Z-NET

Pre-normalisation of Grid Impedance Measurement in the Power Line communication frequency band

3rd Interessenverband Netzimpedanz web conference

2nd of November 2021

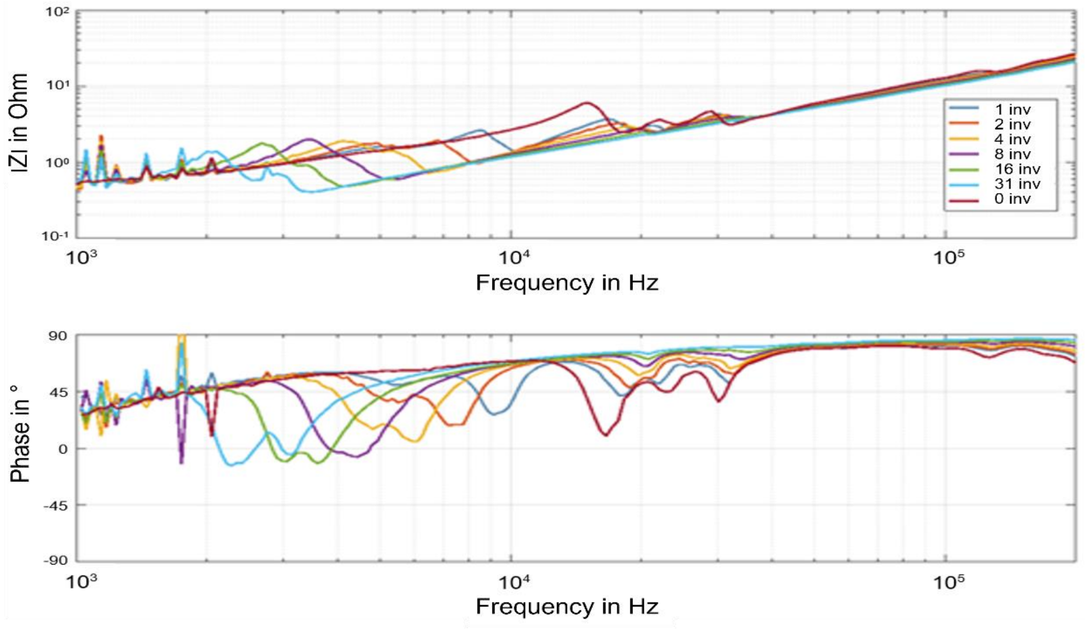
Topics

1. Short introduction about Z-NET project and objectives
2. Realisation of a ‘Static Line Impedance Reference’ and test results
3. Design and testing of a programmable and time variant impedance (FTdGI)
4. On-going activities with standardization and other collaborations

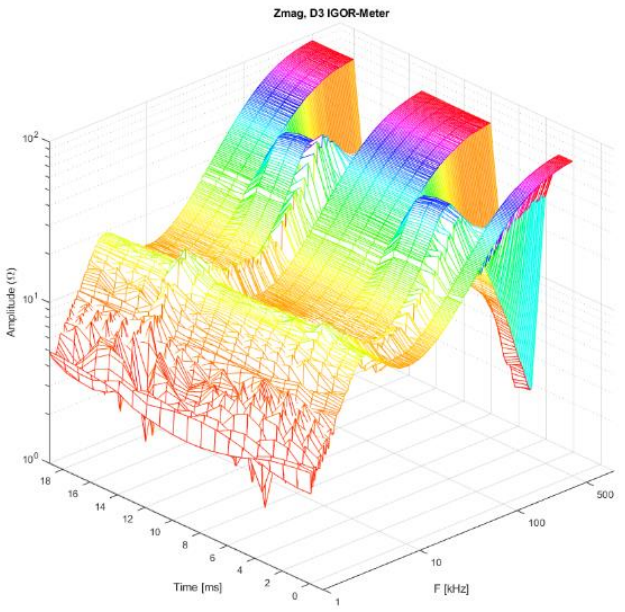
Objectives : Frequency and time dependent Grid Impedance – measurement techniques

- Design, evaluation, calibration of laboratory equipment
- Common definition for standardization activities

Frequency dependent Grid Impedance



Time dependent Grid Impedance



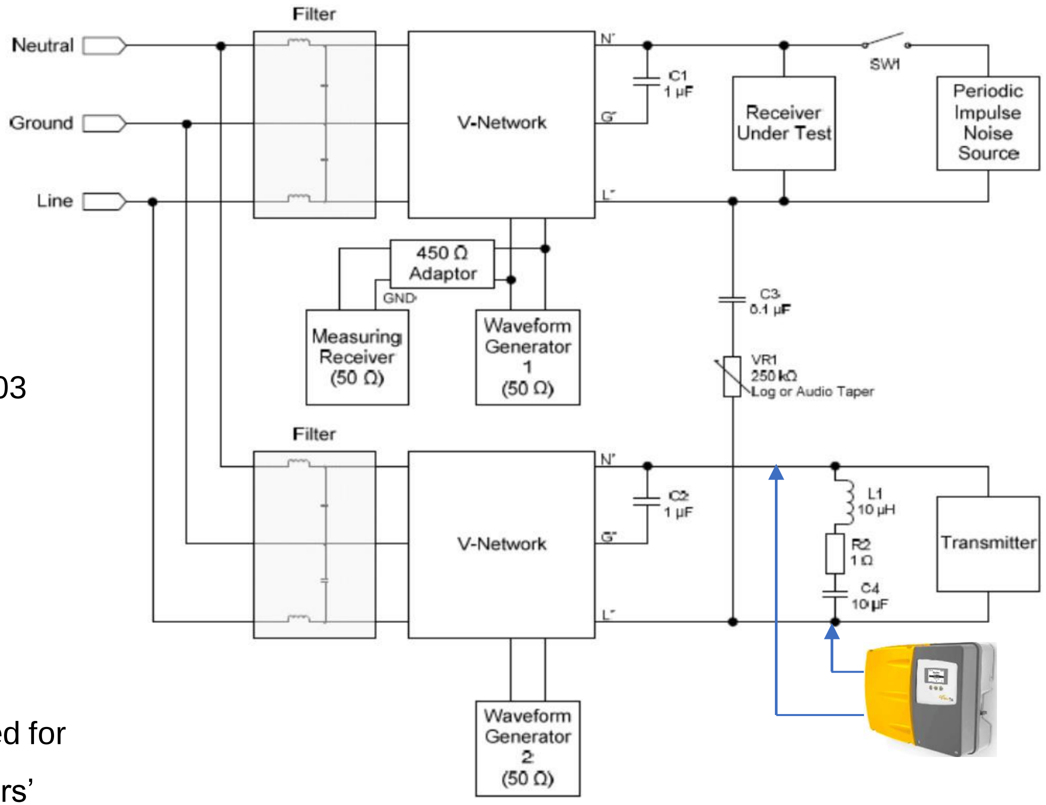
Objectives : PLC communication for smart metering - EM compatibility test set-ups

Laboratory trials with variation of the PLC channel and PV converter

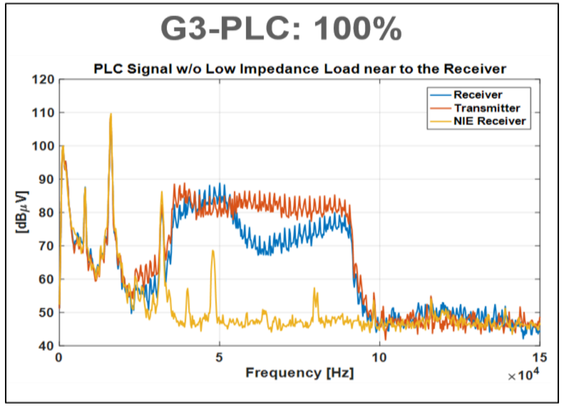
PLC Test bench according to ETSI TS 103 909 V1.1.1 Standard (2012-12)

or

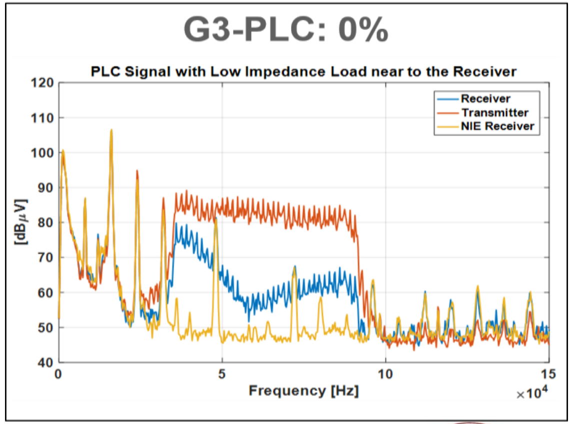
EN 50065-2-3 Edition 2: ‘Immunity requirements for mains communicating equipment operating in the range of frequencies 3 kHz to 95 kHz and intended for use by electricity suppliers and distributors’



No inverter:

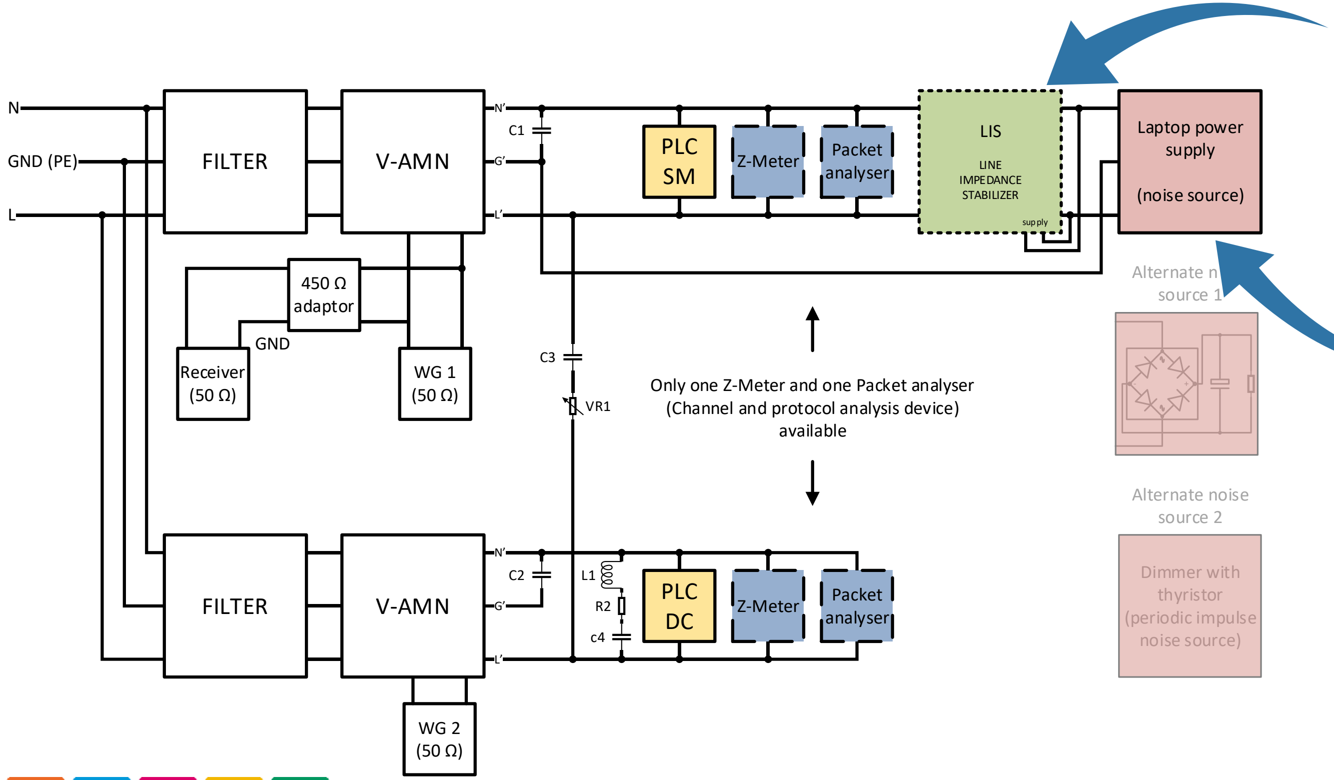


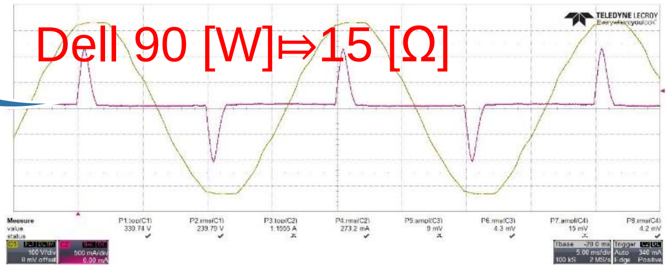
With inverter:

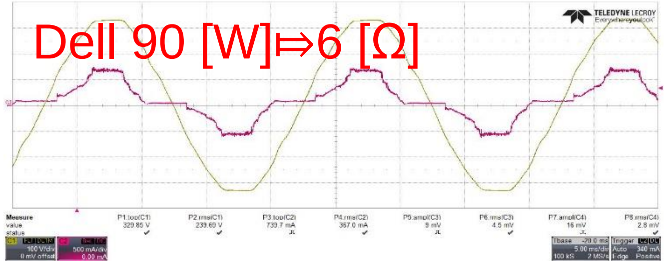


Objectives : References impedances for passive and active EMC filters design

- Impact of spectral and time varying line impedance of EMC filters on PLC
- Line Impedance stabilizing active circuit realized by one of the project partner







HES-SO Valais-Wallis

Institute Systems Engineering

Group IE&D (Industrial Electronics and Drives)

Competences:

- Converter design
- Advanced electric machines and drives
- Controller design and fast converter prototyping (POETIC platform)
- EMC and impact of converters on Power Quality
- Control hardware in the loop (C-HIL)

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Bundesamt für Energie BFE

Project partners overview

METAS

- Swiss Metrology Institute
- Laboratory Electrical Energy and Power
- Realisation SLIR (WP1)
- Realisation VLIR (WP2 - 3)
- Uncertainty evaluations
- EMPIR projects
- Standardisation comitees TC 85, …

HES-SO Valais-Wallis

- University of Applied Science, Institute System Engineering
- Industrial Electronics & Drives Lab
- Project Leader
- Specification and evaluation of SLIR and PLIR (WP 1-3)
- Intercomparison Z-Analysers and recommendations (WP4)
- Recommendations (WP5) Standardisation comities (WP6) TC 77A, TC 219, TC 8X

SCHAFFNER

- EMC Filters design, production and slaes
- R&D Unit (B. Stauffer, S. Pasko)
- Development of Line Impedance Stabiliser
- Participation to ERIGrid measuring campaign in Bilbao
- Standardisation committee TC 77A, WG8 …

SIG

- DSO in Geneva
- Power Quality Group (Cedric Pellodi)
- Power Quality measurements with PQ-Box on sites with DER and e-Mobility, Heat Pumps, etc.
- Smart Metering implementation pilot projects with G3-PLC
- Member of GRUT : Technical uniformization WS

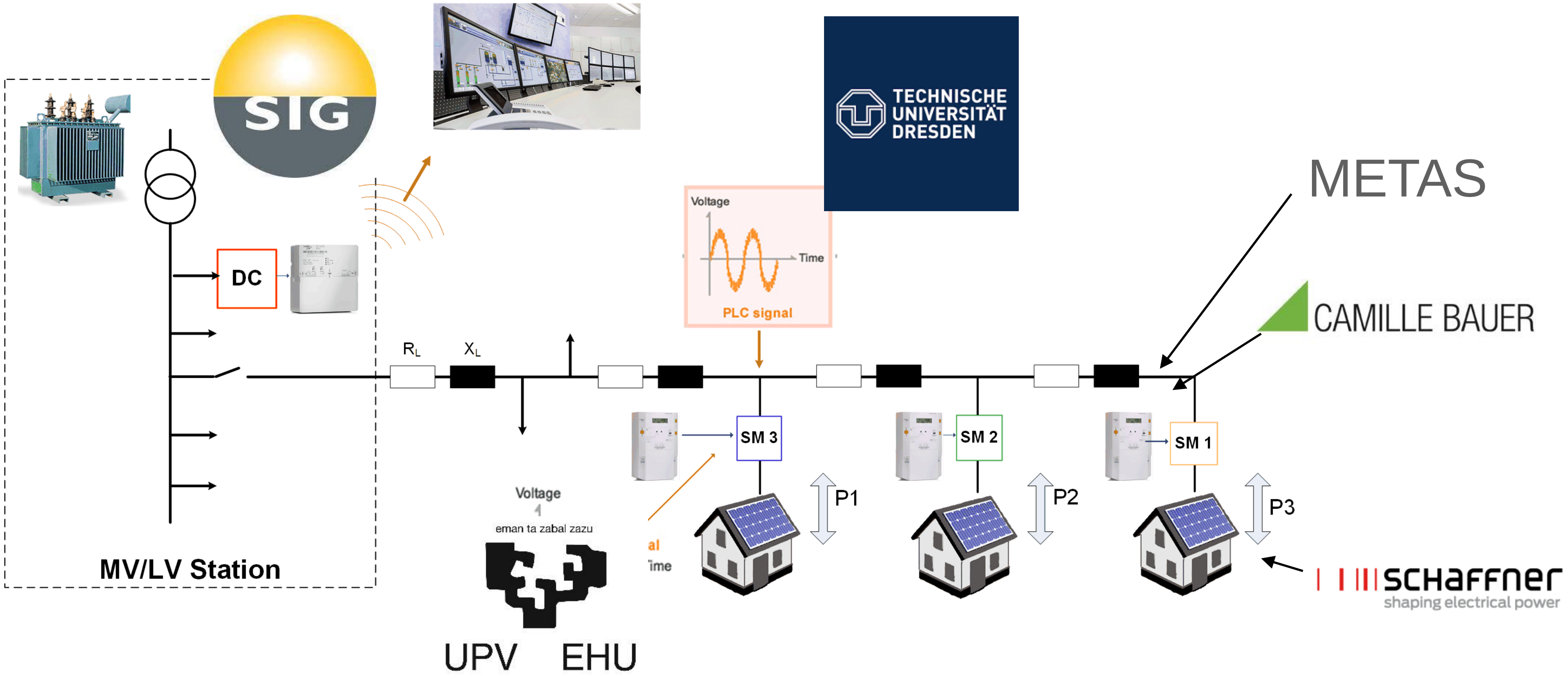
Camille Bauer Metrawatt

- PowerAnalysers Design and production
- R&D Unit (Thomas Naef) & Management (Max Ulrich)
- Interest to integrate FdGI in their equipement
- Involved in several Research projects with field measuring campaigns of grid impedance
- Standardisation activities TC 85, TC 8x, DACH-CZ …

European partners

TU Dresden	UPV/EHU	morEnergy
Chair of Electricl Power Supply	University of Basque Country, Bilbao	PQ laboratory Equipments
Power Quality Group (Jan Meyer)	TSR Group	R&D Unit (Trung Do, M. Jordan)
Conception of FTdGI measuring device (IMD 300)	Design of FTdGI measuring device	Development of Line Impedance Analyser for LV and MV
Numerous PQ research activities with FTdGI measurements on site and in lab	Research activities with PRIME PLC and impact of DER on PLC	Participation to Z-meters intercomparison
	Intercomparison Z-Analysers , Participation to ERIGrid measuring campaign in Bilbao	
Standardisation comitees and WGs, TC 77A WG8, WG9, TC 219 WG 11, DACH-CZ …	Standardisation comitees and WGs, TC 219 WG11…	Netzimpedanz Interessen Verband (Stefan Hoffmann)

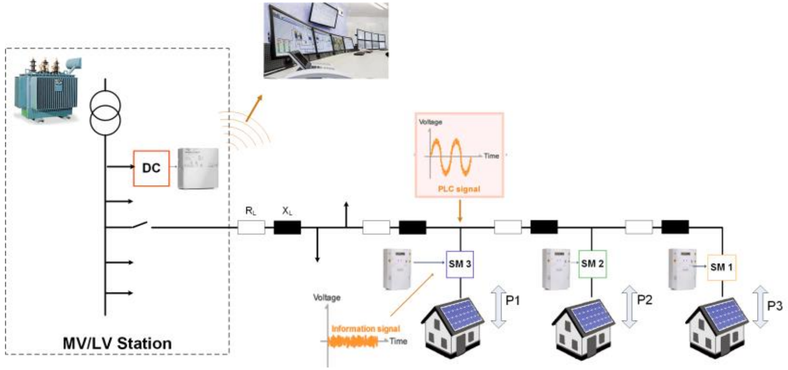
Project partners domains of expertise

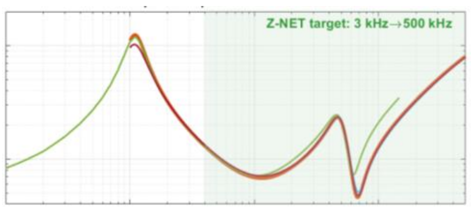


- Great complementarity of expertise to cover the PLC and Impedance topics

Main findings of the Z-NET project

- Better understanding and capability to model the impact of Frequency dependent and Time varying Line impedance on signal transmission for Power Line communications systems
- Static and programmable/time varying Line Impedance references developed and tested
- Intercomparison of several FTdGI analysers with the help of the Z-NET references
- Stronger technical expertise available for standardisation in EMC, Power Quality and/or electric energy distribution

