Konference
Energetické Rušení 2024

ERU

Grid Impedance Analyzer up to 150 kHz

Bernhard Grasel, NEO Messtechnik GmbH

NEO MESSTECHNIK

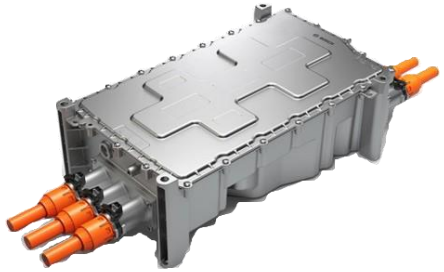
NEO Messtechnik

MOBILE POWER QUALITY & GRID IMPEDANCE

PHOTOVOLTAIC TEST SYSTEMS

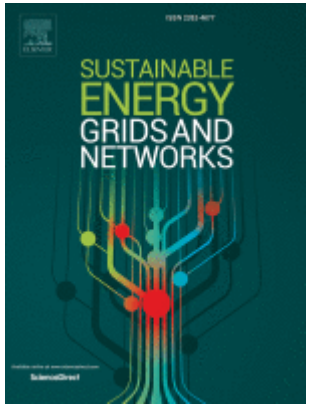
POWER QUALITY MONITORING & POWER PLANT MONITORING

ELECTRIC VEHICLE INVERTER



Bernhard Grasel

CEO	**NEO Messtechnik**
Senior Lecturer	**University of Applied Sciences Technikum Vienna Renewable Energy Systems**
Standardization	**Member of IEC - TC 77/SC 77A/WG 9**
Publication	**>10 publications about Supraharmonics and Higher Frequency Grid Impedance**



Latest Publication Elsevier SEGAN:

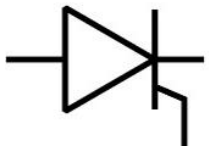
The impact of V2G charging stations (active power electronics) to the higher frequency grid impedance

https://www.sciencedirect.com/science/article/pii/S2352467724000353?via%3Dihub

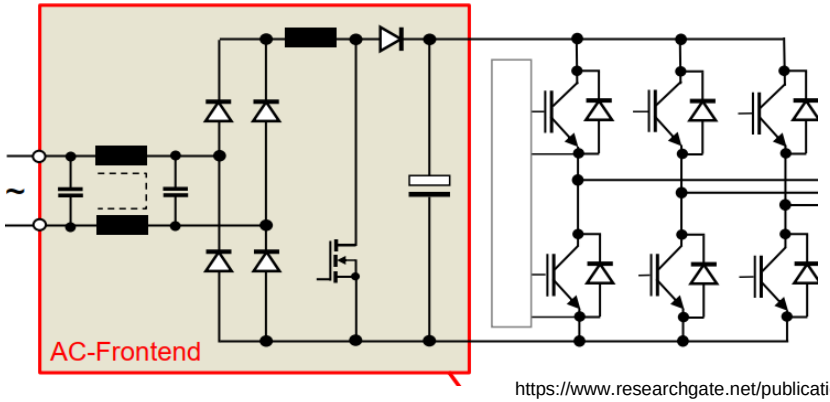
DOI: https://doi.org/10.1016/j.segan.2024.101306

