Metrology for Future Energy Transmission

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The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

STAKEHOLDER WORKSHOP

EMPIR 19ENG02 FutureEnergy

Metrology for future energy transmission

LCOE, Madrid May 24, 2023

Alf-Peter Elg

FUNDACIÓN PARA EL FOMENTO DE LA INNOVACIÓN INDUSTRIAL

LCOE
LABORATORIO CENTRAL OFICIAL DE ELECTROTECNIA

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AGENDA

13:00	Welcome & Cocktail	
14:00	Introduction	RISE
14:10	WP1: UVDC calibration and testing	PTB
14:50	WP2: Lightning Impulse voltage calibration and testing	VTT
15:30	Coffee brake & Poster session	
16:15	WP3: Voltage dependence at HVAC	VSL
17:00	WP4: Metrology for HVDC grid monitoring	FFII
17:45	Summary of results	RISE
18:00	End of workshop	
20:30	Dinner	

CONSORTIUM

NMI

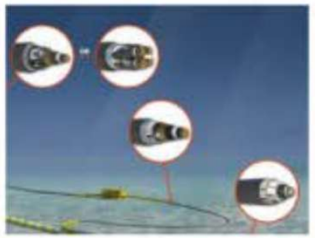
UNIVERSITIES AND INDUSTRY

COLLABORATORS

Project infrastructure

UHVDC calibration

HVAC capacitance linearity



HVAC and HVDC Cable transmssion

HVDC transmission

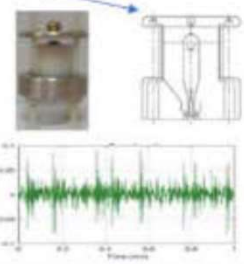
Ultra high voltage calibration and Monitoring infrastructure

HW Development/ Grid monitoring

HVDC Converters

Lightning Impulse linearity

PD under DC stress



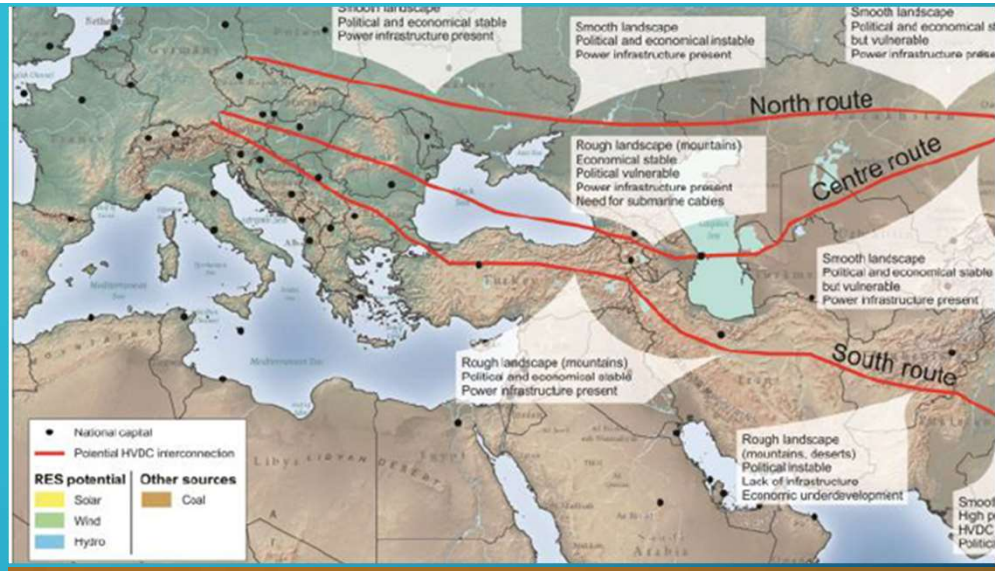
FUTUREENERGY

'PROVIDE TRACEABILITY FOR METROLOGY IN TESTING AND CALIBRATION OF COMPONENTS FOR FUTURE ELECTRICITY GRIDS'

https://www.ptb.de/empir2020/futureenergy/home/

PREPARING EUROPE FOR FUTURE ENERGY GRIDS MEET HORIZON 2050

- Metrology for increased energy efficiency for power transmission in **long interties**
- **Integration** of renewables
- **Grid balancing** and redundancy
- Create means for a strong grid **backbone**
- Minimize losses beyond 20/20/20 – **Horizon 2050**



