field grading realized by metallic foils inserted in RIP material

Innovative RIP insulator design for DCCS ±320 kV

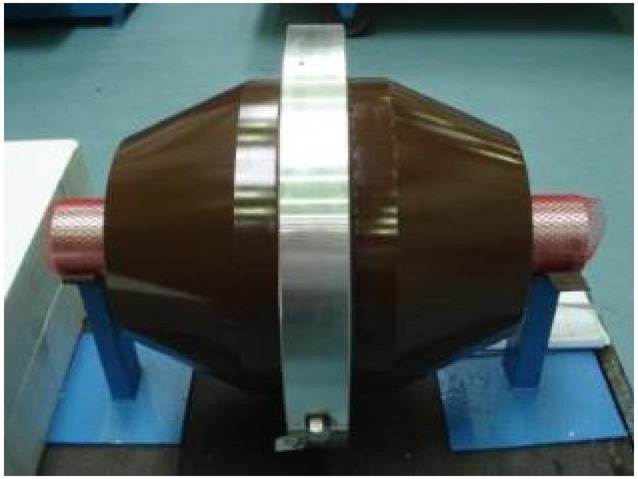
Benefits of RIP insulator

- long-term experience with RIP material from HVDC bushing available
- Field grading effective for AC, DC and impulse voltage stress



DC field distribution

AC field distribution

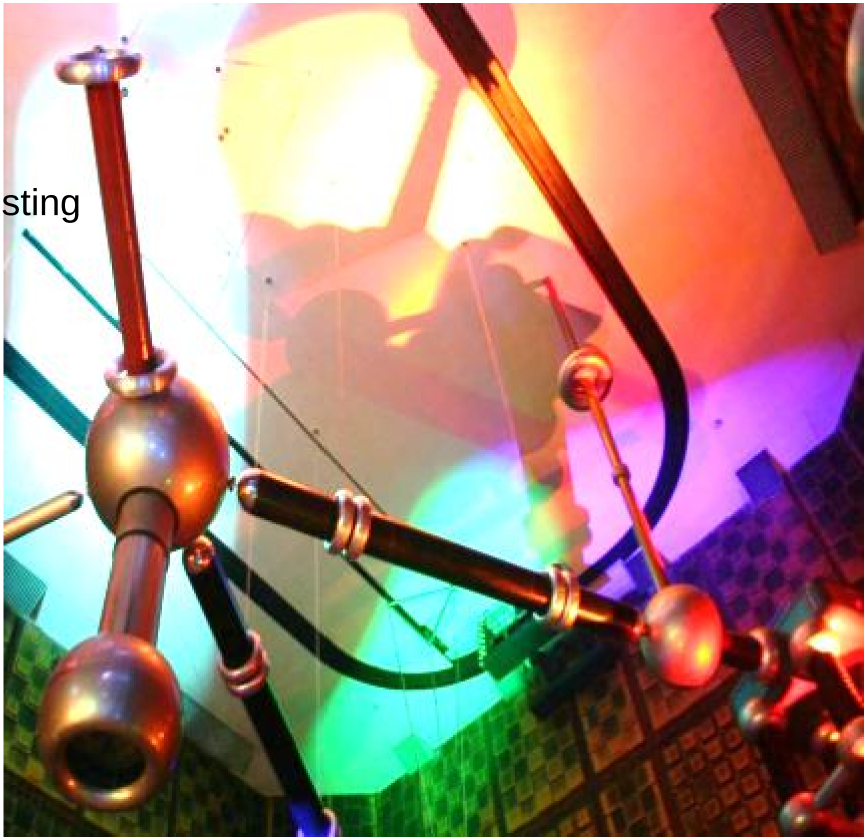


Benefits of RIP Insulator

- Comparable electric field distribution for AC and DC due to field grading

Testing Strategy

There are NO international agreed standards for this kind of equipment



First approach:

- Application of IEC 62219 DC Bushing
- Application of CIGRE Recommendations for cable testing
- Application of various manufactures specified test (depending on the insulation system)

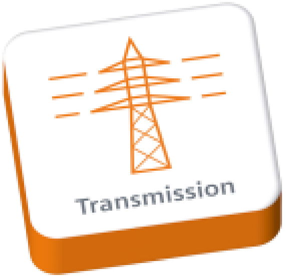
List of the possible dielectric tests:

- DC withstand test at higher level
- DC voltage with superimposed impulse voltage
- Polarity reversal
- Long(er) term test with specified voltage, current, temperature and time profile
- etc.

Summary

- In Addition to traditional Central Power Generation Large Scale **Renewable Energy Sources (RES)** have to implemented into Transmission Systems

- ✓ **New Transmission Solutions are needed**
- ✓ **Standardization of HVDC Grids has started in Europe**
- ✓ **Compact Gas Insulated Systems for HVDC Applications are feasible and ready for use**



Thank You!

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