AC/DC conversion

Passiv Power Electronics

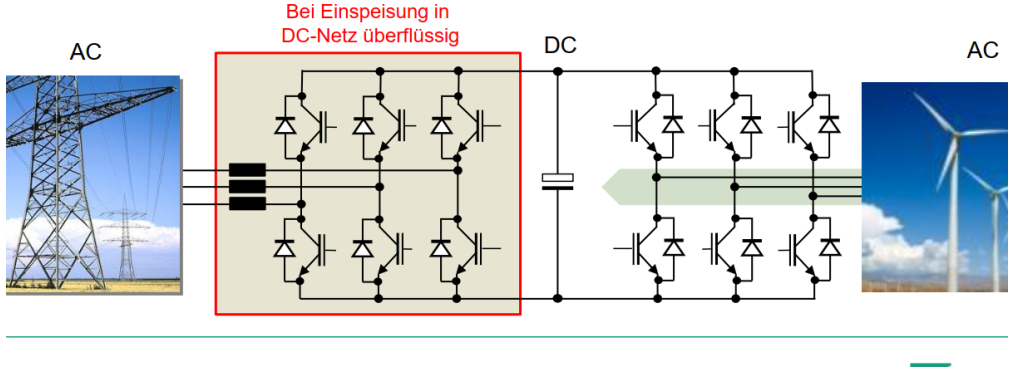


Low Efficiency
20 – 50 %



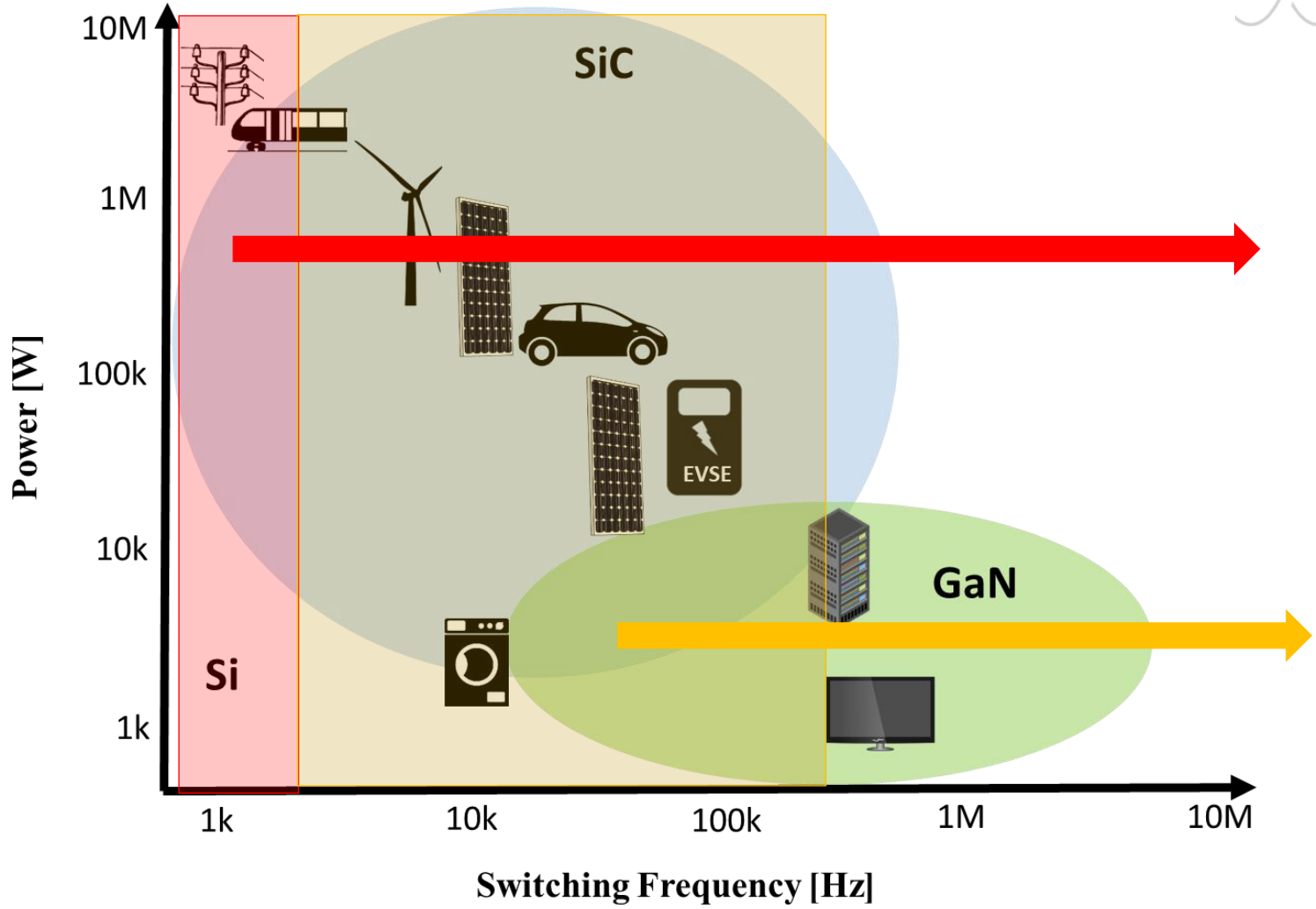
Active Power Electronics

High Efficiency
90 – 98 %



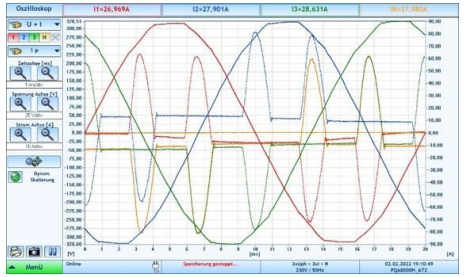
https://www.researchgate.net/publication/291697917_Niederspannungs-Gleichstromnetze_-_eine_thematische_Einfuhrung?enrichId=rgreq-824a866e4342cf079c701e50a0d7fc1d-XXX&enrichSource=Y292ZXJQYWdlOzI5MTY5NzkxNztBUzozMjE1MTI0NzU2OTMwNTdAMTQ1MzY2NTk1NTg3OQ==&el=1_x_2&_esc=publicationCoverPdf