SCIENTIFIC CHALLENGES

State of the art (2020)

1. HVDC 1000 kV (20 µV/V)
2. Lightning impulse – No proven traceability for linear extension beyond 2500 kV
3. Method for voltage dependence of any HV capacitor
4. PD detection under DC stress in HVDC cables, GIS and converters

OBJECTIVES

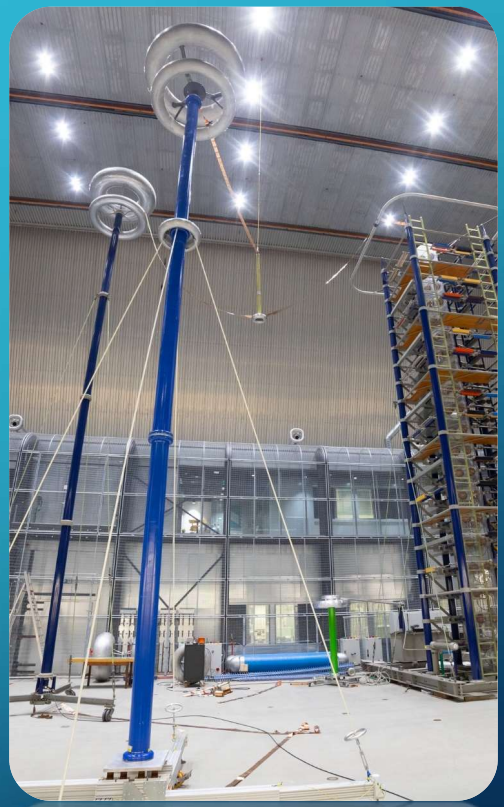
WP 1: UHVDC (Dr. Meisner, PTB)

To extend the traceable calibration of Ultra-High Voltage Direct Current (UHVDC) **up to at least 1600 kV, possibly 2000 kV,** by developing new methods and hardware. In addition, to **facilitate on-site measurements** by developing two modular voltage dividers, one with an expanded measurement uncertainty better than **200 µV/V at 1600 kV,** and one better than **40 µV/V at 1200 kV**.

OBJECTIVES

WP 2: UHV Lightning Impulse - UHVLI (Dr. Hällström, VTT)

To extend and research methods for lightning impulse voltage calibration for testing of UHV equipment. The target is to provide new input to IEC 60060-2 for time parameters and voltage measurement on ultra-high voltages above 2.5 MV, with an uncertainty for peak voltage better than 1 %. To resolve unexplained effects on measurements from front oscillations, corona, proximity, and signal cable.



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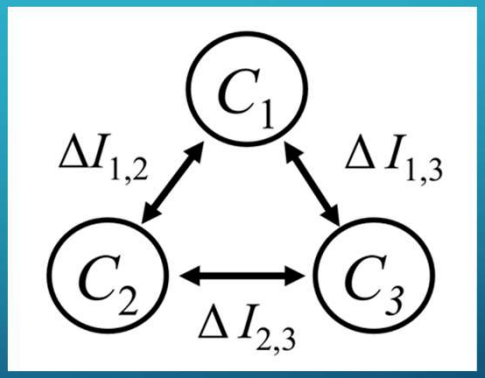
OBJECTIVES

WP 3: Non-linearity of HV capacitors (E. Houtzagher, VSL)

To develop new methods for linearity determination of HV capacitors with a target calibration uncertainty for HVAC of 80 µV/V at 800 kV.



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OBJECTIVES

WP 4: PD detection under DC stress in HVDC cables, GIS and converters (Prof. Garnacho, FFII-LCOE)

To develop and demonstrate implementation of partial discharge (PD) measurement techniques for testing of equipment under d.c. stress, with specific emphasis on detection and prevention of insulation failures in HVDC cables, GIS and convertors.