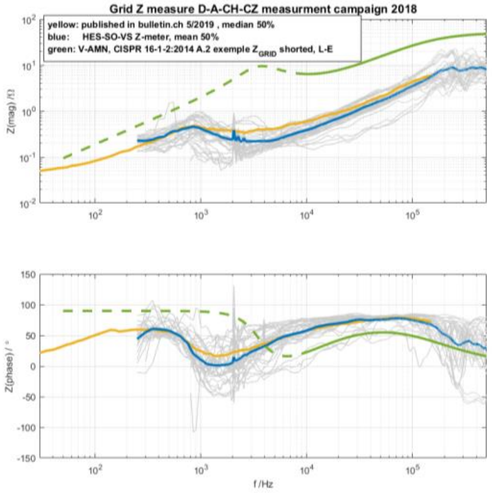


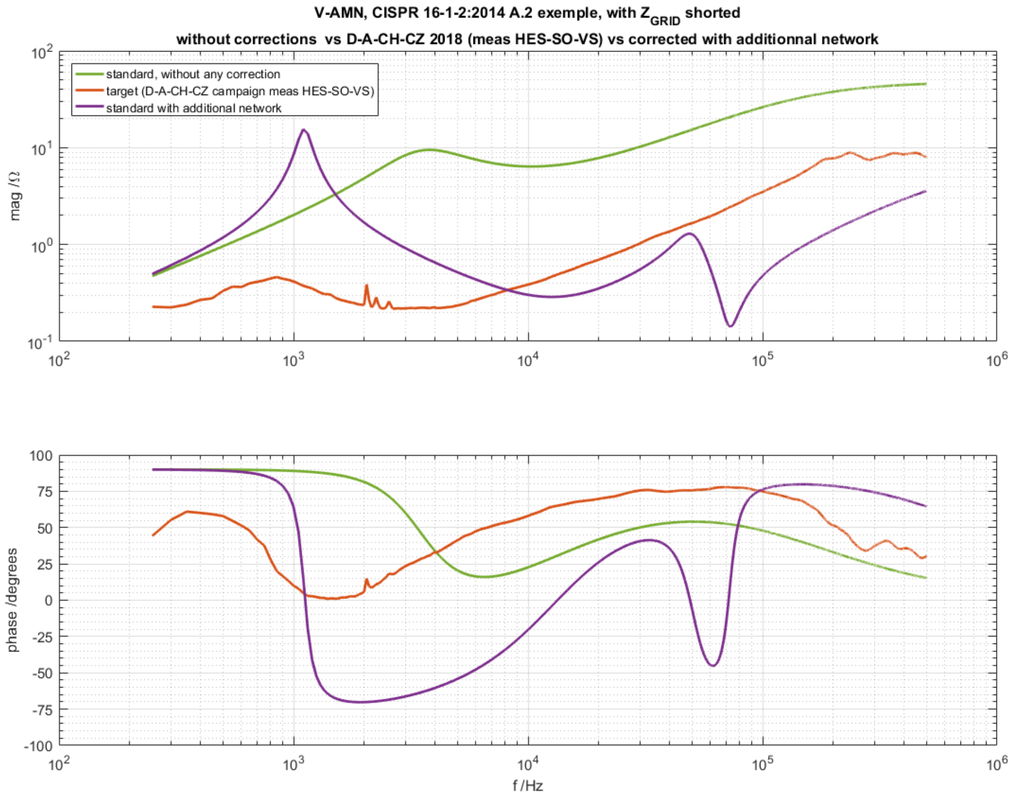


Design and tests of static Line Impedance reference

- Goal: Inter-comparison of spectral grid impedance meters
- Based on V-AMN (CISPR 16)
- Unique static impedance reference measured by 4 institutes and 1 engineering company
- Comparison
    - Measuring ranges
    - accuracy in amplitude and phase
    - Functionality
    - measurement duration

Static impedance reference – reference curve



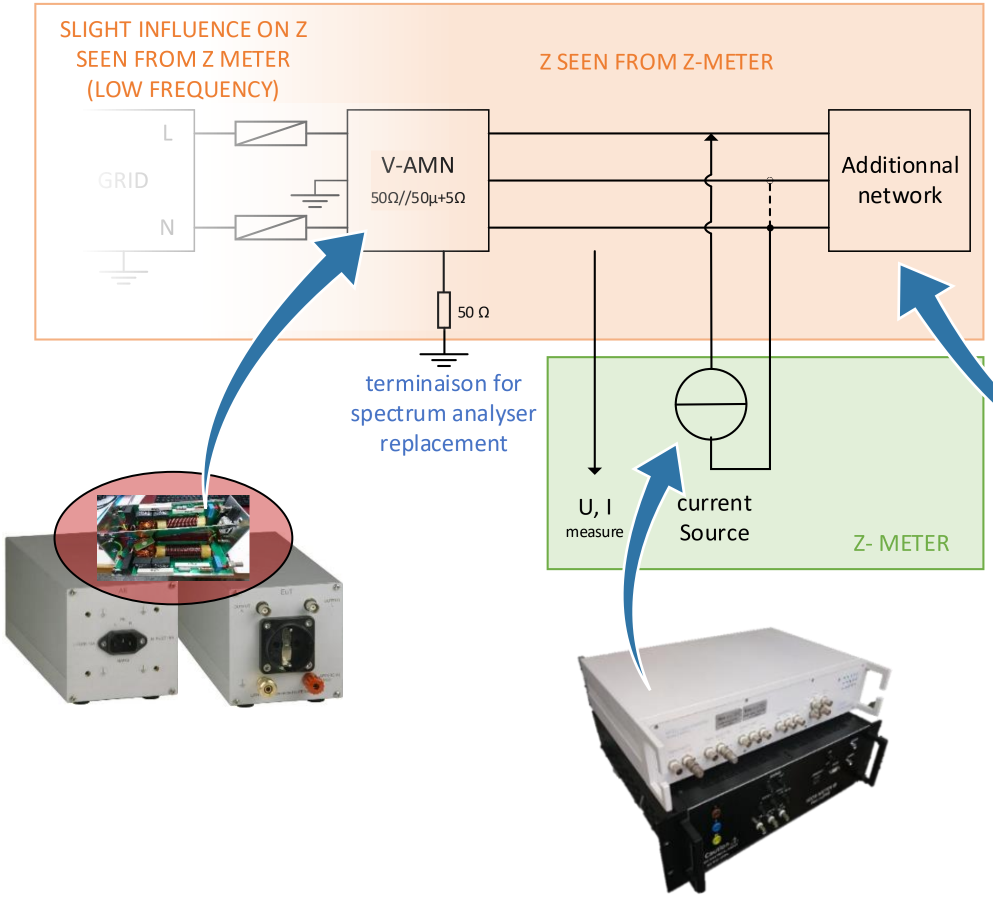


Target → blue (left) / red (right) (D-A-CH-CZ campaign 2018

Final static impedance reference curve, theorical → purple

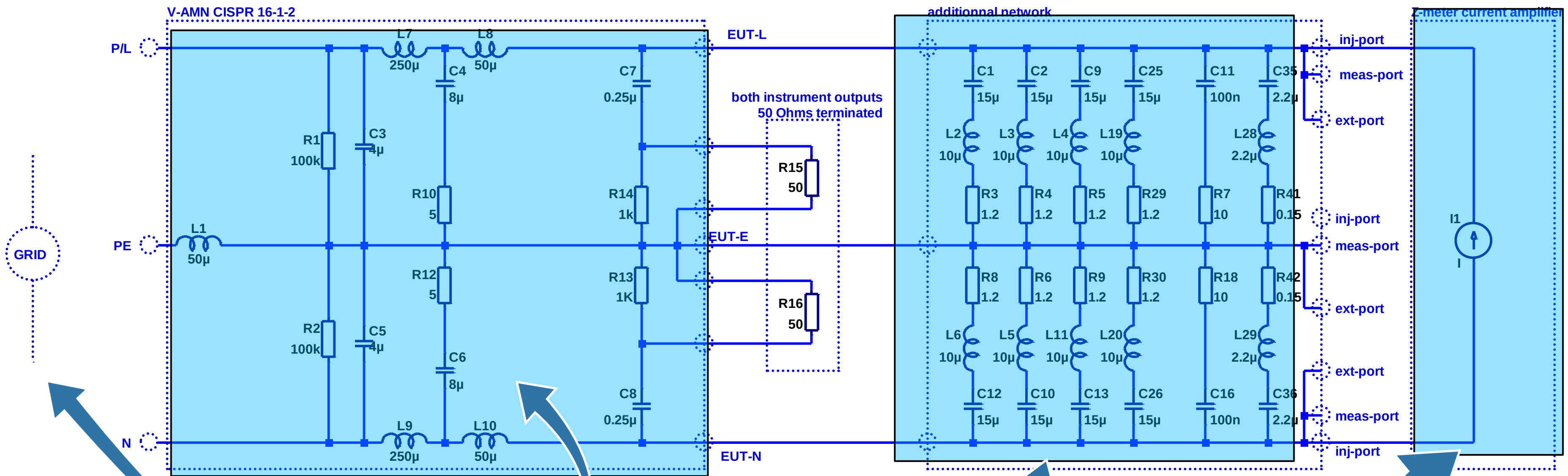
Graphic source: bulletin.ch 5/2019 (Höckel – Meyer)

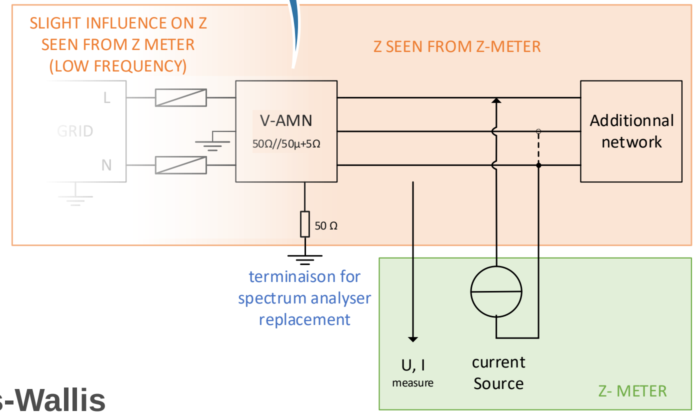
Static impedance reference – adaptation of V-AMN



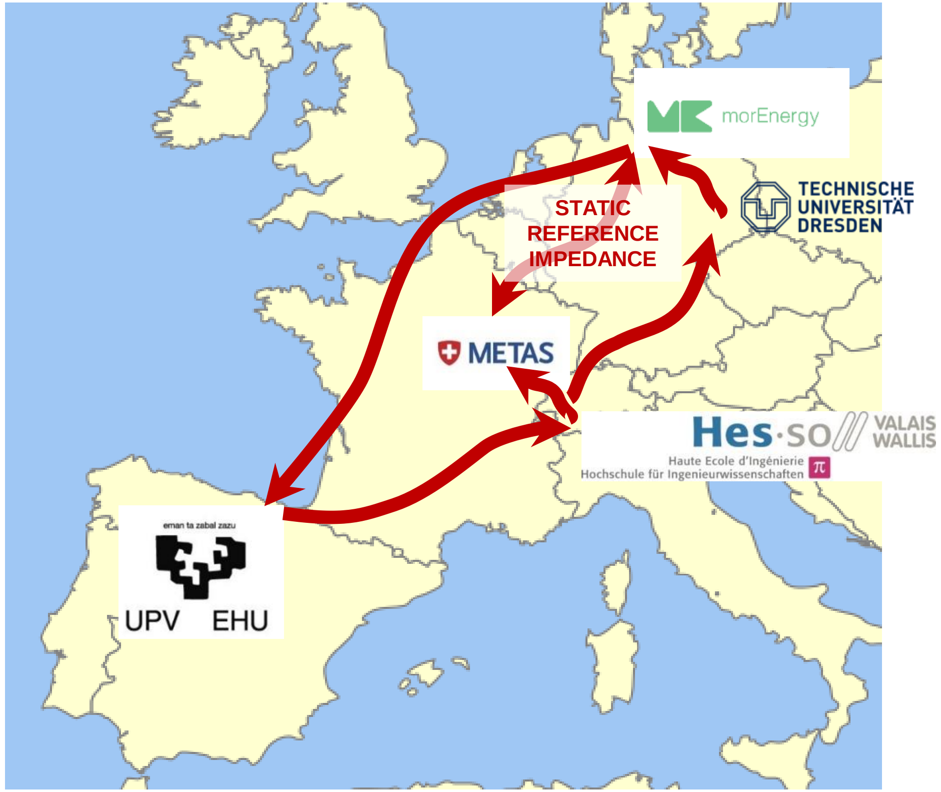
- ➢ Keep V-AMN unmodified
- ➢ Supplement additional network to reduce impedance seen (from Z-meter)
- ➢ Replace spectrum analyser by a 50 Ω termination

Static impedance reference - schematic





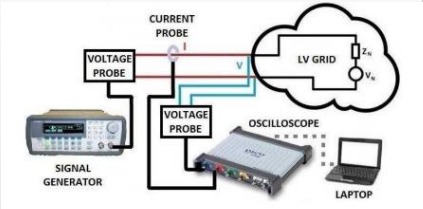
2. Sites of measure - Overview



Source wikipedia

1. METAS
   Federal Institute of Metrology
   CH - Bern
2. TUD
   Technische Universität Dresden
   D - Dresden
3. morEnergy
   D - Hamburg
4. UPV-EHU
   Universidad del Pais Vasco
   ES - Bilbao
5. HES-SO VS
   Haute Ecole Spécialisée de Suisse occidentale Valais//Wallis
   CH – Sion
6. METAS
   Federal Institute of Metrology
   CH – Bern
7. morEnergy
   D – Hamburg
8. METAS
   Federal Institute of Metrology
   CH – Bern