Supraharmonics



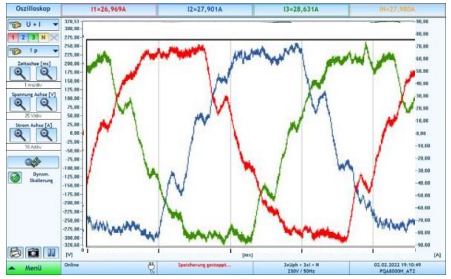
HARMONICS

→ **Passiv Power Electronics**



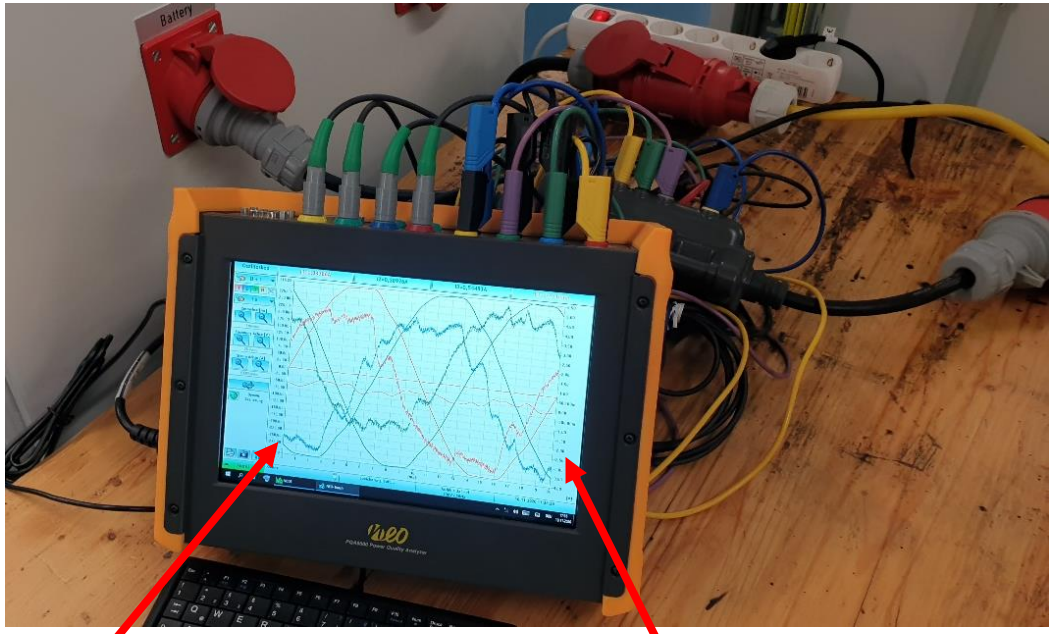
SUPRAHARMONICS

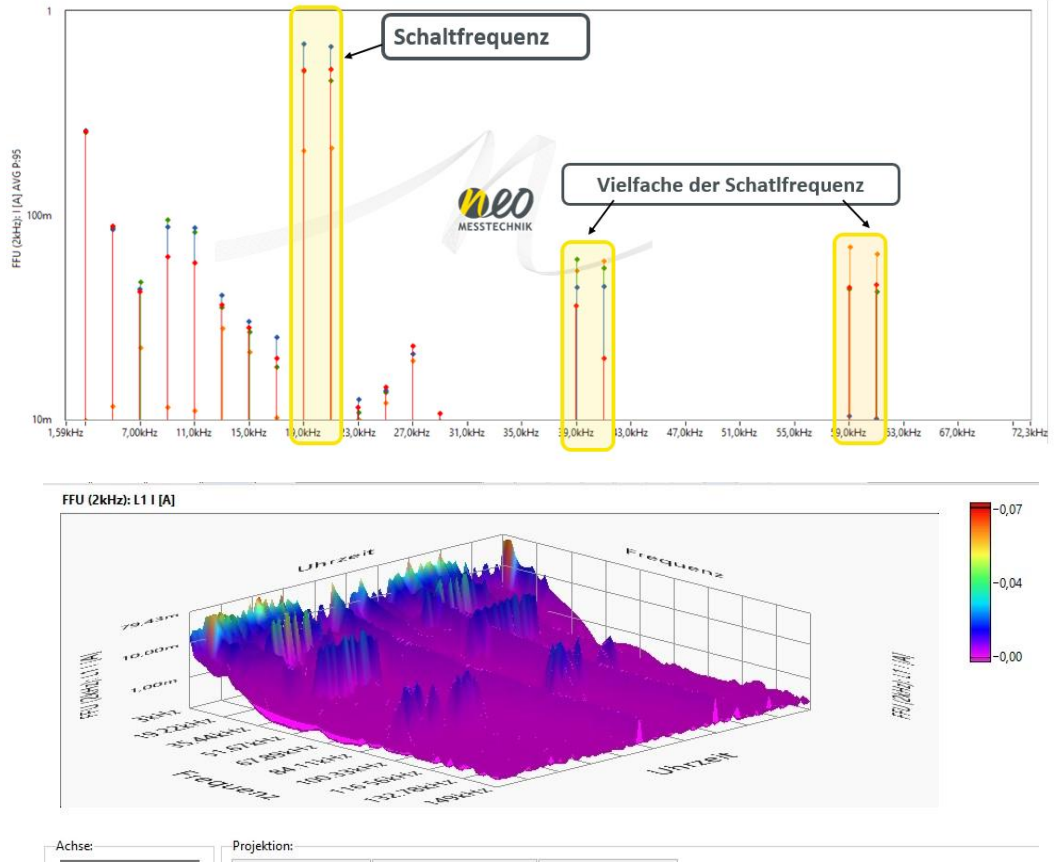
→ **Active Power Electronics**



Supraharmonics

ENA8000H / PQA8000H



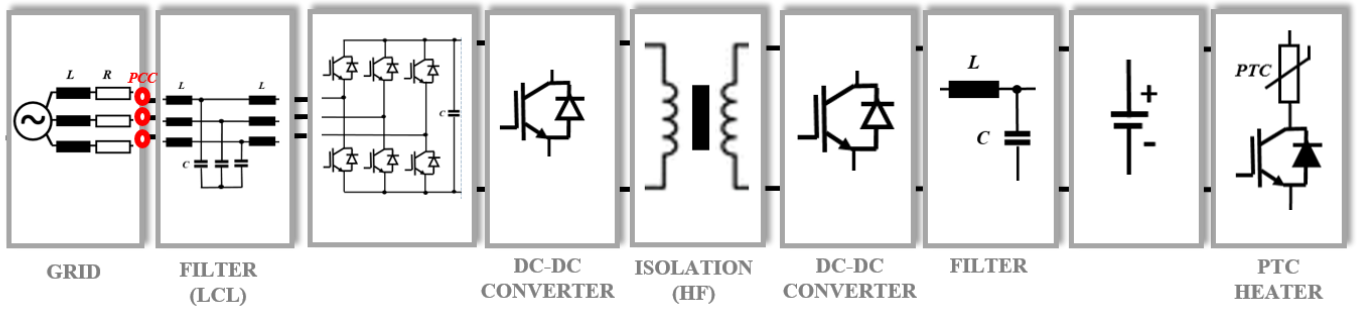


HARMONICS + SUPRAHARMONICS

Active Power Electronics

Additional capacitances and inductances are introduced to the electrical grid by

- LCL Filter
- DC Link
- DC / DC conversion

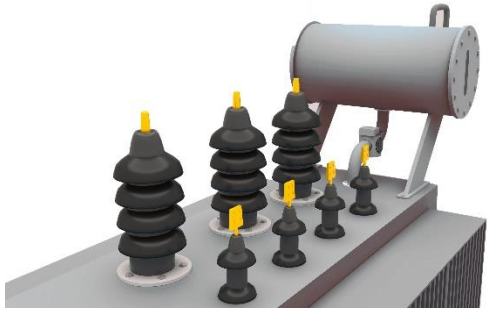


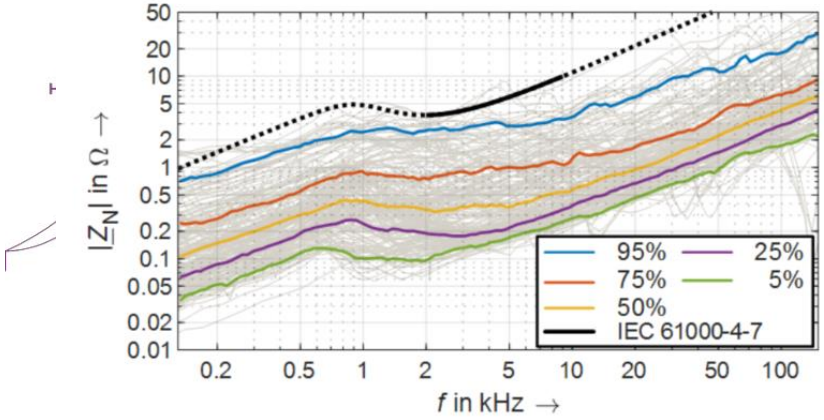
High Switching Frequency
Capacitances: Input Filter, DC capacitance

