FutureEnergy project

This is the first newsletter of the EMPIR project 'Metrology for future energy transmission (FutureEnergy)'. The three-year project started in June 2020, and it is building on the EMPIR projects 'Metrology for the electric power industry (14IND08 ElPow), 'Techniques for ultra-high voltage and very fast transients (15NRM02 UHV) and the EMRP project 'HVDC future power grids (07ENG HVDC)'.

Driven by the need for increased efficiency, transmission grid voltages have been pushed to ultra-high voltages (UHV), beyond 1000 kV. This project will realise metrology solutions for grid component testing and condition monitoring required for successful implementation of future UHV transmission grids.

Society's increasing demand for electrical energy, along with the increased integration of remote renewable generation has driven transmission levels to ever higher voltages in order to maintain (or improve) grid efficiency. Consequently, high voltage testing and monitoring beyond voltage levels covered by presently available metrology infrastructures are needed to secure availability and quality of supply.

Calibration services for UHVDC are not available above 1000 kV. There is a need to extend the calibration capabilities for voltage instrument transformers up to 1200 kV and for factory component testing capabilities up to 2000 kV.

The overall aim of the project is to provide traceability for metrology in testing and calibration of components for future electricity grids, and to provide improved means for HVDC grid condition monitoring. The specific objectives are:

- extend the traceable calibration of Ultra-High Voltage Direct Current (UHVDC) up to at least 1600 kV
- extend and research methods for lightning impulse voltage calibration for testing of UHV equipment
- develop a new method(s) for linearity determination of HV capacitors
- develop and demonstrate implementation of partial discharge (PD) measurements under d.c. stress
- facilitate the take up of the technology and measurement infrastructure developed in the project
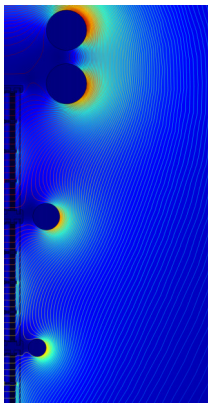

Project infrastructure
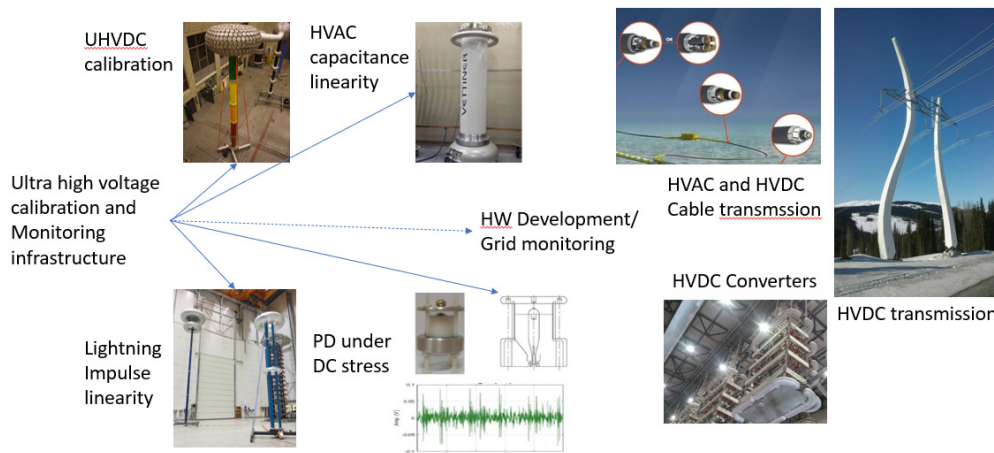
Research highlights

UHVDC traceability

For the traceability to 1200 kV with the target measurement uncertainty of 40 µV/V, in total seven new 200 kV HV modules are being built. The target is to have at least two complete sets of HVDC dividers for traceability to 1200 kV in Europe, one complete at PTB and one at RISE.

Field modelling to avoid corona discharge in the 1200 kV divider design has been completed by RISE with input from PTB, TUBITAK and VTT. Measurements have been performed by RISE to support the modelling. The results show which additional corona rings need to be added to joints between the HV modules.

Precision resistors have been purchased and tested by PTB in order to find the voltage and temperature coefficient. The results have been discussed by the partners and plans for purchase of components and assembly are ready for seven additional 1200 kV HVDC divider modules.

For the traceability to 1600 kV with the target measurement uncertainty of 200 µV/V, a divider design based on work at PTB has been disseminated. PTB has finalised a prototype for 1600 kV and tested it in the open field at PTB. The results feed into optimisation work on the divider. At least one complete traceable measurement system to 1600 kV, possibly extended to 2000 kV, will be available at PTB. Field modelling to avoid corona discharge for a 2000 kV divider has been completed by RISE with input from PTB, TUBITAK and VTT.

Lightning impulse linearity extension

Activities in preparation for drafting of the "Good Practice Guide" are ongoing. VTT has started modelling of the signal cable effects. First version of the simulation model based on telegraphers' equations embedded into circuit simulator is running.

In parallel to modeling, a literature study has been carried out by PTB and TUBITAK to investigate the influence of the attenuation in the coaxial cable between the high voltage hall and control room, as well as effect of measurement cable quality and length. Results from 14IND08 ElPow are being disseminated by RISE, and a bachelor thesis as well as a doctoral thesis at PTB shows several correlations which will feed into the "Good Practice Guide"
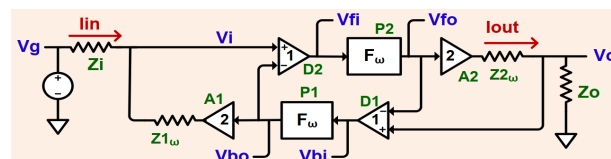
RISE has established collaborations in form of Letters of Agreement with 1) NIM, China, to support the work on front oscillations; 2) Haefely AG, Switzerland, to support the work on both front oscillations and cable effect; and 3) NMIA, Australia, to support the work on linearity extension methods.