3. Impedance measuring equipment’s - Pictures

METAS (Keysight E4980AL)	TUD (Spitzenberger & Spies IMD300)	morEnergy ONIS-690V	UPV-EHU	HES-SO VS IGORMETER IV
				

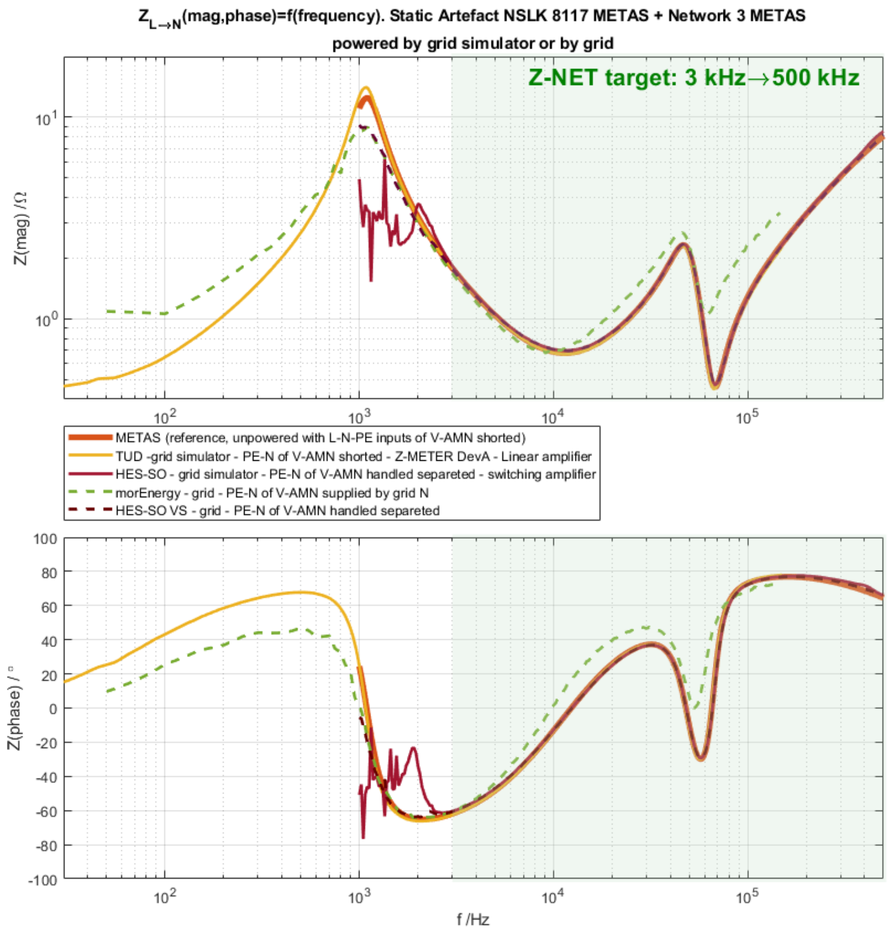
3. Impedance measuring equipment's – characteristics-1

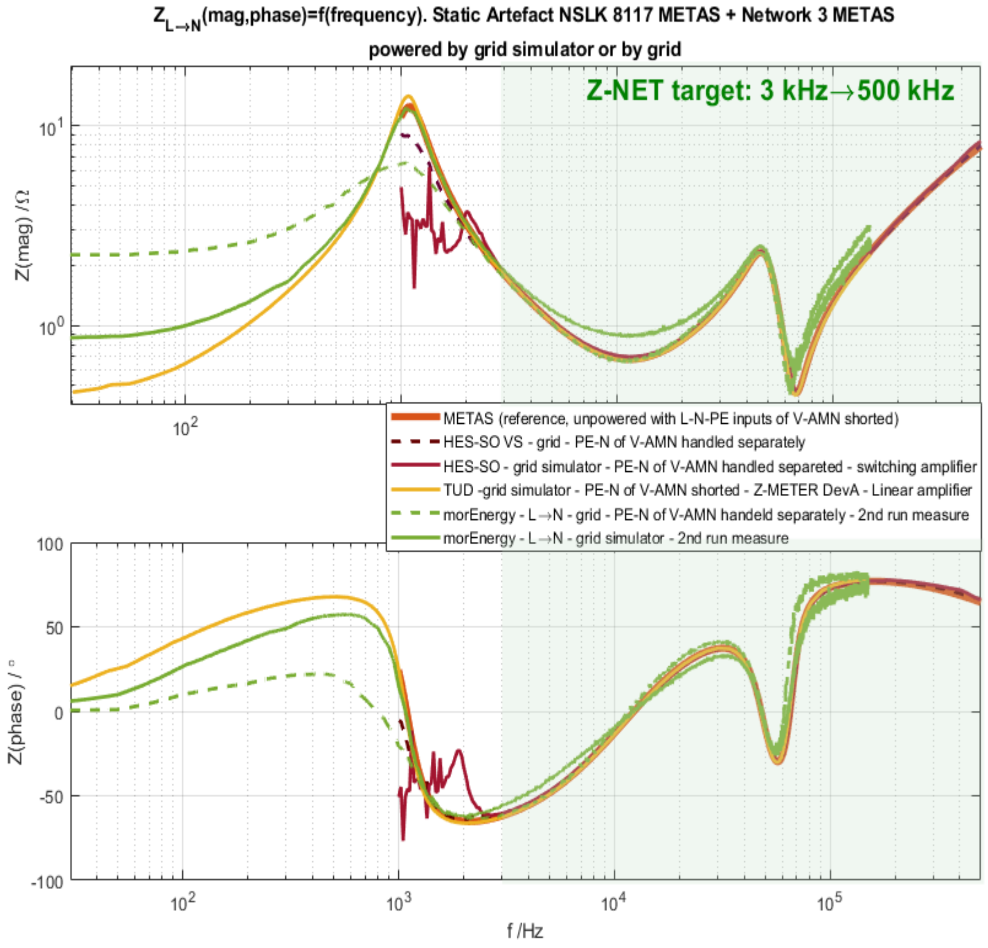
Characteristics	TUD (Spitzenberger & Spies IMD300)	morEnergy ONIS-690V	UPV/EHU	HES-SO VS IGORMETER
Coupling to grid	Direct connection	Direct connection	Via capacitive coupler	Direct connection
Connection for measurement	4-wire (current injection and voltage measurement separately)	2-wire (controllable load)	4-wire (current injection and voltage measurement separately)	4-wire (current injection and voltage measurement separately)
Excitation source Type and value	Current (3 A_{RMS})	Switched controllable load	Voltage (config. up to 3.5V_{RMS})	Current (90 mA_{RMS})
Frequency sweep	Single frequency steps	Randomly pulsed signals (broadbandexcitation)	Single frequency sweep	Single frequency steps (config.)
Suppression of fundamental	None	None	Filtering of 50/60 Hz and low order harmonics	None

3. Impedance measuring equipment’s – characteristics-2

Characteristics	TUD (Spitzenberger & Spies IMD300)	morEnergy ONIS-690V	UPV/EHU	HES-SO VS IGORMETER
Signal processing	Fourier analysis (DFT)	Fourier analysis (DFT)	Fourier analysis (FFT)	Dual-Phase Demodulation (Lock-In Amplifier Detection)
Time windowing	Rectang., 200 ms (10 fundamentalcycles length)		Rectang., Config. (Typ.: 20 ms window, 5 ms sliding window)	--
Bandwidth	0 kHz -200 kHz	0 kHz - 150 kHz	20 kHz - 500 kHz	1 kHz - 500 kHz (extendable 250 Hz - 2 MHz)
Frequency resolution	5 Hz	Configurable Best resolution: 5 Hz	Configurable. Typical: 50 Hz. Best resolution: 5 Hz	Configurable, (logarithmic orlinear stepping)
Measurement time	Several minutes		Configurable (related to sweep time). Typ.: 2 sec	From 1 to 10 min (related to resolution in freq.)

5. Results – 1st and 2nd rounds



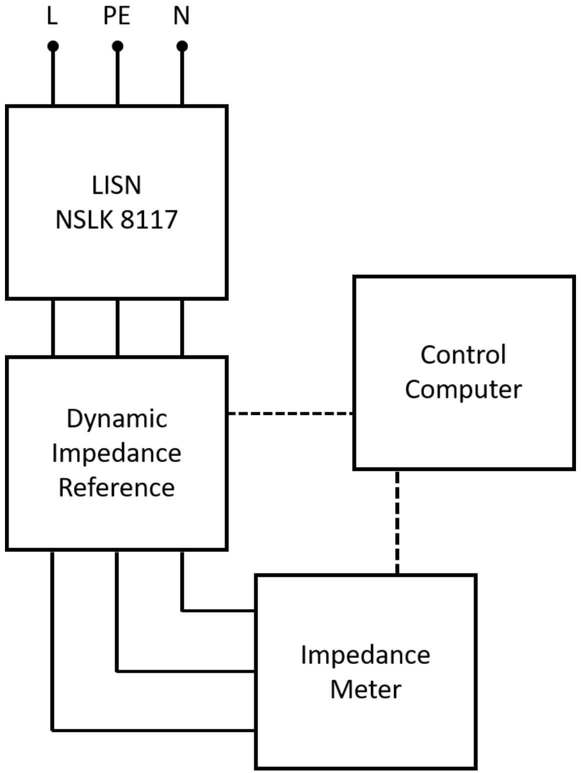


Design, realization and test of the programmable and time variant impedance (FTdGI)