Example: Topolgy for HF-transformer isolation

Distribution Grid & Active Power Electronics

Distribution Grid

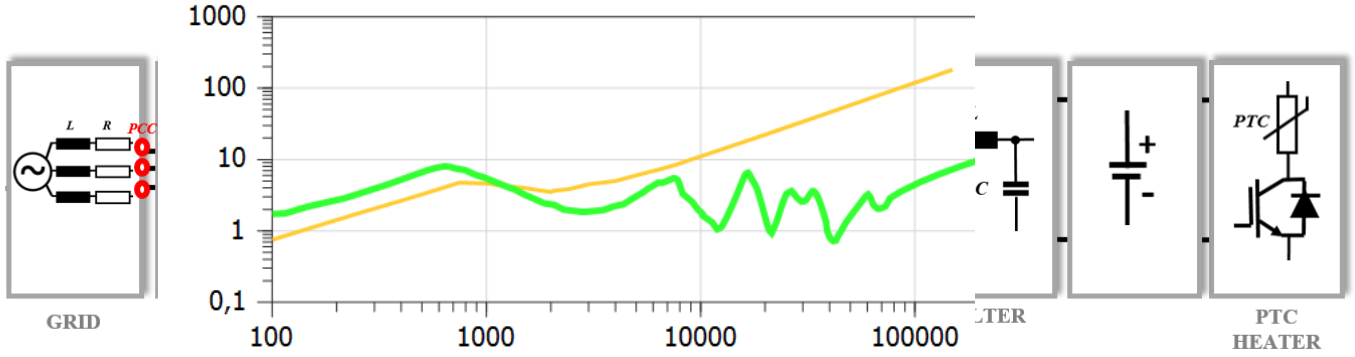




Grid: ohmic-inductive
Capacitances: Cable, Filter, Transformer

V2G Charger

Example: Topolgy for HF-transformer isolation

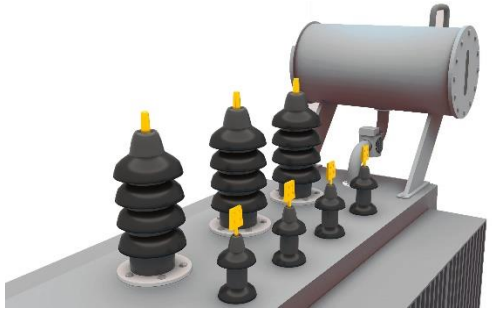


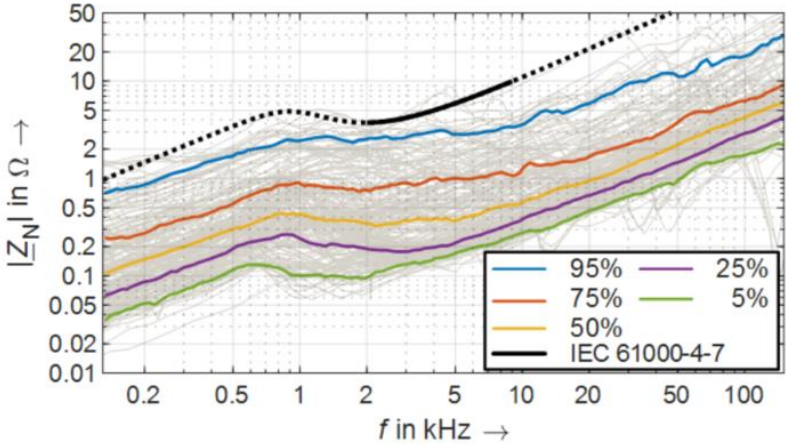
High Switc... Frequency
Capacitances: Input Filter, DC capacitance

TU Dresden, Berner FH et al. (2019)SURVEY OF NETWORK IMPEDANCE IN THE FREQUENCY RANGE 2-9 KHZ IN PUBLIC LOW VOLTAGE NETWORKS IN AT/CH/CZ/GE

Distribution Grid & Active Power Electronics

Distribution Grid





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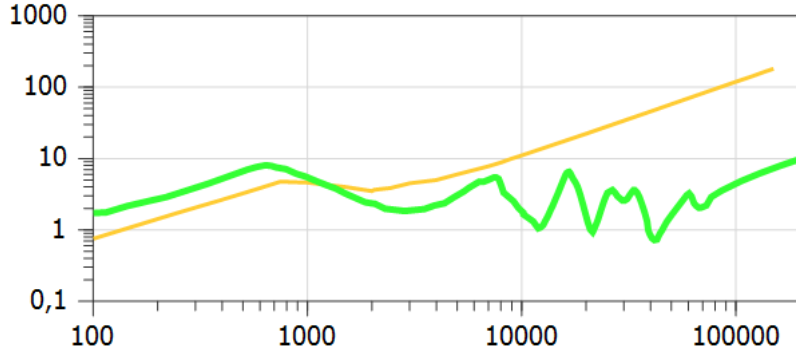
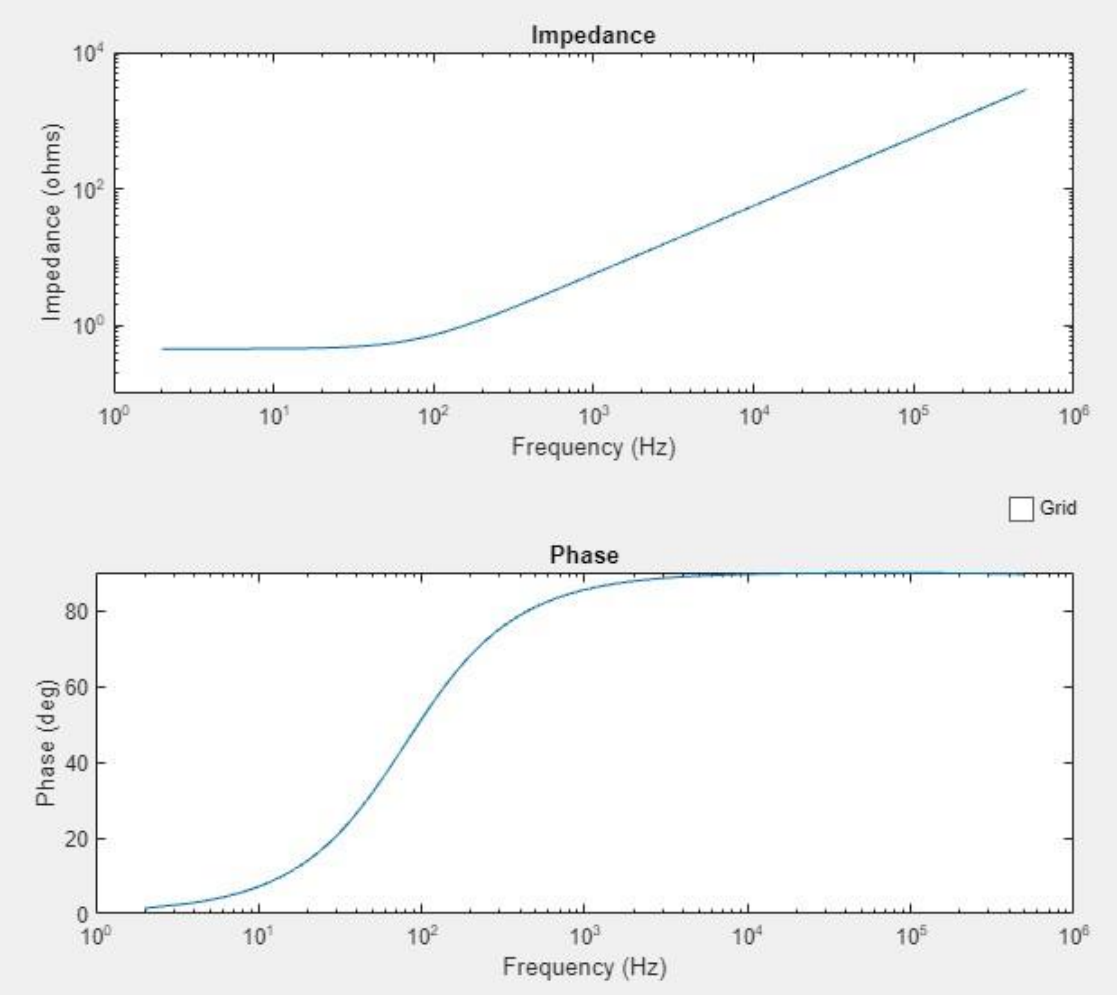
V2G Charger