To develop special PD calibrators of representative PD pulses associated with insulation defects and a new characterisation setup up to 100 kV for a HVDC gas insulated substations (GIS).

WORK PACKAGES

1. UHVDC **traceability for metering** to 1200 kV and **traceability for testing** to 1600 kV and beyond
2. UHVLI **linearity methods** >2500 kV
3. UHVAC new **methods** for voltage **non-linearity of HV capacitors**
4. HVDC **PD detection methods** - HVDC grid monitoring, develop HV cables, GIS and converters

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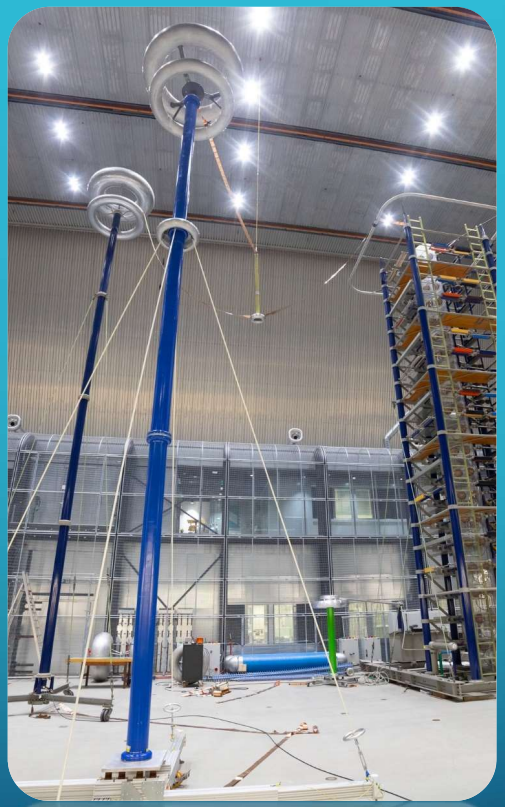
Summary
Discussion and future needs

SUMMARY OF RESULTS



UHVDC TRACEABILITY TO 1200 KV

- **UHVDC 1200 kV unc. < 20 µV/V (40 µV/V)**
- 9 existing 200 kV modules from ENG07 HVDC + 7 new 200 kV modules 19ENG02 FutureEnergy
  - RISE and PTB - Two complete 1200 kV dividers
  - TUBITAK – Two modules, 400 kV divider
- Intercomparison 1200 kV at RISE March 2022 - UHVDC Traceability → 1200 kV unc. < 20 µV/V (target 40 µV/V)
- One paper at CPEM2022 (stability of HVDC systems)
- IEEE TIM in progress

UHVDC TRACEABILITY TO 1600 KV

- **UHVDC 1600 kV unc. < 40 µV/V (200 µV/V)**
- New modular dividers
  - RCRC divider – 5 x 400 kV (< 40 µV/V @ 1600 kV)
  - RCR divider – 2 x 500 kV (< 35 µV/V @ 1000 kV)
  - UHVDC Traceability → 1600 kV unc. < 40 µV/V (target 200 µV/V)
- New Greinacher/Cockroft-Walton DC generator
  - Ultra-low ripple 2000 kV (300 Hz)
- New testing site – open air 50 x 60 m arranged at PTB
- Intercomparison up to 1600 kV PTB in June 2022
  - Two papers at ISH 2023

