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

Workshops on grid metrology for efficient electricity grids

– Day 2 –

Stakeholder Workshop of the EMPIR TrafoLoss project

- Start at 13:00 (CEST)
- Workshop will be recorded (will be made available at the TrafoLoss website)

Attendants and Meeting rules

More than 40 registered participants (from all over the world)

- Utilities
- Power transformer manufacturers
- Instrument manufacturers
- NMIs
- Universities and research institutes

In order to assure a smooth meeting, please

- Switch of your video and audio when not speaking to limit bandwidth and interference
- Use the “raise hand” function for asking questions

Opening address

Fabienne van Booma

VSL director

17.06.2021	Stakeholder Workshop	
13:00	Opening of the meeting by VSL Director	F. van Booma (VSL)
13:05	Overview and Progress of TrafoLoss	G. Rietveld (VSL)
13:25	Overview and Progress of FutureGrid II	E. Mohns (PTB)
13:45 14:05 14:25 14:35	<u>Industrial Loss Measurement Systems (LMS)</u> • Active voltage divider with small phase error • New Loss Measurement System instrumentation – voltage transformer • Reference setup for evaluating LMS voltage channels • Harmonic analysis of non-sinusoidal waveforms during NLL measurement of power transformers	J. Hällström (VTT) A. Vukadinovic (EPRO) P. Räther (PTB) G. Ye (VSL)
15:00	Coffee Break	
15:20 15:40 16:20 16:40	<u>Primary references for calibrating industrial LMS</u> • Calibration guidance for power transformer and reactor LMS • New high-end reference setup for transformer LMS system calibration • LMS calibration setup and onsite experiences <u>Impact</u> Project outputs, Stakeholder uptake Outlook – future work	G. Rietveld (VSL) E. Houtzager (VSL) H. Cayci (TUBITAK) G. Rietveld (VSL)
17:00	End of Workshop	

17NRM01 TrafoLoss

EMPIR EURAMET
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TrafoLoss project introduction: “Loss Measurements on Power Transformers and Reactors”

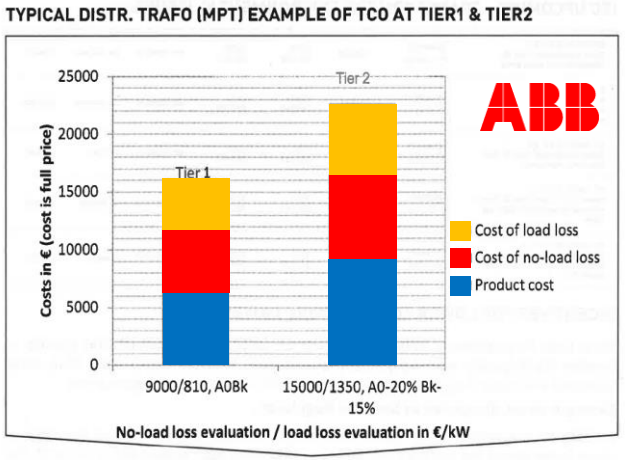
Gert Rietveld
gert.rietveld@vsl.nl

TrafoLoss final workshop
17 June 2021

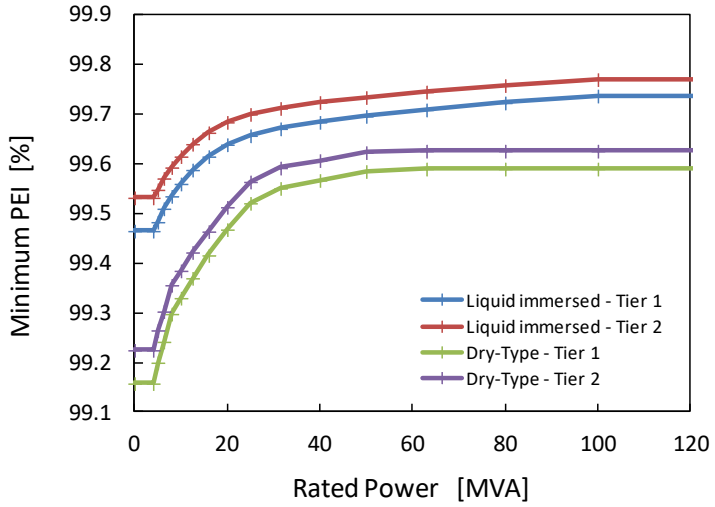
Drivers for reliable transformer loss measurements