Example: Topolgy for HF-transformer isolation

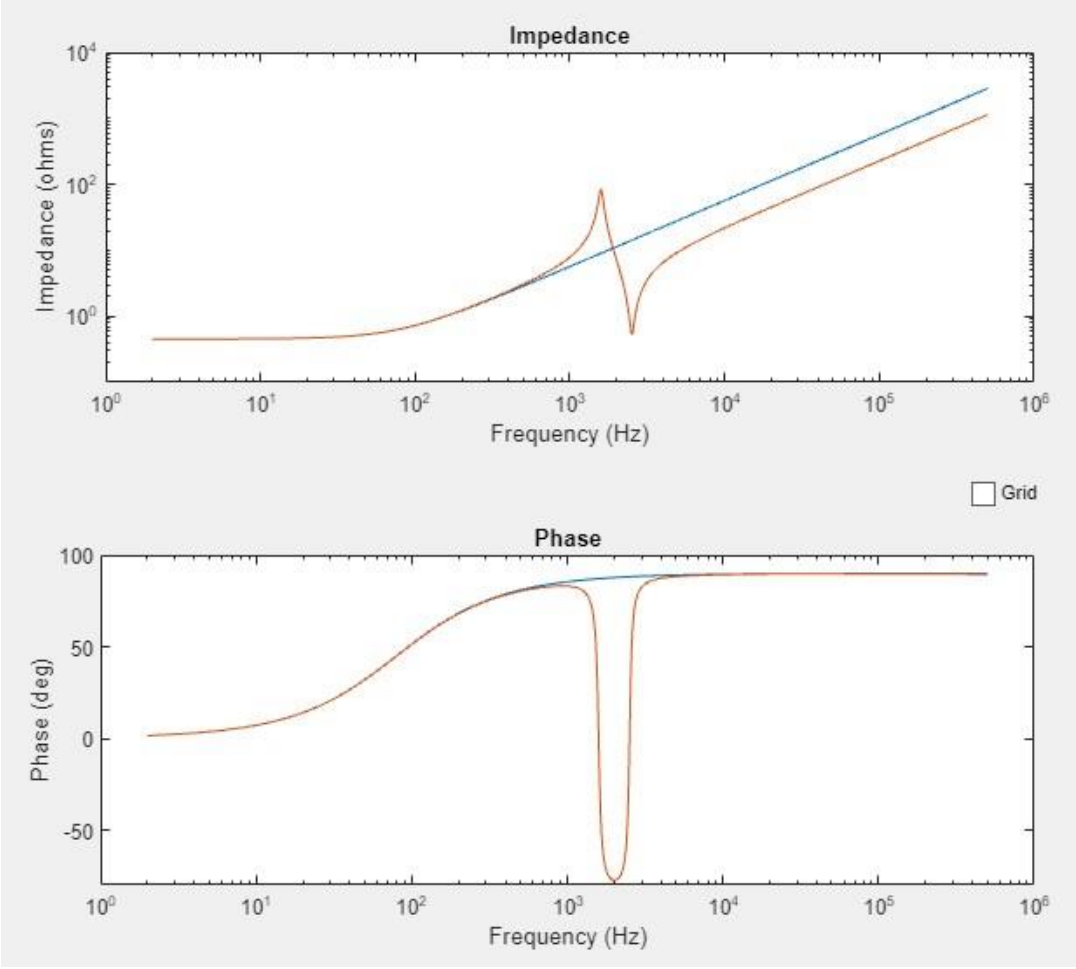


Grid Impedance Example I



GRID at PCC

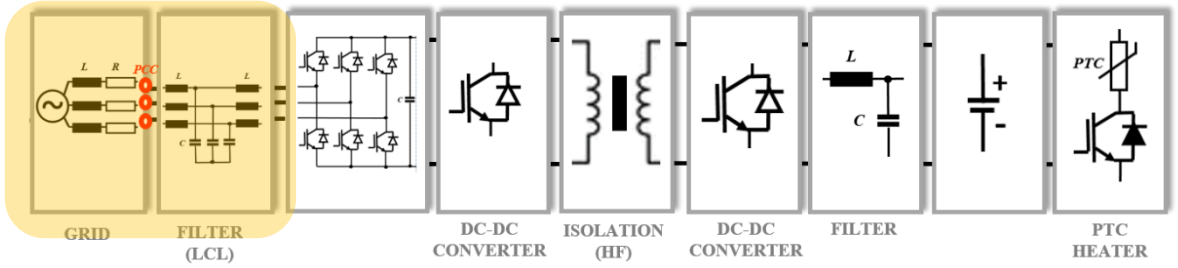
Grid Impedance Example II



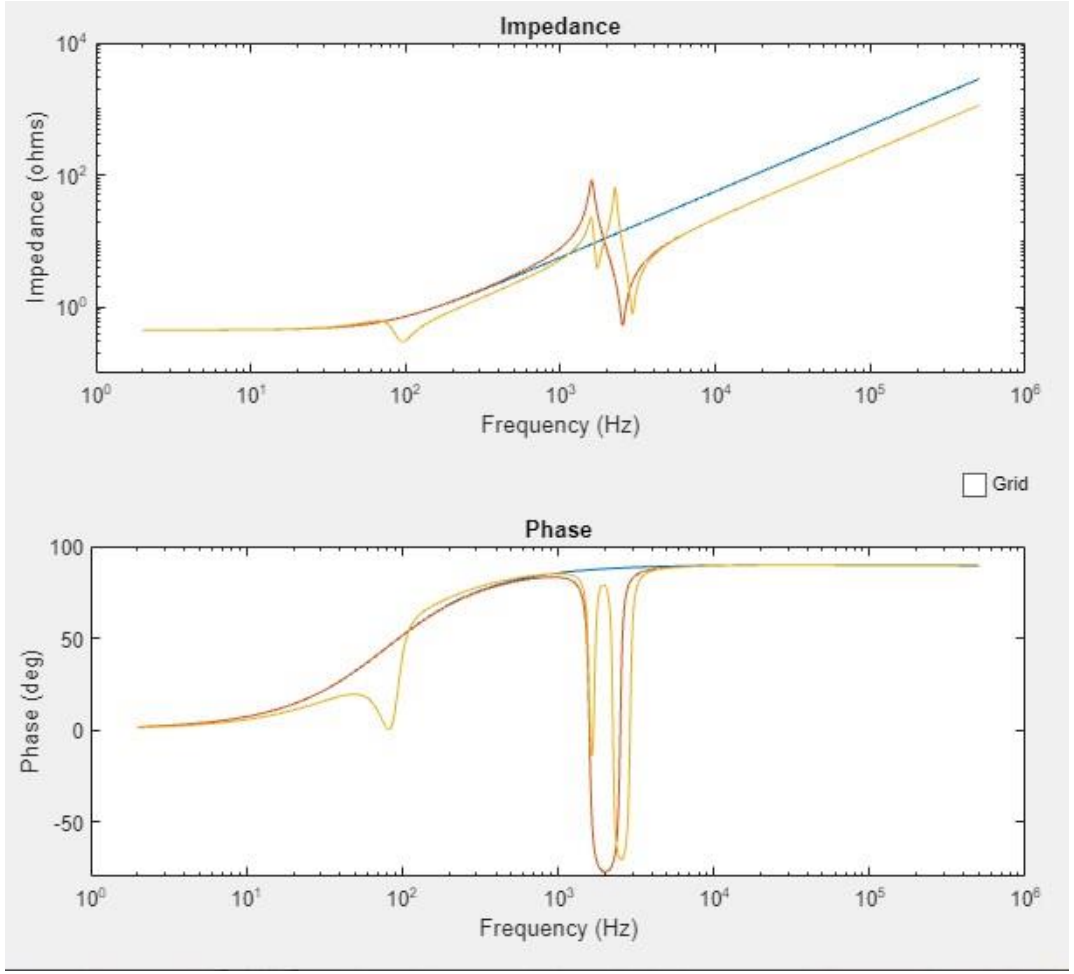
GRID at PCC

EV CHARGER connected (but not in operation)

Reason:
Input LCL filter is already connected