PTB Messen ▪ Forschen ▪ Wissen

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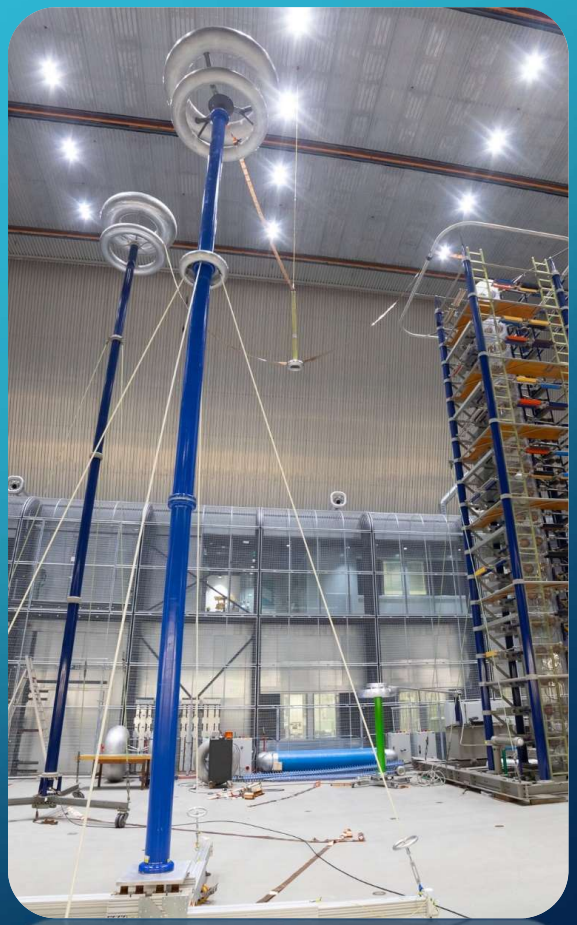
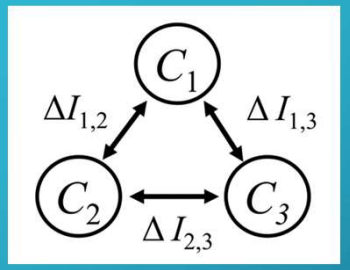
UHVLI LINEARITY TO 3000 KV

- Good practice guide for UHVLI dividers
  - Linear extension - Charging voltage, field probe, system with higher rating – 1% possible, deviation not proof of non-linearity
  - Influence factors - Front oscillations and sources, Corona, Proximity and Signal cable length effects
- Intercomparison at TU Delft to 3000 kV
  - Six resistive dividers (400 – 2000 kV)
  - Four damped capacitive dividers (1000 – 4000 kV)
  - Agreement within 1% of peak voltage up to 3000 kV
- Paper submitted to ISH 2023



UHVAC METHODS ON LINEARITY OF HV CAPACITORS

- Six methods evaluated – one new
  - Kinetic method (Latzel) - 0.1 µV/V (ISH2021)
  - Three equations method – 10 µV/V (CPEM2022)
  - Field sensor – 50 µV/V
  - Simplified tilt and CCD method – 10 and 6 µV/V (NIM)
- Papers CPEM2022 – method and loss factor of bridges
- New 800 kV gas capacitor designed by Vettiner
- Campaigns to 300 kV (2022) and 500 kV April 2023
  - Vettiner 800 kV capacitor delayed (subsupplier)



HVDC PD DETECTION METHODS – HVAC AND HVDC

- HV cables 1 – 30 MHz
  - Synthetic PD generator
    - Qualification of PD calibrators for insulation diagnostics of HVAC and HVDC cables
    - Generates PD pulse trains of stable charge values from 2 pC to 15 nC with an uncertainty of less than ±2% or ± 1 pC
  - Round-Robin ongoing (FFII, LCOE, UPM and RISE)

HVDC PD DETECTION METHODS

- Calibrated PD charge evaluation in HVDC GIS 30 – 300 MHz
  - 1GHz bandwidth workbench developed and validated for PD sensors characterization
  - Balanced magnetic antenna with a frequency range of up to 300MHz
  - Combination of VHF electric and magnetic sensor for PD power flow
- More than 5 peer review papers

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High voltage laboratory planning Hylten-Cavallius, Nils 1986
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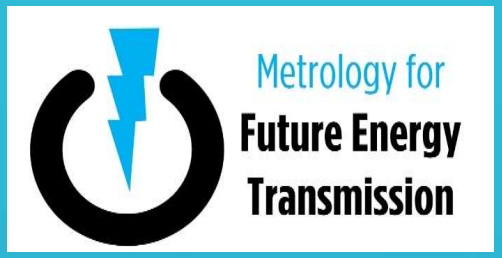

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Spectrum of HVDC metrology

On behalf of the FutureEnergy consortium

Thank you for your attention!

Alf-Peter Elg

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