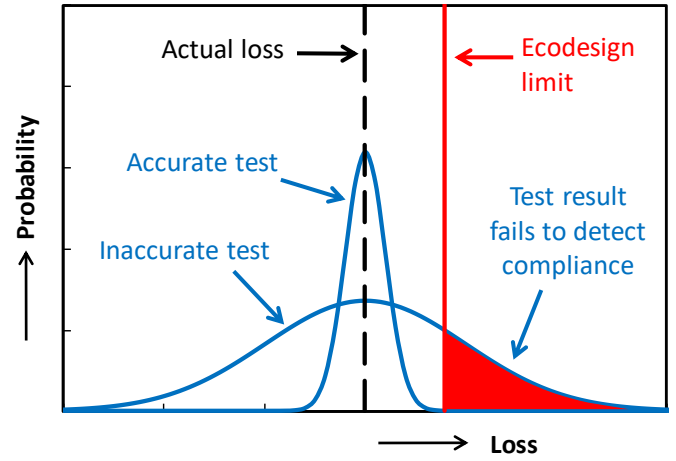
- Losses are significant cost (TCO) and significant environmental impact
- EU Ecodesign requirements per 1 July 2015, saving 16 TWh/year (≈ 17 % of total grid losses)
- Customers: fines on losses in excess of guaranteed losses

  ⇒ 3 % uncertainty corresponds to 150.000 € for 100 MVA transformer



High accuracy = low risk of incorrect decisions





Need expressed by CLC TC14

CLC TC14 “Power Transformer” industry needs:

- Accurate industrial loss measurement systems for transformer & reactor losses
- System calibration of industrial loss measurement systems (TLMS)
- Guidance in complex uncertainty evaluation

Normative issues

- Effects non-sinusoidal waveforms (NLL)
- EU Guidance on TLMS calibration
- Reactor loss tests accuracy evaluation (IEC and CLC 60076-19)

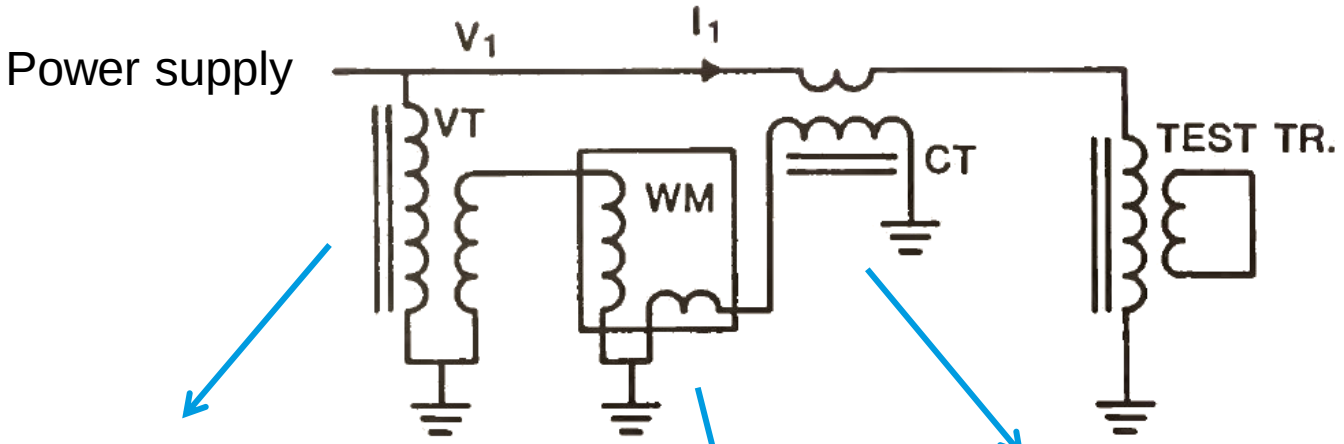
Project response

Key result: new instrumentation for loss measurements

up to 230 kV, 2000 A with 20 µW/VA uncertainty

- 6 partners
- 4 collaborators
- 2018 – 2021 (42 months)
- 1 MEuro

Power Transformer Loss Measurement System (TLMS)