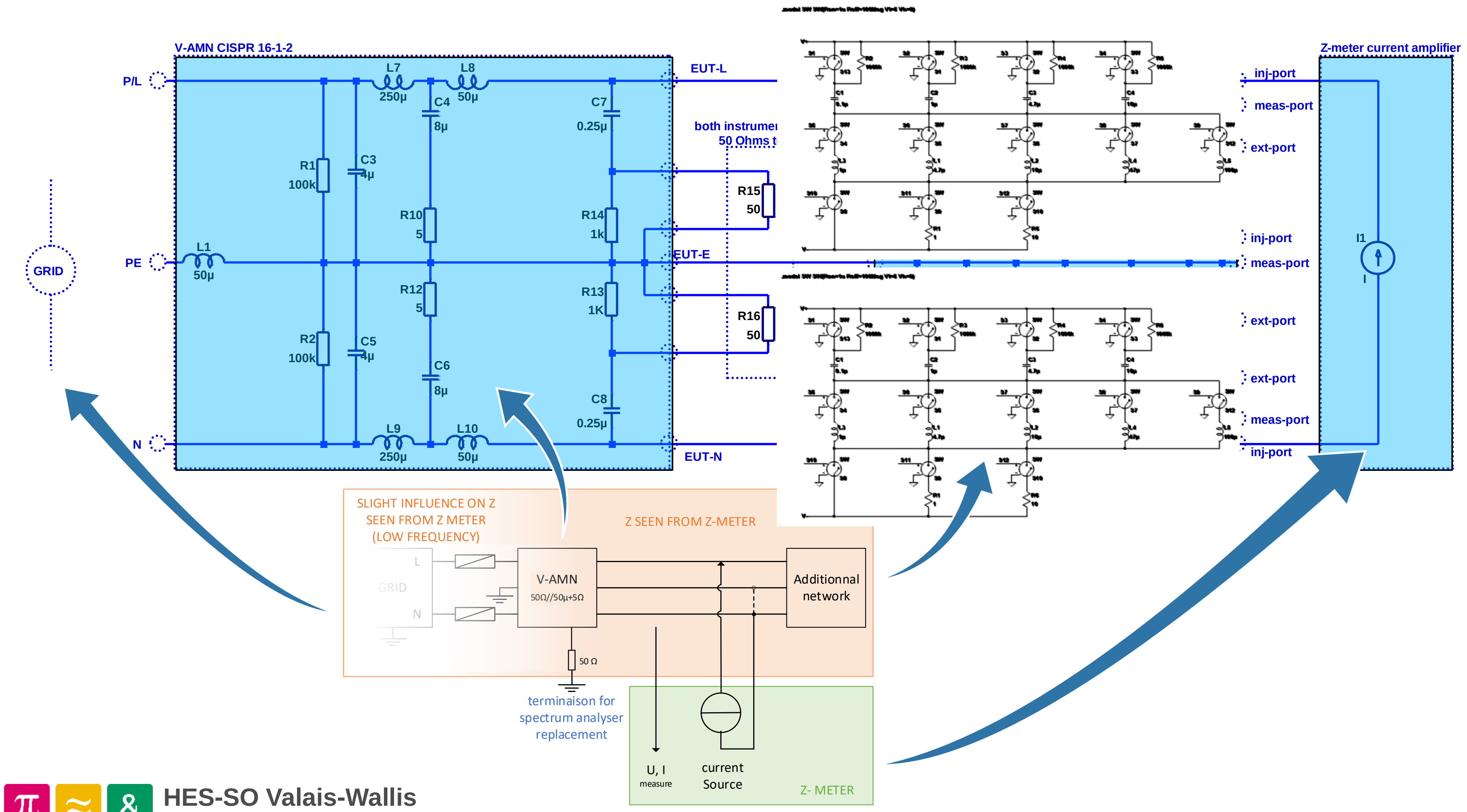
- Goal: Inter-comparison of spectral grid impedance meters for two mode of operations:
  - FdGI Frequency dependant (Programmed resonances / damping)
  - FTdGI Frequency and Time dependant (Programmed resonances / damping / switching time)
- Based on a selectable and programmable array of passive components
- Comparison
  - measuring ranges
  - accuracy in amplitude and phase
  - Functionality
  - measurement duration

Programmable spectral impedance – working principle

- The LISN normalizes the input impedance;
- The programmable impedance is controlled by a web-interface on any network capable computer;
- Components are manually selected form a list;

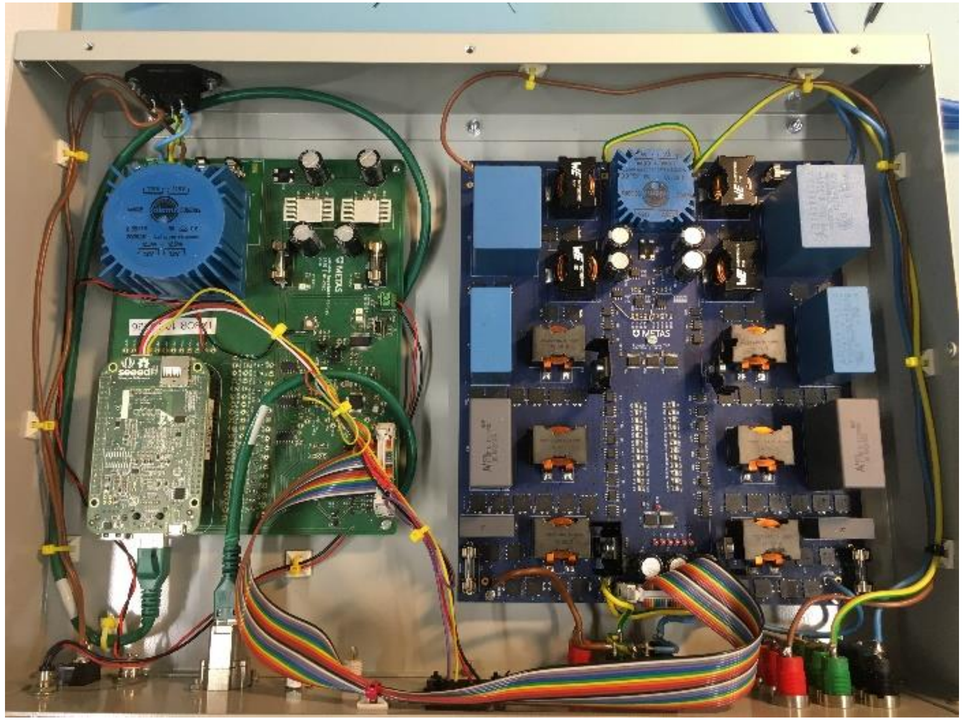


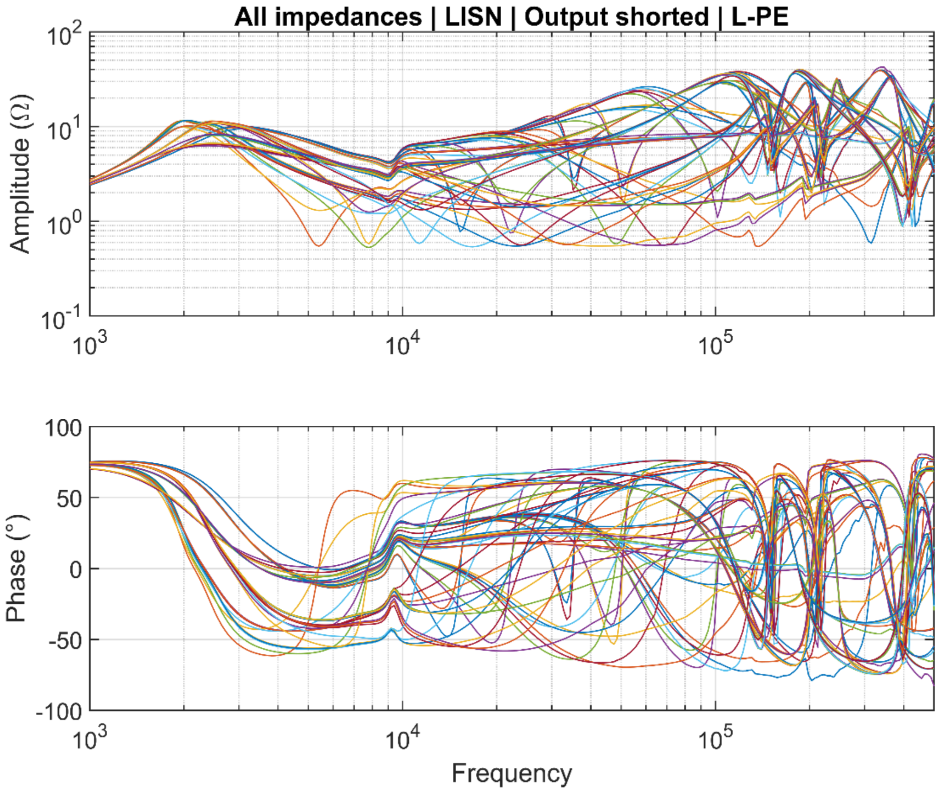
4. FTdGI reference – schematic



Programmable spectral impedance – Realisation

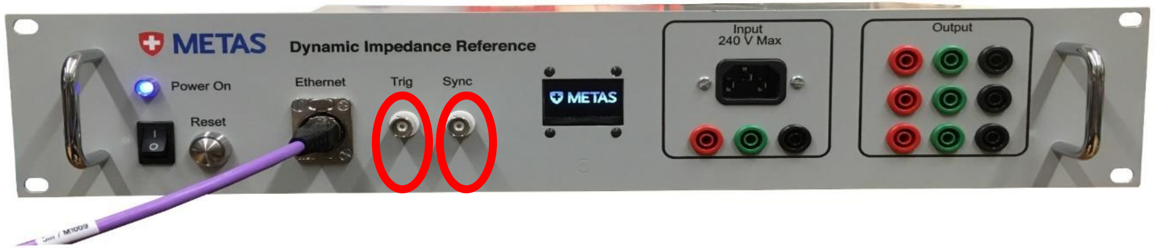
- Power board: holds the discrete components, the switches and handles mains voltages
- Control board: handles the switching, the user interface, the low voltage supply
- 366 different calibrated FdGI curves available

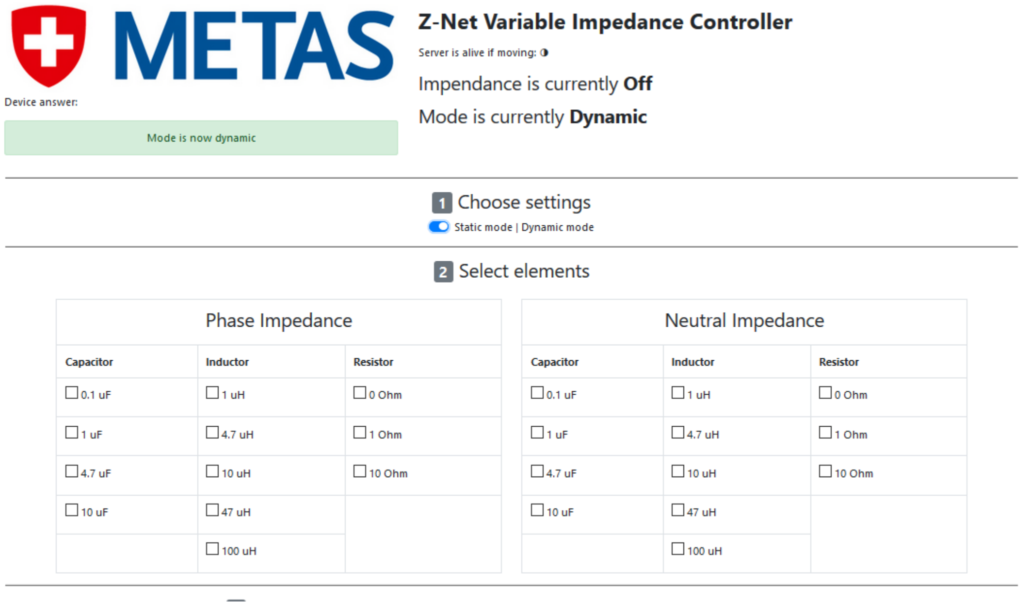


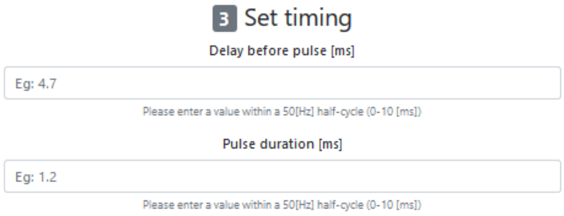


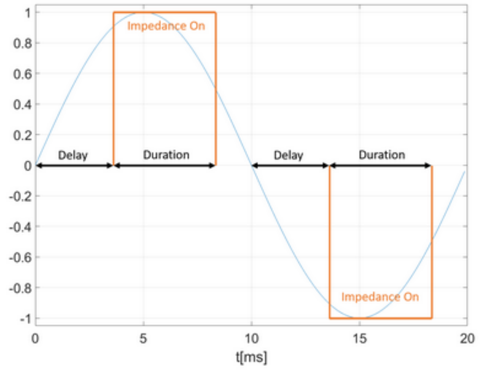
Time variant spectral impedance – Realisation

The time variant impedance is an option of the programmable impedance device;
Same components values, switched on or off within a mains cycle;
The **timing is controlled with a zero crossing detector** and a real-time microcontroller;
An external control is also available.