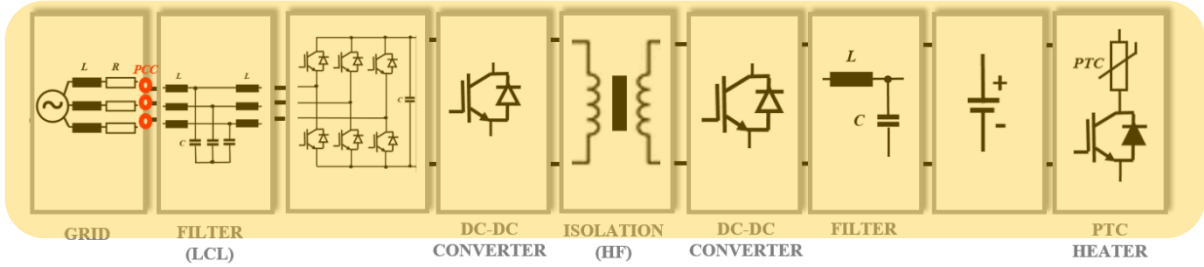
Grid Impedance Example III



GRID at PCC

EV CHARGER connecte (but not in operation)

EV CHARGER in operation



World‘s first mobile Grid Impedance Analyser

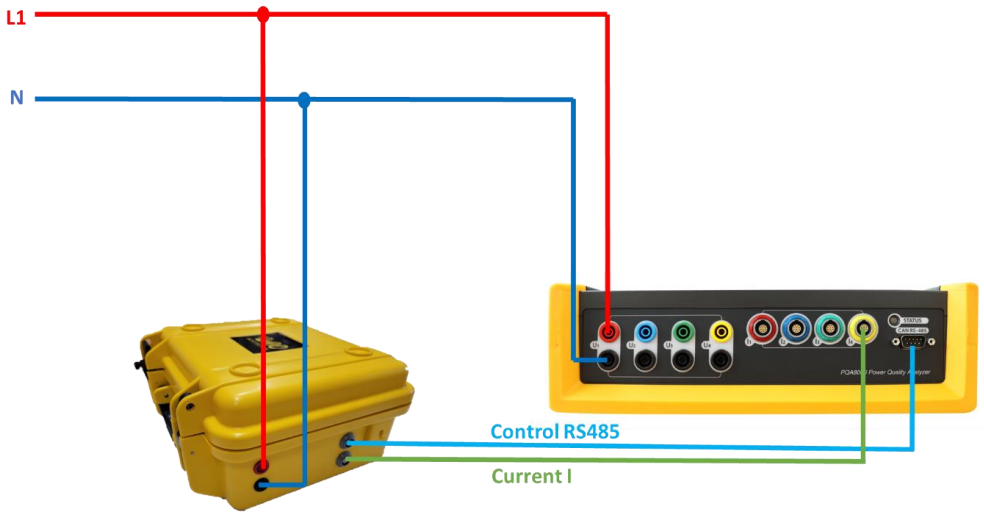
Nominated for the Austrian Innovation Award
(Austrian Association of Electrical Engineers)