$$P = V \cdot I \cdot \cos \varphi$$

Challenge: phase accuracy
< 300 μrad / 1 min

↕

3 % at PF=0.01

TMS typical measurement range: 0 – 100 kV, 0 – 2000 (4000) A

Measurement challenge

Power: $P = U \cdot I \cdot \cos \varphi$ with $\varphi \sim 90°$

$P = U \cdot I \cdot \cos (90° - \alpha) = U \cdot I \cdot \alpha$ with $\alpha = (90° - \varphi) \sim 0°$

U and *I* are large numbers $\Rightarrow$ 1 % uncertainty is very easy

α is a very small number:

for PF=0.01, $\alpha = 0.57°$ $\Rightarrow$ 1 % uncertainty is a big challenge!

(6 m°, 0.34 min, 100 µrad)

1 % losses

$\Rightarrow$ *Phase* accuracy, not *amplitude* accuracy is critical!!

Project Rationale

Aim: support of the power transformer industry in meeting the Ecodesign requirements

Key project data: 650 k€, 6 partners, 3 years, May 2018 – ~~April~~ September 2021

⇒ Follow-up on ELPOW result:

	Industrial state of the art	ELPOW targets	TrafoLoss	
Industrial reactor loss	100 µW/V single phase		50 µW/VA at 0-230 kV three-phase	0.5 %
Industrial transformer loss	100–300 µW/VA at 0-100 kV three phase			
Primary reference reactor loss		10 µW/VA at 0-0.5 kV	10 µW/VA at 0-0.5 kV	0.2 %
Primary reference transformer loss		50 µW/VA at 0-100 kV	20 µW/VA at 0-230 kV	

at PF=0.01

Key results of the project

1. Advanced industrial TLM system with better voltage channels (50 µW/VA)
2. Reference setup for calibration of industrial TLM systems (20 µW/VA)
3. Improved traceability of DF
4. Uncertainty analysis of loss measurements
   - Effect of non-sinusoidal waveforms

Challenge: phase accuracy 10 – 50 µrad

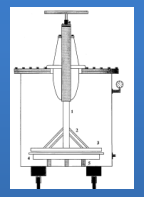
$P = U \cdot I \cdot \cos \varphi$

0.5 % at PF=0.01

2

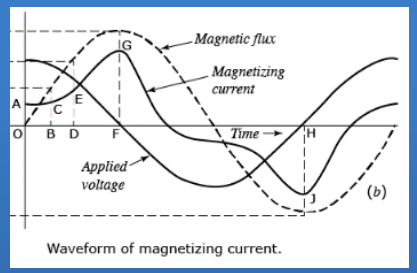
- On-site calibration under harsh industrial conditions
- Reference system: 20 µW/VA

3



- HV capacitor loss (DF) traceability up to 40 kV
- DF verification of HV capacitors

4



Waveform of magnetizing current.

- Reactor loss uncertainty evaluation – guidelines
- Complex uncertainty model
- Non-sinusoidal waveforms in unloaded trafo testing (NLL)