2. Sites of measure - Reminder

Source wikipedia

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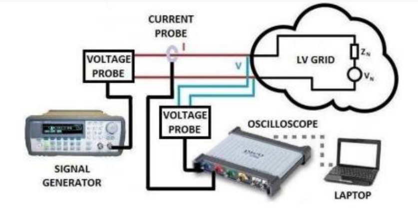
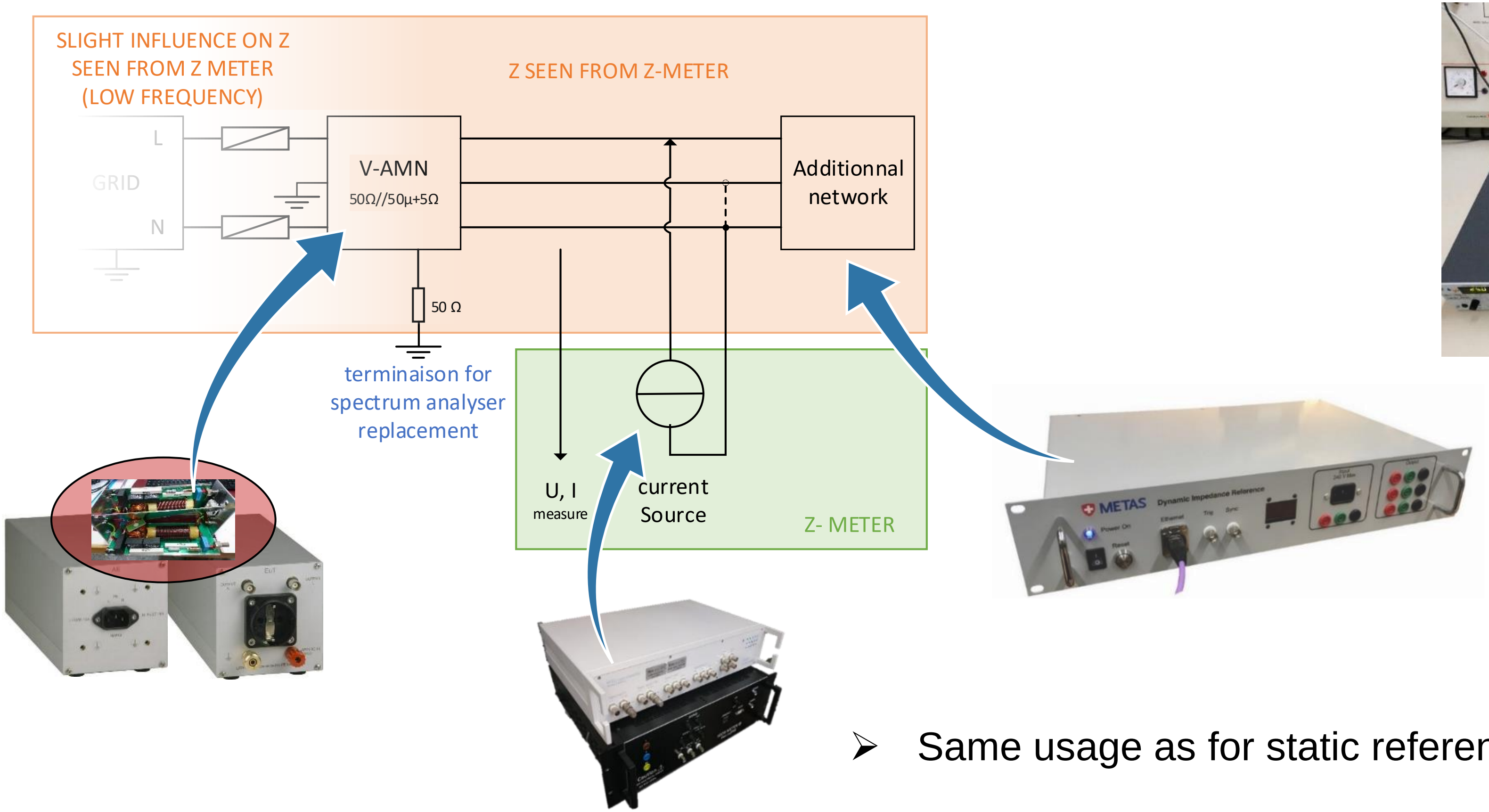
3. TUD (Technische Universität Dresden) / D - Dresden
4. morEnergy / D - Hamburg
5. UPV-EHU (Universidad del Pais Vasco) / ES – Bilbao
6. METAS

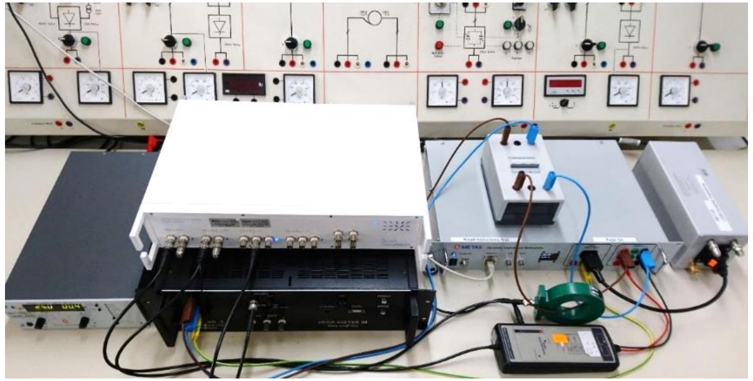
3. Impedance measuring equipment's - Reminder

METAS (Keysight E4980AL)	TUD (Spitzenberger & Spies IMD300)	morEnergy ONIS-690V	UPV-EHU	HES-SO VS IGORMETER IV
				

Characteristics	TUD (Spitzenberger & Spies IMD300)	morEnergy ONIS-690V	UPV/EHU	HES-SO VS IGORMETER
Subcycle analysis capability?	Yes	Yes	Yes	No (although (hardware ready)

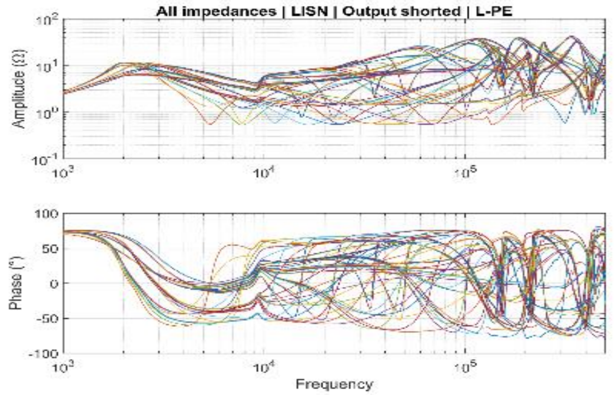
FTdGI reference – Test setup

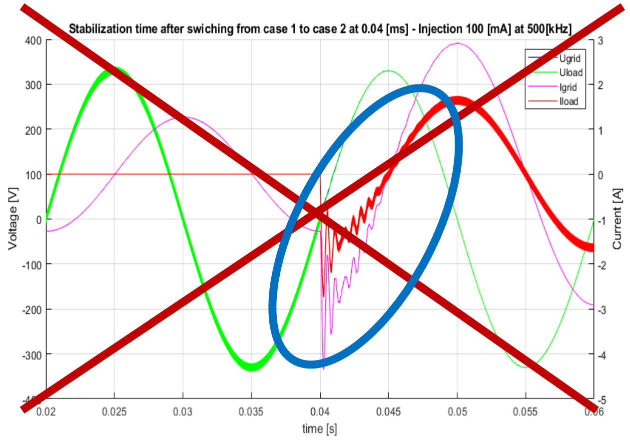




- Same usage as for static reference impedance
- Additional network will be replaced by FTdGI
- Devices supplied by an independent grid

4. FTdGI reference – Dynamic scenarios selection

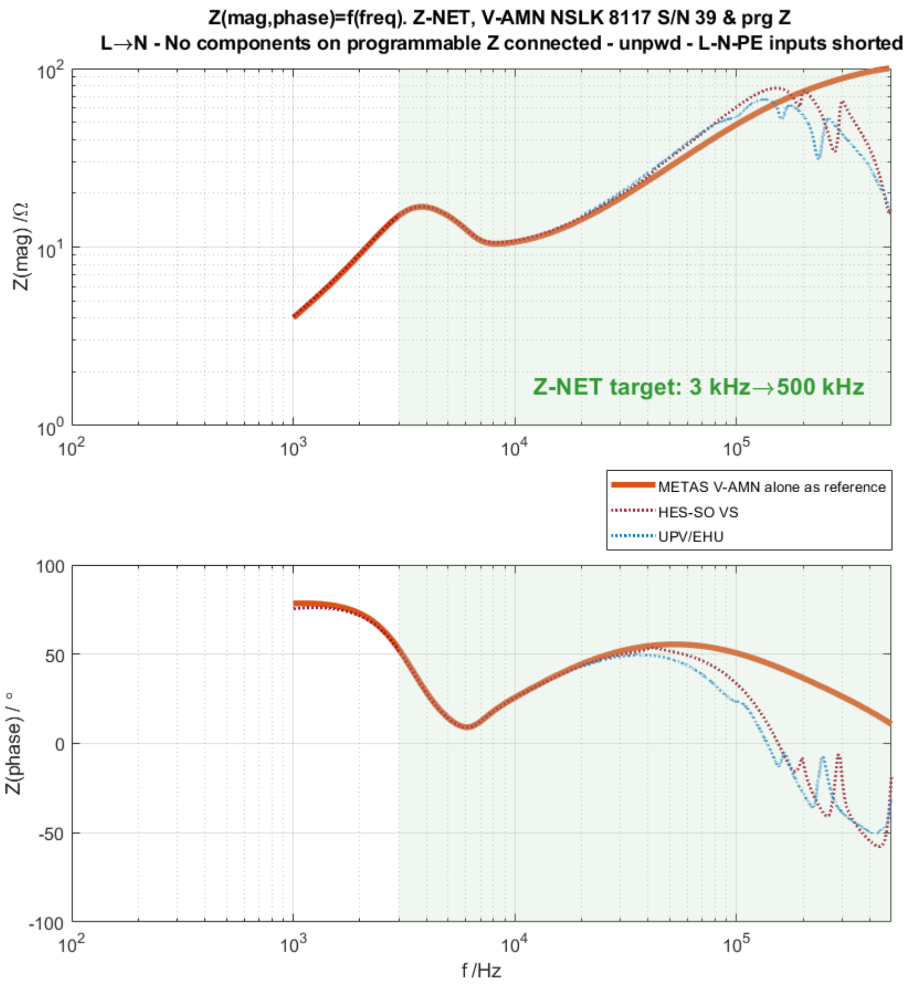




- 366 calibration curves made available by METAS!
  - Keep curves between phase and neutral → 61 curves
    - Selection of interesting resonance frequencies → 9 tests
      - **Rejection of cases without damping (R = 0 Ω) → 5 tests**
        - Initial situation S1 + 4 curves (S3/S4/S7/S8) available!
          - Keep tests that do not present important oscillation at switching time
            - **Finally → 3 comparative tests executed**

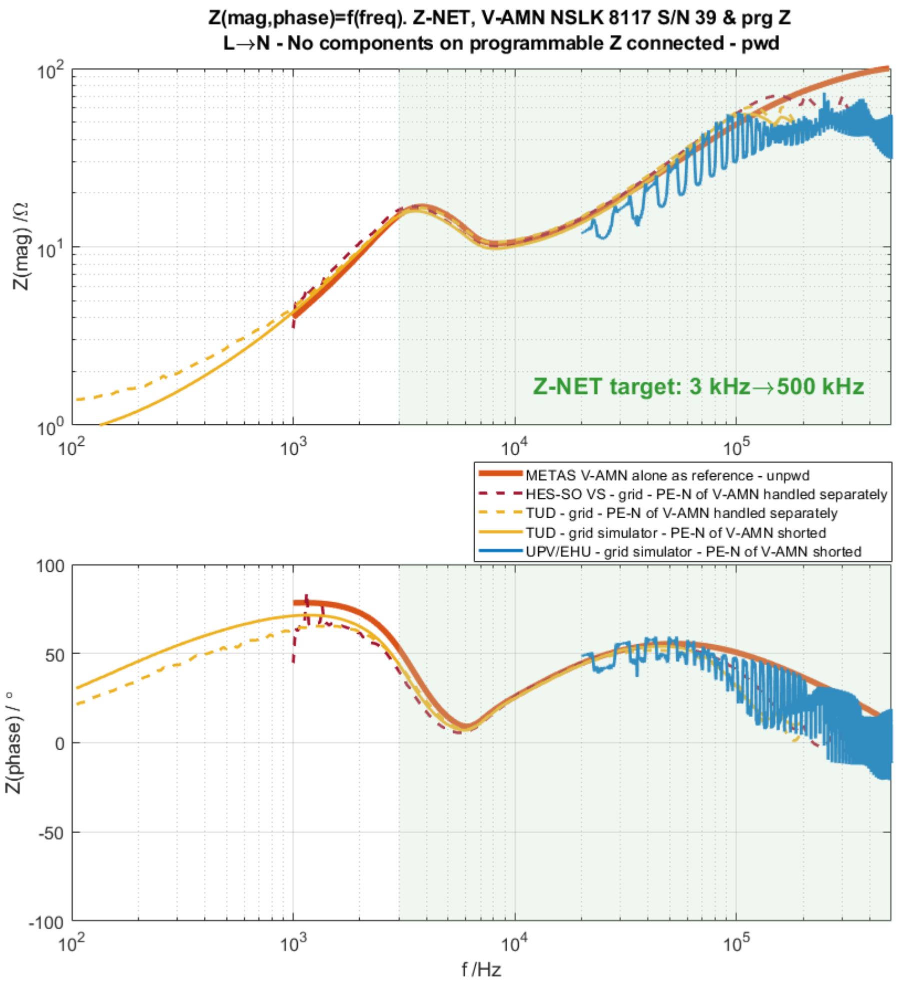
Dynamic test	C /F	L /H	R /Ω	Delay sw on /ms	Length sw on /ms
S1	**no value settled**	**no value settled**	**no value settled**	**n/a**	**n/a**
D2	0.1e-6	1e-6	0	n/a	n/a
D3	**0.1e-6**	**1e-6**	**1**	**2.5**	**3.39**
D4	**1e-6**	**47e-6**	**1**	**2.5**	**3.39**
D5	4.7e-6	4.7e-6	0	n/a	n/a
D6	10e-6	10e-6	0	n/a	n/a
D7	**10e-6**	**10e-6**	**10**	**2.5**	**3.39**
D8	10e-6	100e-6	10	n/a	n/a
D9	All C settled	All L settled	0	n/a	n/a

Results – static scenarios – unenergized (1)



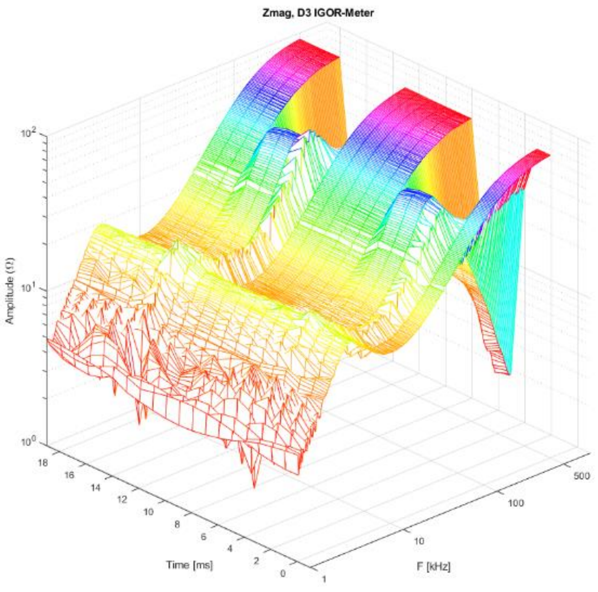
- Exemple test S1: no components of programmable impedance selected
- Reference: METAS measure for V-AMN alone
- 2 institutes could achieve the tests
  - HES-SO VS
  - UPV / EHU
- Measurements match from 1 kHz → 30 kHz
- Unexpected behaviour above 100 kHz
  - impedance goes capacitive
  - several serial and parallel resonances
  - parasitic elements?
  - Parasitic resonances do not match between both Z-meters, but correct trend

Results – static scenarios – energized



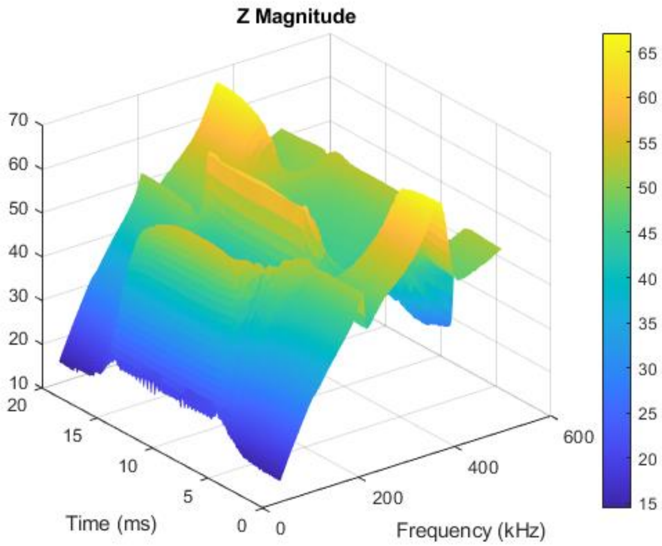
- Exemple test S1: no components of programmable impedance selected
- Reference: METAS measure for V-AMN alone
- 3 institutes could achieve the tests
- One equipment could not perform the test (permanent error)
- Behaviour as expected for HES-SO VS and TUD
- Surprising behaviour of meter from UPV/EHU!

Results – dynamic scenarios – energized (1)



Simulation (HES-SO VS)

Measure (UPV/EHU)



- Exemple test D3, results issued as 3D graphics
- Reference: Simulation issued by HES-SO VS (LTspice®)
- Expected serial resonance → 503 kHz
- 2 institutes could realise the tests
- Simulation does not take into account the defaults of the programmable impedance → strict comparison difficult
- 3D graphics are difficult to read

6. Conclusion and discussion

SO FAR:

- The demonstration of the utility of a traceable impedance reference to improve comparison of equipment’s is achieved.
- One equipment could be improved between 2 tests rounds
- A redefinition of the minimum frequency of use at 9 kHz would even allow an alignment with the CISPR 16-1-2 standard
- Programmable FdGI to test static scenarios is a good tool but it does not withstand all architecture of impedance meters.
- Stability at switching times must be carefully studied to allow a meaningful comparison
- Testing conditions and results presentations need to be better coordinated!

NEXT:

- Uncertainty of static impedance will be evaluated in the frame of EMPIR Grid EMI project
- Further comparative measurements of impedance analyser should be realised with selected Power Electronics Equipment
- Report to standardisation committee
- Investigations with HIL simulation tools

Standardisation activities and collaboration

CENELEC TC 219 – Mains Communication Systems (Ex SC205) WG 11 Immunity

EN 50 065-2-3, Ed. 2

Signalling on low-voltage electrical installations in the frequency range 3 kHz to 148,5 kHz - Part 2-3: Immunity requirements for mains communicating equipment operating in the range of frequencies 3 kHz to 95 kHz and intended **for use by electricity suppliers and distributors**

- defines limits and test methods for the immunity of MCE
- **provides guidelines for the assessment of the performance of the communication function of an MCE**

→ Smart Metering!

EMI Report IV
First draft

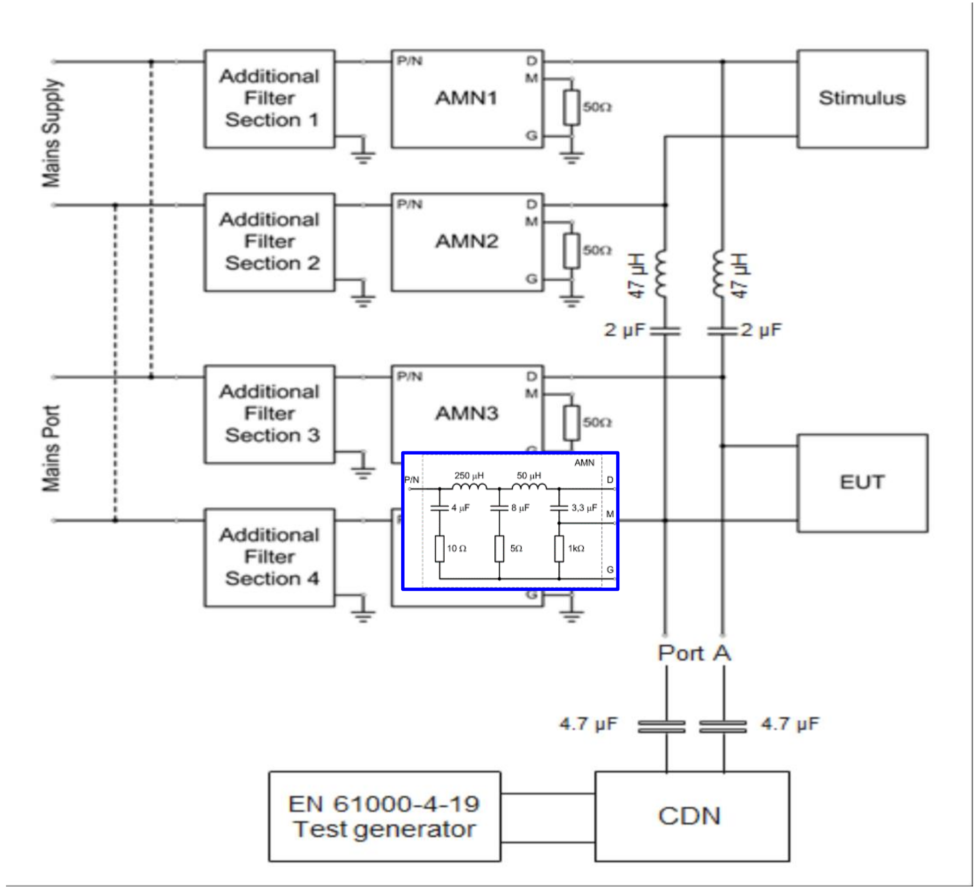
Electromagnetic Interference in the Frequency Range below 500 kHz

- Current state of EMI to electrical equipment and systems up to 500 kHz
- Characterisation of EMI related phenomena
- **Measurement issues**
- Known EMI cases: sources and victims
- Legislation, regulation and standardization
- Recommendations

- **→ Supraharmonics vs PLC for Smart Meter!**

EN 50065-2-3 – Immunity of MCE in CENELEC A-Band –

Proposed test circuit for differential mode conducted disturbances and signals immunity test (Annex A)



…. Test circuit for differential mode conducted disturbances and signals immunity test, AC input and AC output power ports. "This Annex B provides additional guidelines for an **optional assessment of the MCE communication performance**, which may be measured during the EMC tests and documented in the test report"

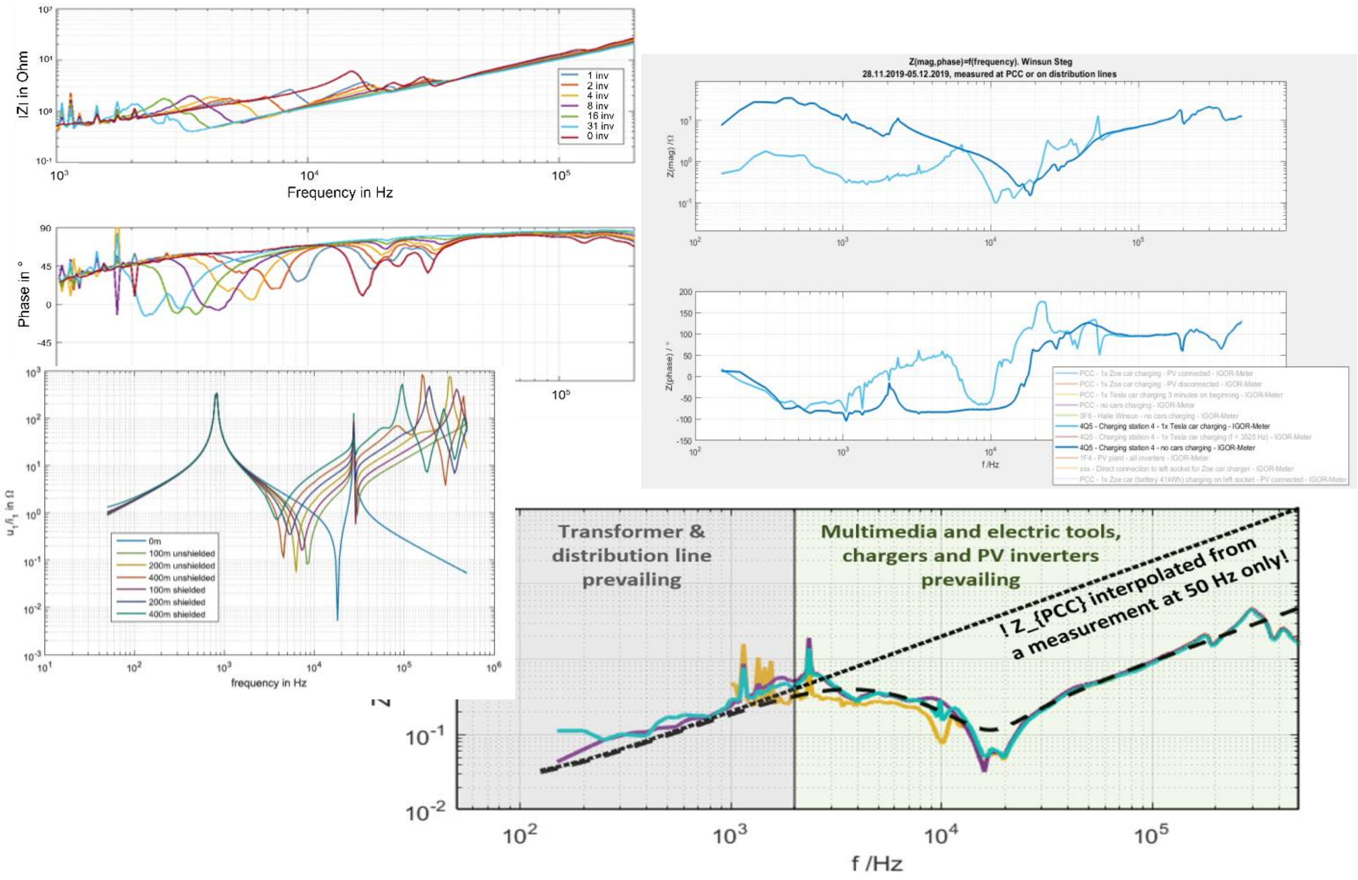
→ Not only the transmission channel is considered

IEC 77A EMC Low Frequency Phenomena

WG8 : EM environment associated with disturbances on electricity supply networks

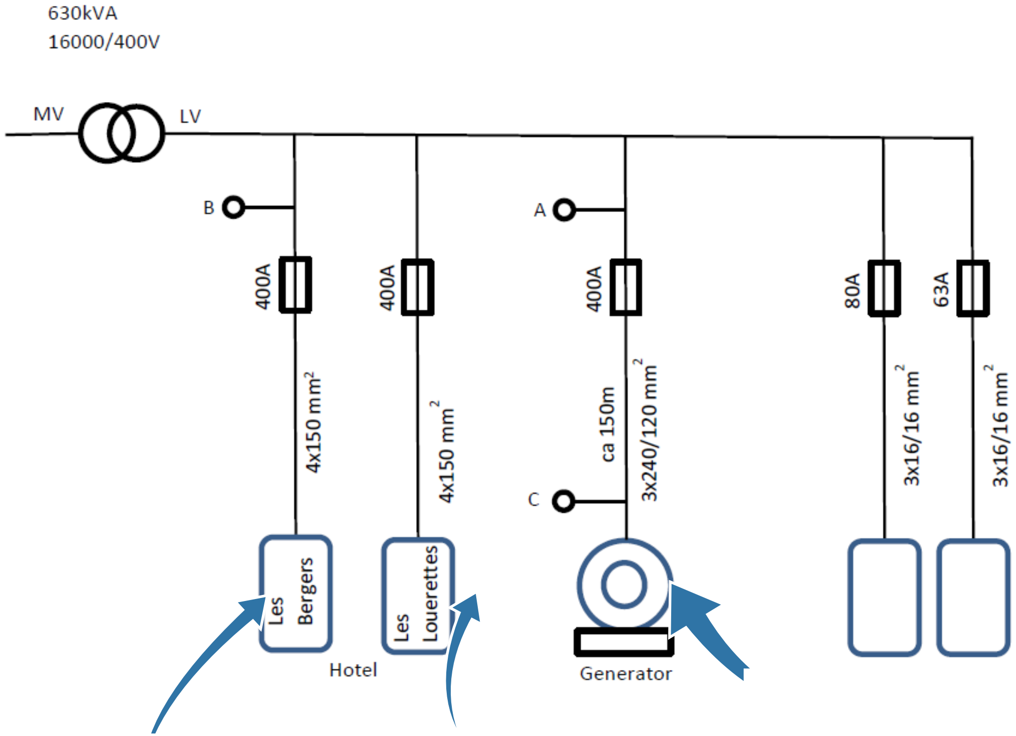
TR 61000-2-5
First draft

- **Resonance phenomena with network and power electronics equipment based on actual cases**
- Impact of modern power electronics on propagation and amplification of voltage distortion
- Cases of a large amount of converters
- **Impact of grid conditions on the operation of converters**



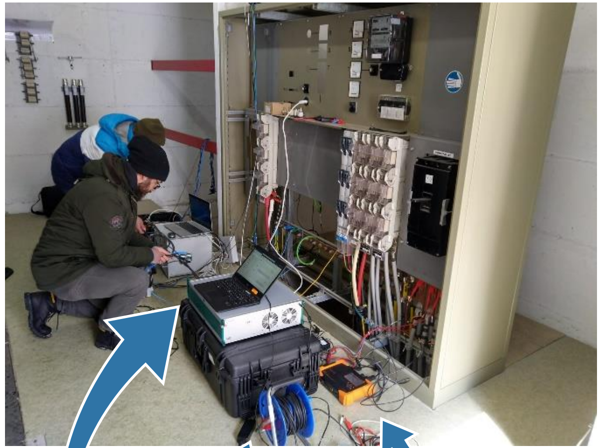
On-site measurements with CBM team : Siviez (VS)

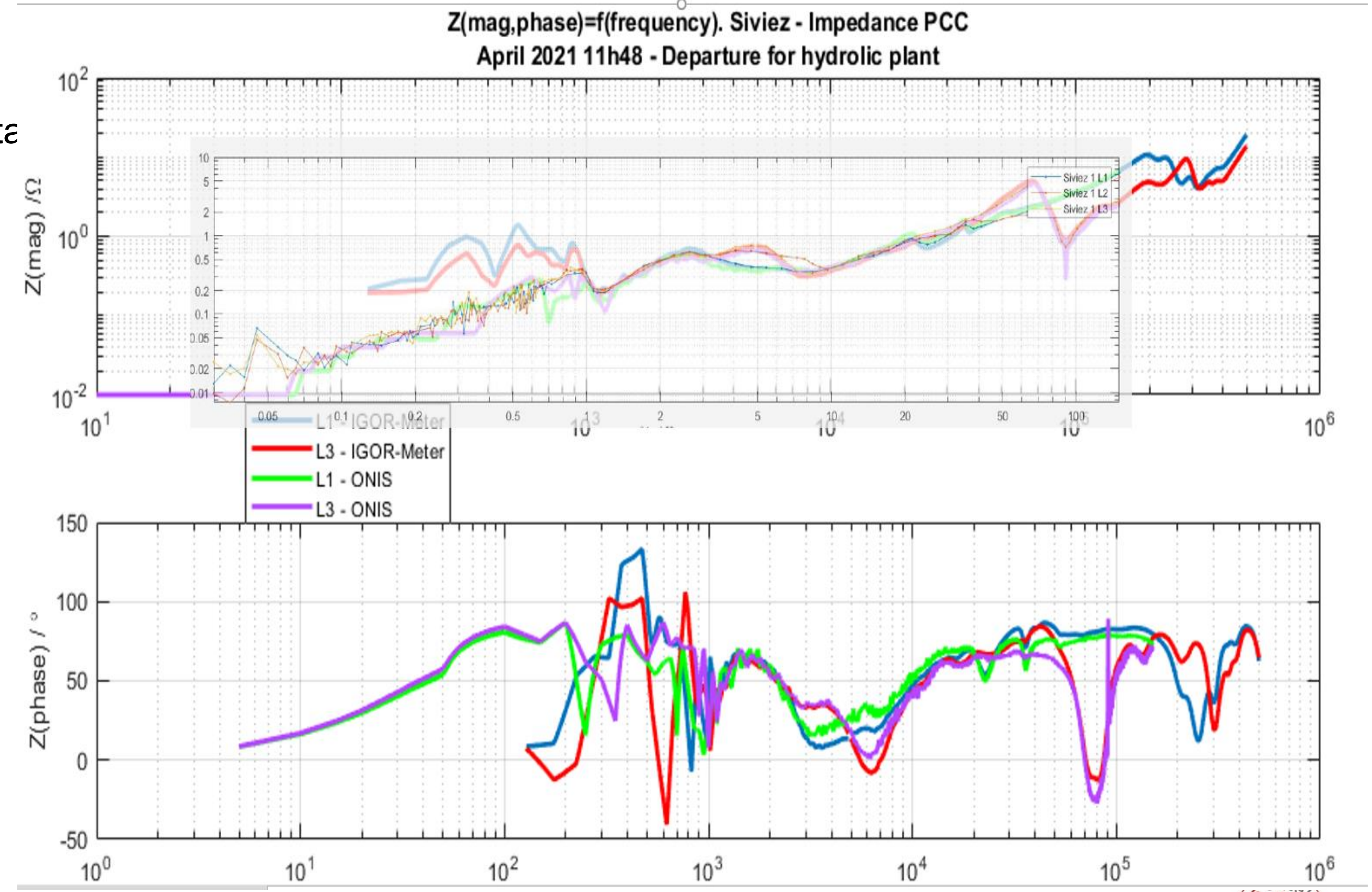
- Traditional' MV/LV transformer station
- Small Renewable energy production plant (IM)
- Looking for a resonance and 7th to 11th harmonics



First comparative HF Impedance measurement with 3 Z-Meters on Alps site

➢ Traditional' MV/LV transformer sta





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Hes·so // VALAIS WALLIS

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