Voltage linearity of UHVAC references

Information has been collected by TUBITAK on gas-capacitors accessible to project partners and their voltage dependencies based on which the best references will be selected as well as the measurement bridges. Review of linearity extension techniques used in industry utilising electrical field probes has been started by VTT and VSL.

Latzel's method has been repeated by LNE on a high-voltage capacitor to review the technique. The resulting measurements are a good start and will be improved on.

A new design of a high-voltage capacitor has been made by VET-TINER and is being fine-tuned.

A prototype field probe has been made by VSL to review the technique and the expected uncertainty. The results seem promising and will be improved upon and will serve as further input to VTT and TAU.

PTB has started the measurement of the temperature dependence of their eight capacitors, which will be used in the development of the calibration method.
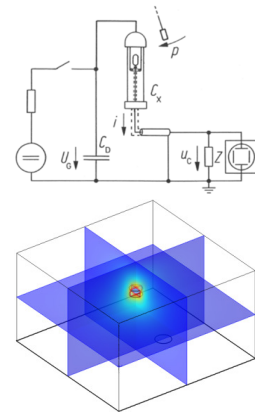
RISE has established a collaboration in form of a Letter of Agreement with NIM, China, to add to the work on new methods for voltage linearity determination.

HVDC grid condition monitoring

PD procedure for qualifying PD analysers used for d.c. measurement in the 1 – 30 MHz range

An attenuation study in HVAC and HVDC cable systems has been carried out. This study includes attenuation tests in AC cable samples (MV and HV) and theoretical determination for AC and DC cable systems. Attenuation is much lower in HV cable systems than in MV cables. Real data have been supplied from on-site tests.

Test cells of representative defects have been used for aging (floating electrode, cavity, corona, surface) in two different testing facilities. One site is focused on corona, on surface and on floating test cells and the other is focused on cavity defects. A comparison between real data and laboratory test cells has been performed with a small number of PD trains. The preliminary conclusion is positive: test cells represent real defects. It will be extended with a bigger number of PD trains.

A set of 1000 PD pulse trains was supplied by a collaborator to be used for an AI tool to be developed. First results from laboratory set-up using test cells are available. A neuronal network is being developed and DC PD pattern recognition is ongoing. An HVDC converter test cell has been presented, developed for tests in a lab. A review of the bibliography about the state of the art of failures in DC and HVDC converters has been presented together with a test plan.

Real data of noises were obtained from real installations (wind plants, PLC from MV substations and DC plants). Several data have been prepared for a synthetic PD generator as noise data to be mixed with real PD defects. Data analysis is in progress to reproduce them by a synthetic way.

FFII has developed three software tools for characterisation of PD analysers for AC: a) PD sensitivity vs noise. b) PD pattern recognition. c) PD clustering. These tools allow the determination of the capabilities of PD analysers. These tools must be extended with DC PD patterns.
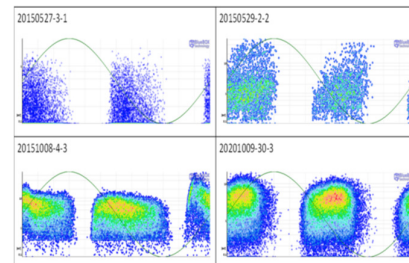
PD charge evaluation in HVDC GIS using magnetic sensors measuring in the 30 MHz – 300 MHz range
The magnetic antenna design for PD measurements in GIS has been improved extending the bandwidth above 300 MHz. A mathematical model of the antenna frequency response has been developed that will be instrumental for the charge estimation of the partial discharges. Analysis on the GIS PD signal attenuation is done in the working frequency range of the magnetic antenna.

The magnetic antenna frequency response has been extended above 300 MHz and reasons for resonances have been cleared. A mathematical model of the antenna response has been developed. A calibration testbench up to 1 GHz bandwidth has been built and tested. Preliminary work on charge estimation error calculation has been done, showing positive results. The work will be extended with theoretical developments and laboratory experiments to demonstrate the suitability of the proposed method based on the double time integral of the measured signal.

RISE and VETTINER has established collaborations in the form of a Letter of Agreement with the SUPERGRID Institute, which is going to provide measurements on GIS systems.

Contact and further information

The consortium consists of 7 National Metrology Institutes, 3 universities, and 2 companies and thus have measurement capabilities traceable to national standards, sites to host the measurements facilities and test their performance and companies to develop and exploit their technology.

Project coordinator: Alf-Peter Elg, RISE (alf.elg@ri.se)

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

To register as a project stakeholder, contact Alf-Peter Elg, RISE (alf.elg@ri.se).

Project partners:

RISE	RISE	Research Institutes of Sweden	Sweden	**NATIONAL METROLOGY INSTITUTES**
	FFII	Fundación para el Fomento de la Innovación Industrial	Spain	
	LNE	Laboratoire national de métrologie et d'essais	France	
	PTB	Physikalisch-Technische Bundesanstalt	Germany	
	TUBITAK	Turkiye Bilimsel ve Teknolojik Arastirma Kurumu	Turkey	
	VSL	VSL B.V.	Netherlands	
	VTT	Teknologian tutkimuskeskus VTT Oy	Finland	
	TAU	Tampereen korkeakoulusäätiö sr	Finland	**ACADEMIA**
	TU Delft	Technische Universiteit Delft	Netherlands	
	UPM	Universidad Poltécnica de Madrid	Spain	
	Vettiner	Appareils Vettiner	France	**INDUSTRY**

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