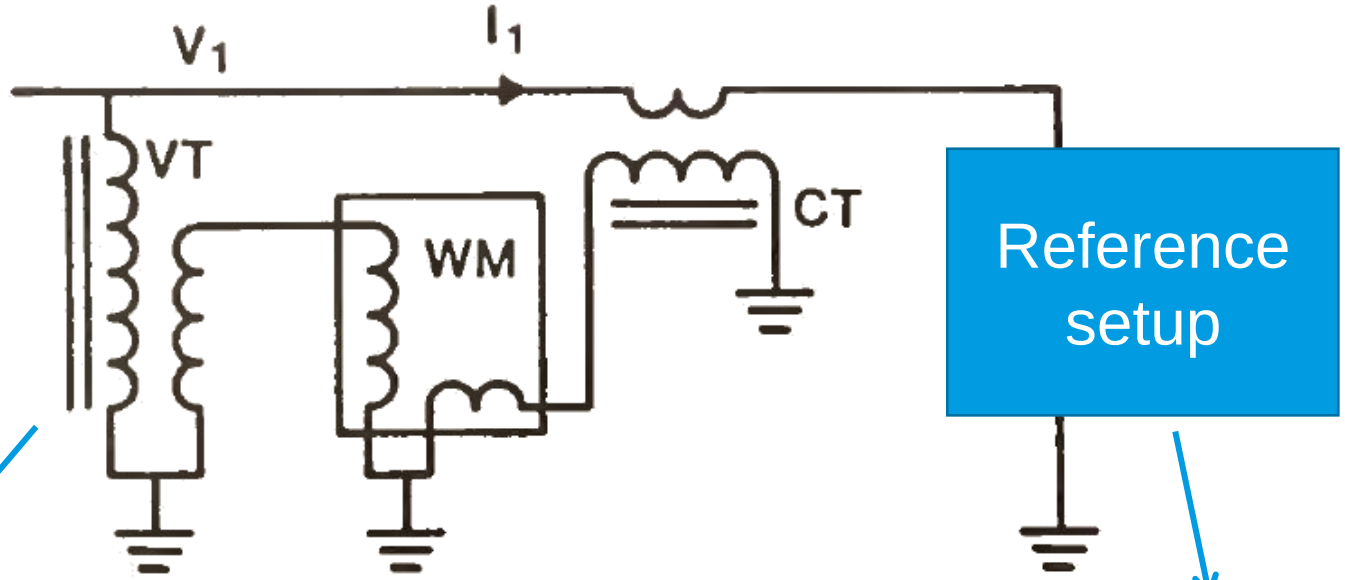
- New capacitive voltage divider with buffered output
- Inductive divider up to 230 kV
- Electronically compensated current transformers

⇒ Industry loss measurement system, 50 µW/VA accuracy

1

Power Transformer Loss Measurement System (TLMS)