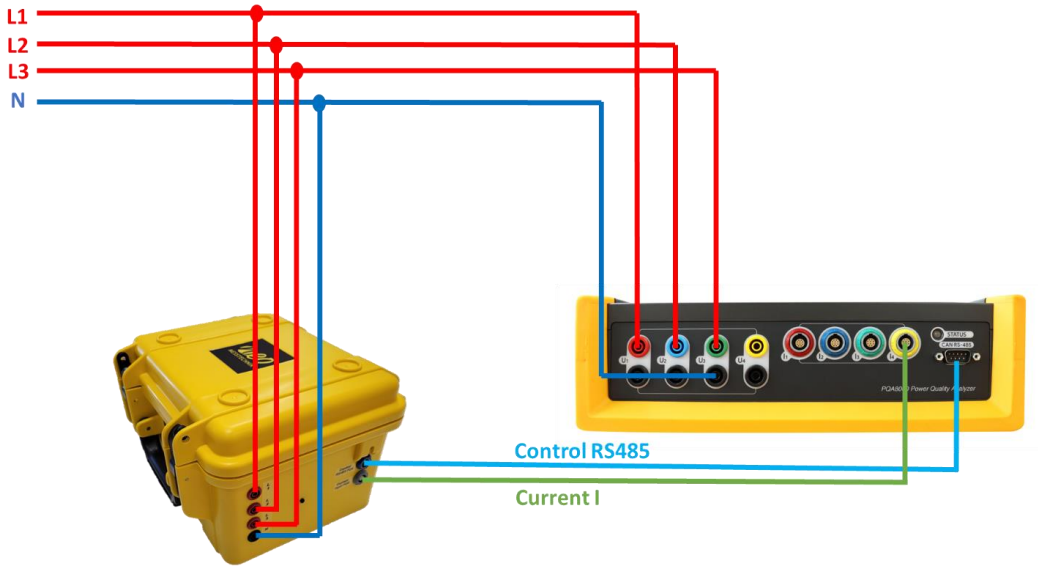
Grid Impedance Anaylser GIA

Specifications	
Measurement Range	230 V / 400 V / (Option 690 V)
Safety Category	CAT IV 300V (Option 600V)
Frequency Range	up to 150 kHz (Option 450 kHz)
Nominal Frequency	50 Hz / 60 Hz / 16.7 Hz
Resolution	18 bit
Signal-to-Noise Ratio (SNR)	>100 dB
Measurement time	400ms per Excitation
Max. Current	5A rms
Wiring	L-N / L-L (Option: 3-Phase)
Battery	4 hours (powered by PQA8000H)
Export	CSV, RAW, JPG
Weight	2 kg
Dimensions (LxBxH)	265 x 255 x 125 mm

- Very short measurement (less than 1s)
- Operation / control with PQA8000H
- 4-wire connection (per phase)
- CAT IV and UL Case

GIA-1 vs. GIA-3

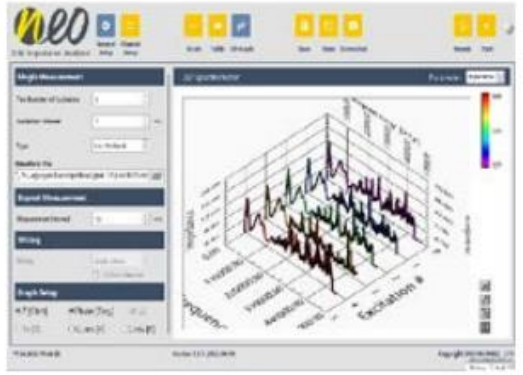

L1
N
Control RS485
Current I


L1
L2
L3
N
Control RS485
Current I

Software & Analysis

Zeit- und frequenzabhängige Charakterisierung der Netzimpedanz (Netzimpedanz) des elektrischen Niederspannungsnetzes

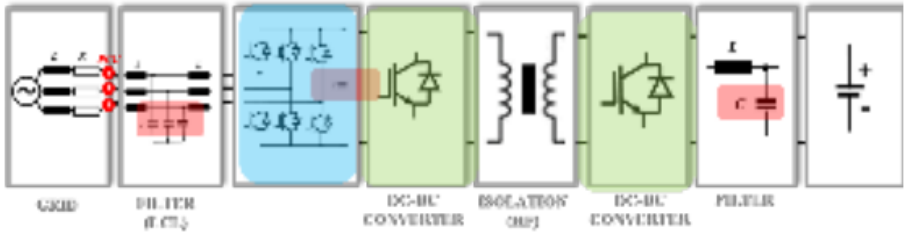
Table View



3D Chart

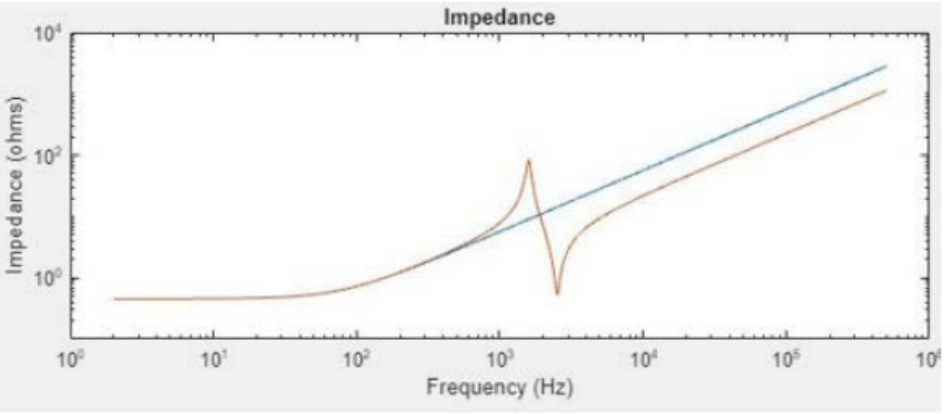
Use Case 1: Resonance Detection & Grid Codes

The high penetration of distributed generation and modern electrical devices based on active power electronics are causing significant changes in the higher frequency grid impedance. The additional inductances and capacitances (LCL filter, DC link etc.) causes multiple parallel and series resonances. Effects are high harmonic currents, high harmonic voltages, overheating of devices, noise, additional losses or malfunction of equipment or malfunction of digital communication.



Grid codes (for example DACH-CZ, TOR, TAR) first time allow the consideration of resonance factors for the determination of harmonic emission limits for each individual harmonic.

- *Definition of Harmonic Emission limits considering resonance factors*
- *Optimization of inverter control (Wind, PV, Motor etc.), filter (EMC) and reactive power control*



Picture 1: Example of connecting a V2G charging station
(Source Grasel 2023 The impact of V2G charger to the frequency dependent grid impedance CIRED Rom)

Reference Grid *V2G charger connected*

Picture 1 shows how resonance points appear while connecting a V2G charging station. Note: Even if the charging station is not in operation, resonance points are caused due to the LCL input filter.

Use Case 2: Supraharmonic Propagation

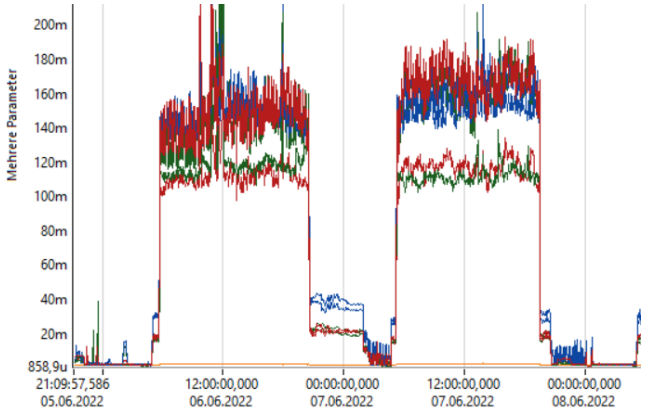
Research of scientific papers and measurement campaigns

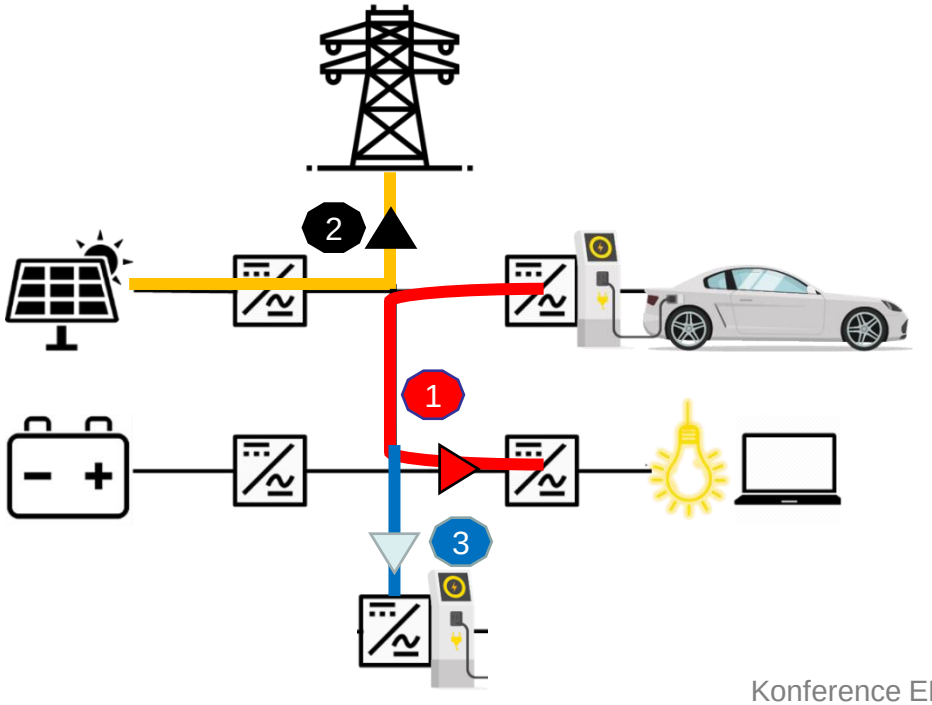
1) Propagation mainly **within** a customer facility (TU Dresden, VDI, VDE 2016)

2) Spread **up to 16 km** (Espin-Delgado et al. 2021)

3) Measurement campaign Bayernwerk: Level of 2V at 10 kHz at e-charging station which is not in operation (Gaßner 2021)

4) Neighbour Photovoltaic system causes problems at heating control



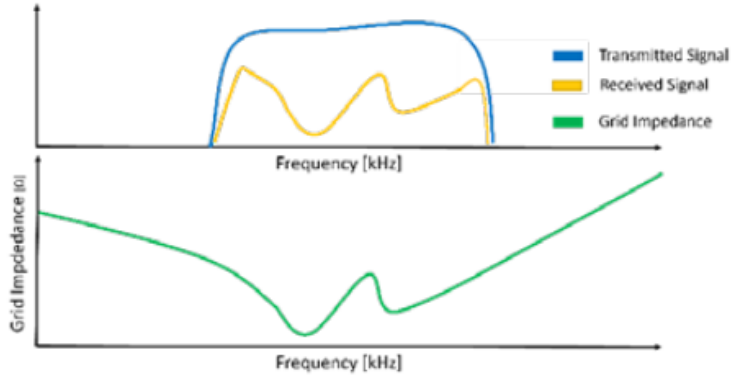


Use Case 3: Power Line Communication (PLC)

Power Line Communication (PLC) is widely used for Smart Metering applications in a frequency range from 10 kHz to 450 kHz (CENELEC A, B, C, D, FCC, ARIB). Existing power cables are used for communciation purposes but represent a "harsh" medium. Communciation failures are resulting due to:

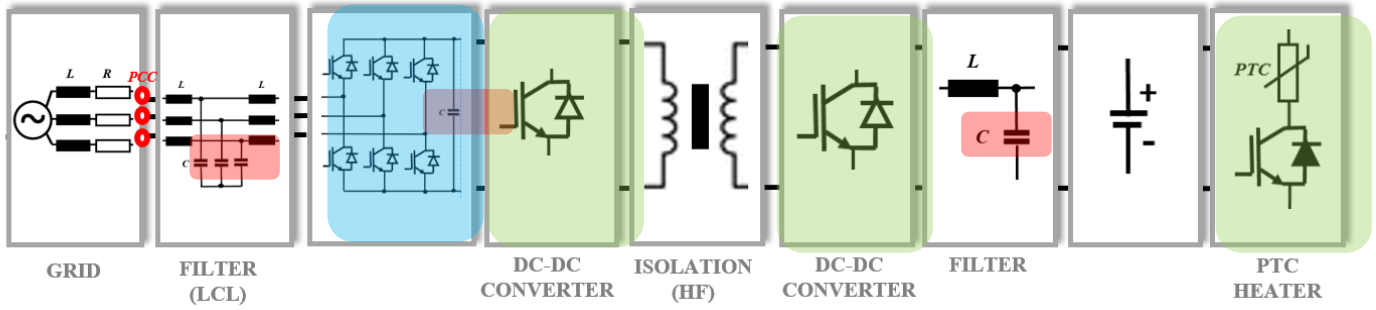
- Increasing Supraharmonic emissions causing a Noise floor
- Series Resonances (e.g. LCL input filter of other devices) representing a low-impedance path for intentional emissions
- Attenuation between transmitter and receiver

Picture 2 shows the relation between transmitted signal and grid impedance



Picture 2: Relation of PLC transmission losses and higher frequency grid impedance

CONCLUSIO …
Ready for the future



Supraharmonic emissions:

High Switching Frequencies AC/DC Conversion

High Switching Frequencies DC/DC Conversion

Changes to the frequency dependent Grid impedance due to:

Capacities: Device input filters, DC link capacitances, etc.