Power supply

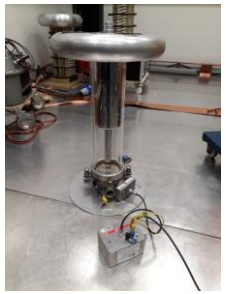


$$P = V \cdot I \cdot \cos \varphi$$

Challenge: phase accuracy
< 300 μrad / 1 min

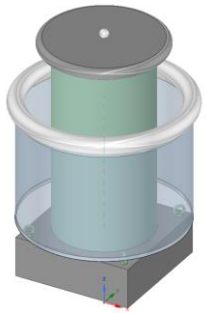
0 – 100 kV,
0 – 2000 (4000) A

1. Advanced TLMS voltage channels (0.005 %)



VTT

epro®



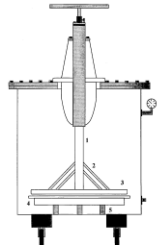
PTB

2. Reference setup for system calibration: simulates adjustable losses to TLM (0.002 %)

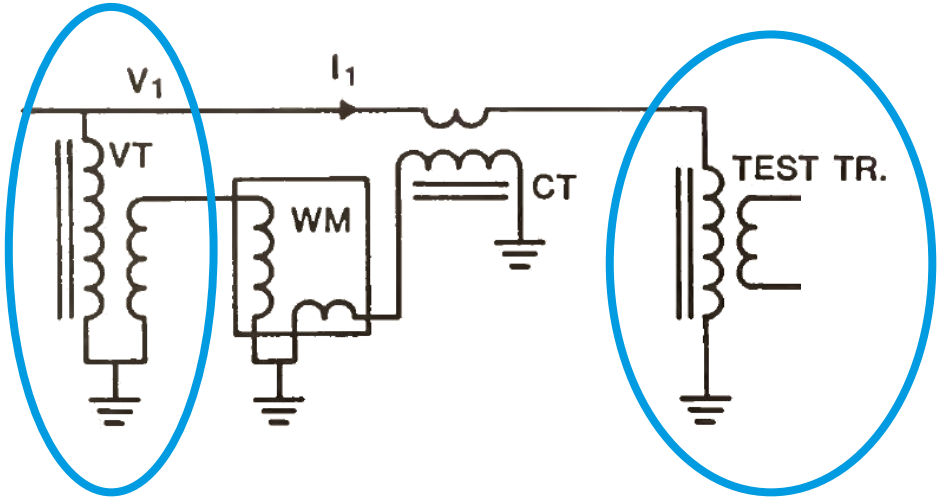
VSL

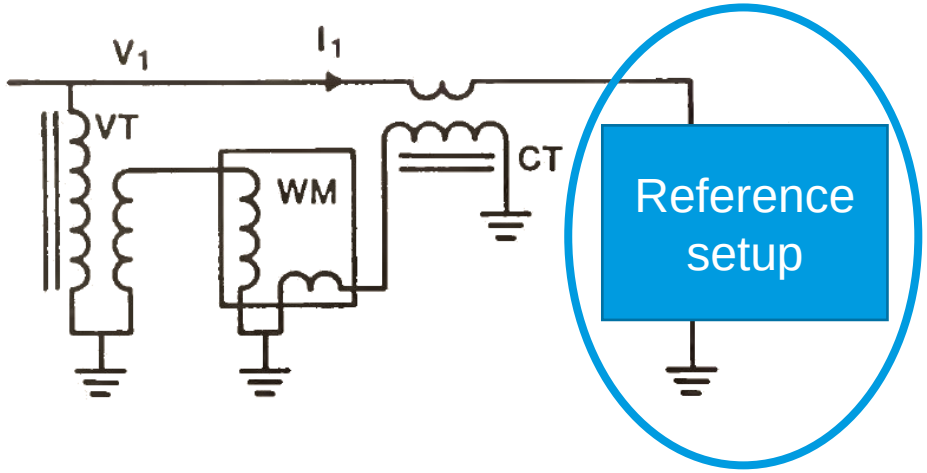
TÜBİTAK UME

RISE



Workshop Agenda





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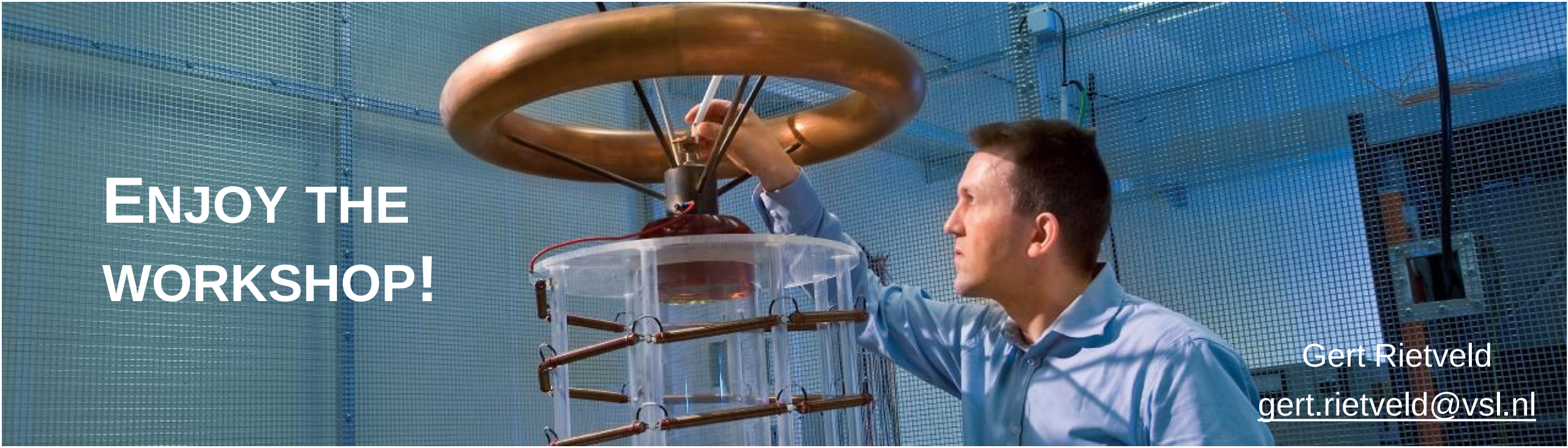

ENJOY THE WORKSHOP!

Gert Rietveld
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"This project has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme"