Unintended Consequences of DER Penetration in Distribution Grids and Micro-grids

New types of measurements, and new standards are needed

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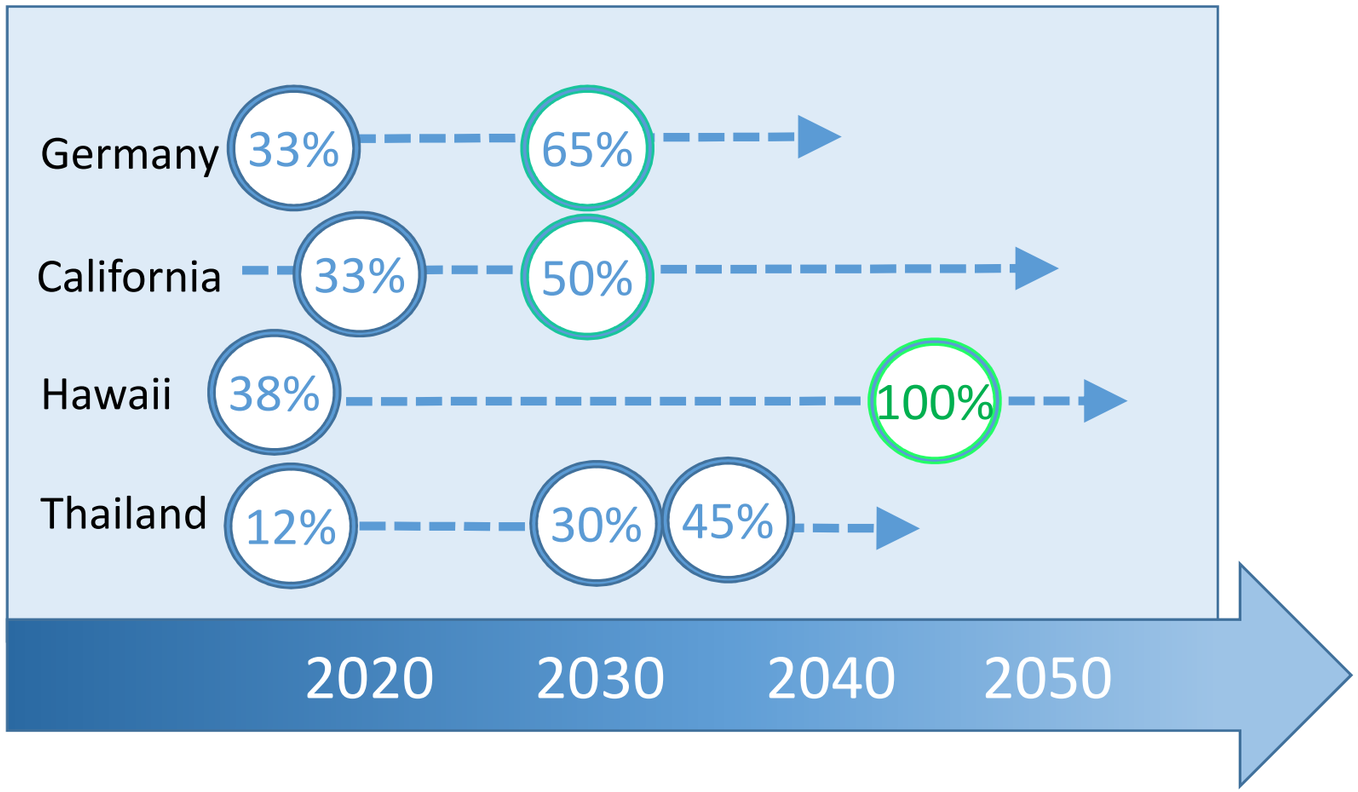
High Penetration of DERs: it's coming your way!

DER generation goals



High Penetration of DER: the Visible Effects on Stability and Control

Individual DER inverters can disconnect during abnormal conditions
(this is changing, see IEEE 1547)

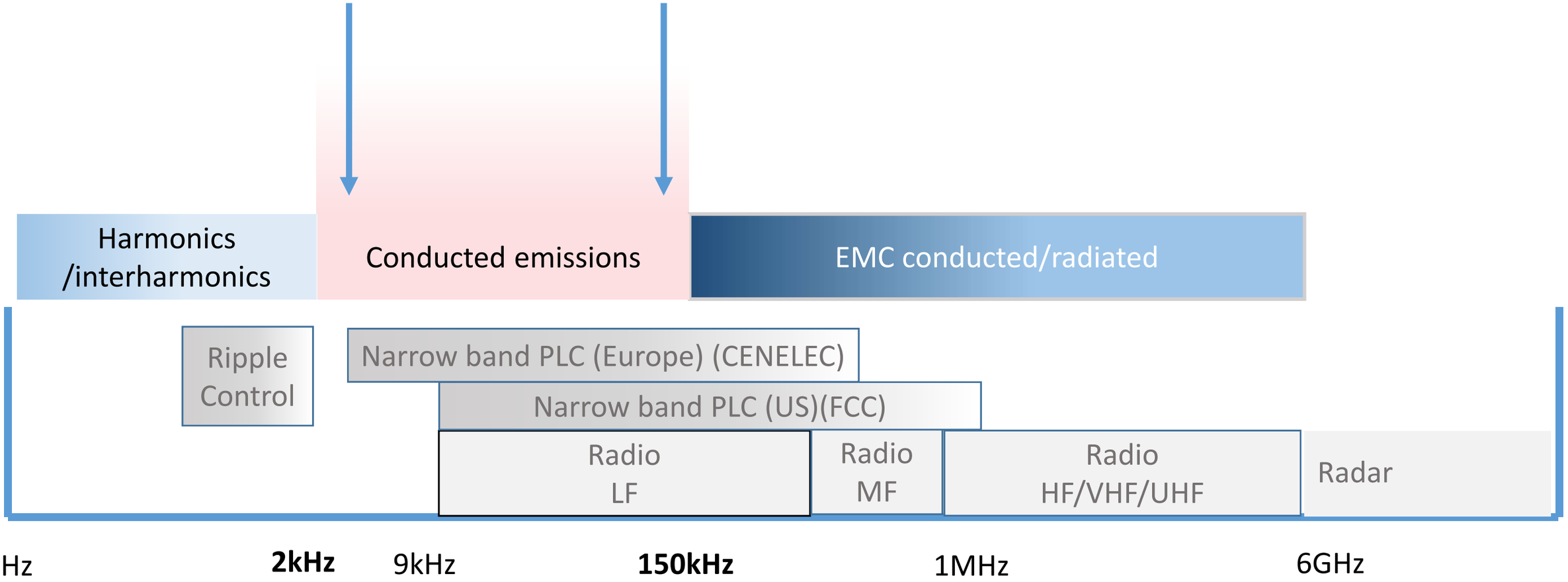
Interaction between inverter controllers may affect overall grid stability

Measure system state and control the behavior of the DER inverters –> new needs!

Real time and accurate voltage, current magnitudes, angles, frequency, ROCOF –> synchrophasors –> PMUs designed for distribution grids

2 kHz -150 kHz Voltage Conducted Emissions

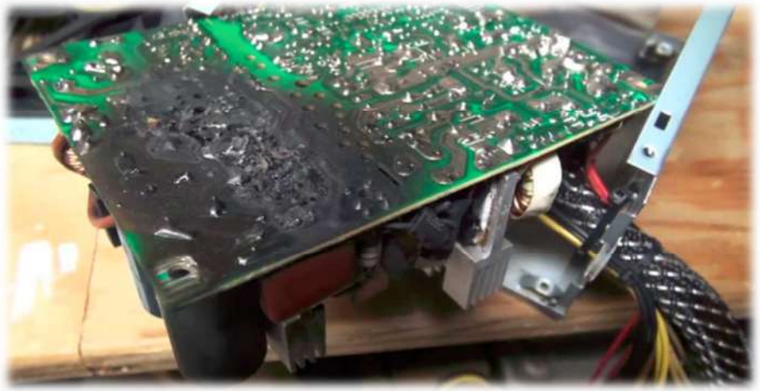
Also called “supra – harmonics”



2 kHz - 150 kHz Conducted Emissions: Symptoms

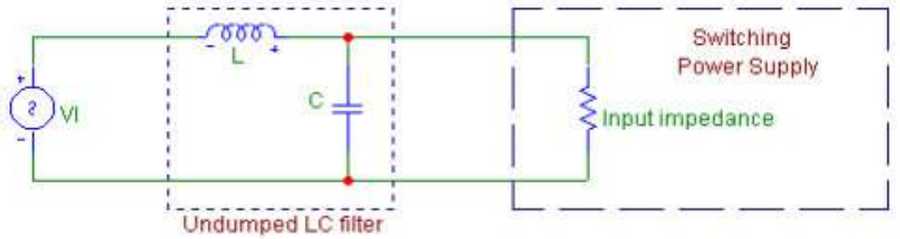
Impact on power supplies:

- Premature aging
- Overheating
- Destruction by fire



Why?

Capacitor impedance $= \frac{1}{2\pi F C}$

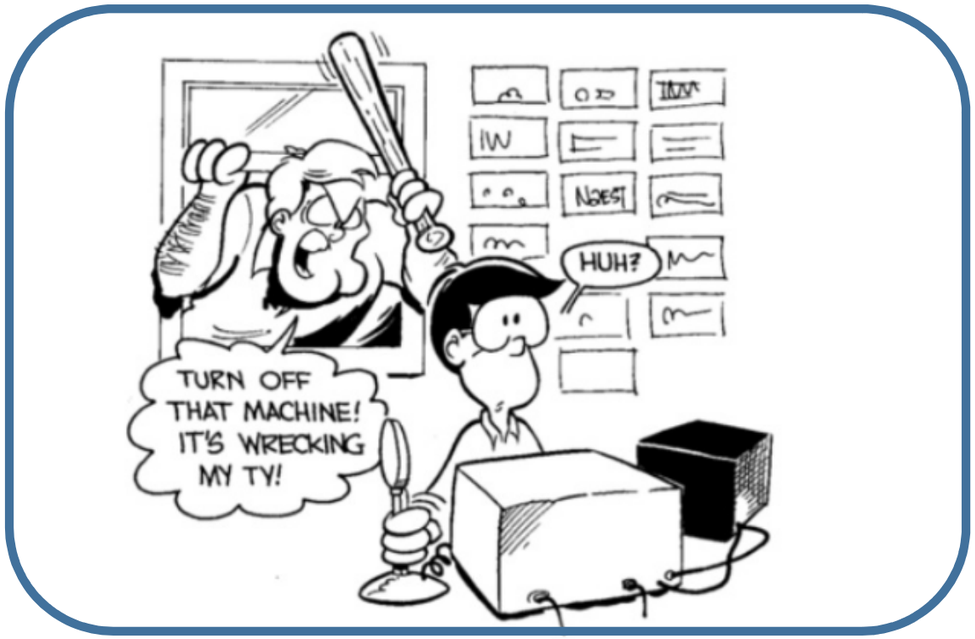


2 kHz – 150 kHz Conducted Emissions: Symptoms

Smart meter communications (PLC) signals disconnection

Mains signaling /Ripple Control signals disconnection

Why?



2 kHz – 150 kHz Conducted Emissions: Symptoms

Energy meter readings are wrong

Why?

Current sensors:
e.g. Rogowski coils
e.g. Hall effect sensors

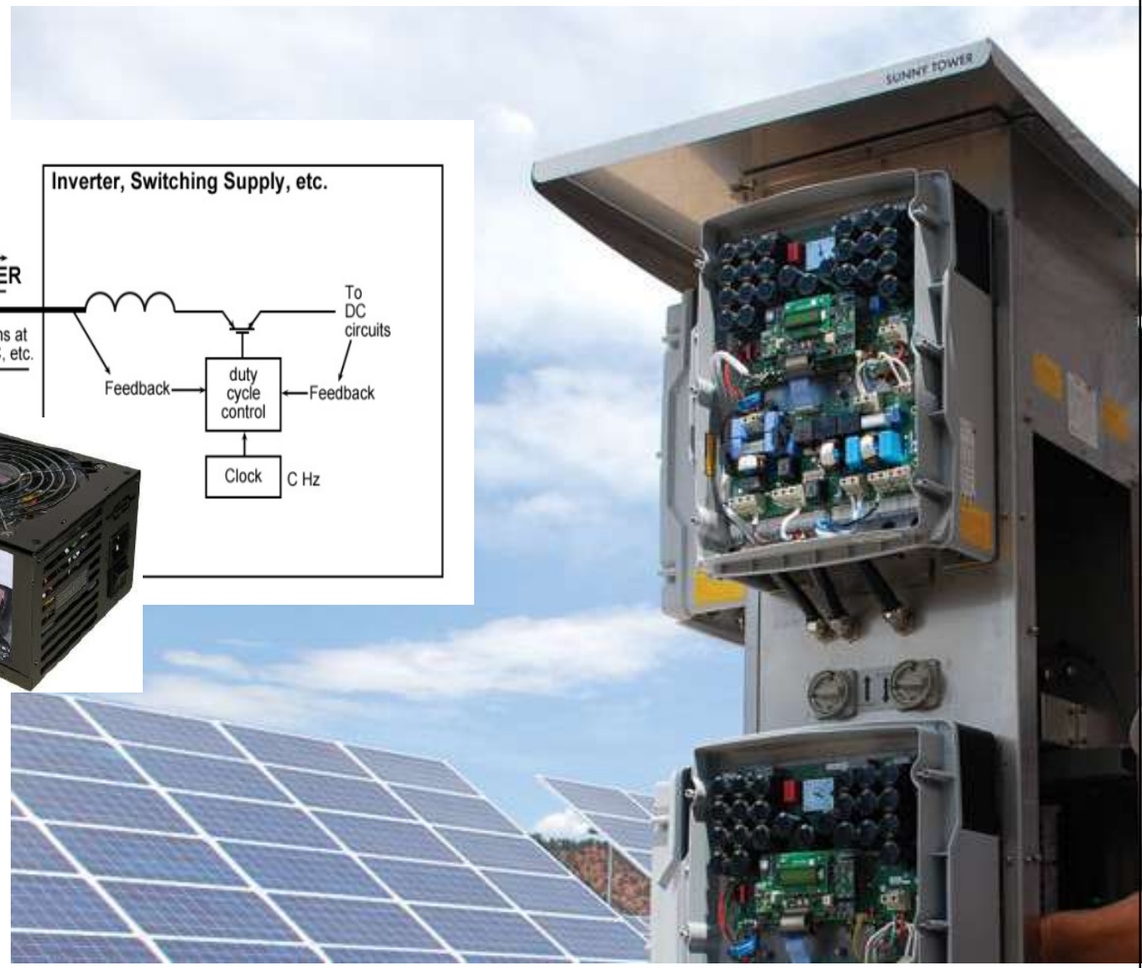
and electronic circuit design

https://www.utwente.nl/en/news/!/2017/3/313543/electronic-energy-meters-false-readings-almost-six-times-higher-than-actual-energy-consumption

2 kHz – 150 kHz Conducted Emissions: Sources

Electronic based switching devices:

- Inverters !
- Solar (PV) farms inverters
- Wind farms inverters



2 kHz – 150 kHz Conducted Emissions: Sources

- Electrical Vehicle (EV) battery chargers
- Variable Frequency Drives (VFD)
- PWM AC/DC converters
- UPS
- LED controllers

2 kHz – 150 kHz Conducted Emissions: Measurement Requirements

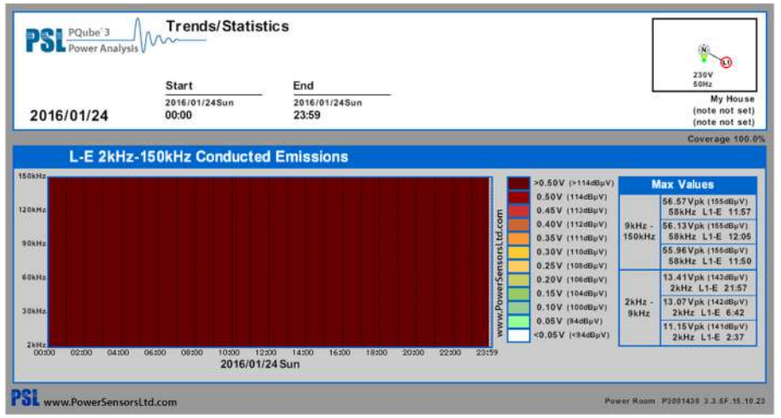
IEC 61000-4-30- Ed3 (2015)

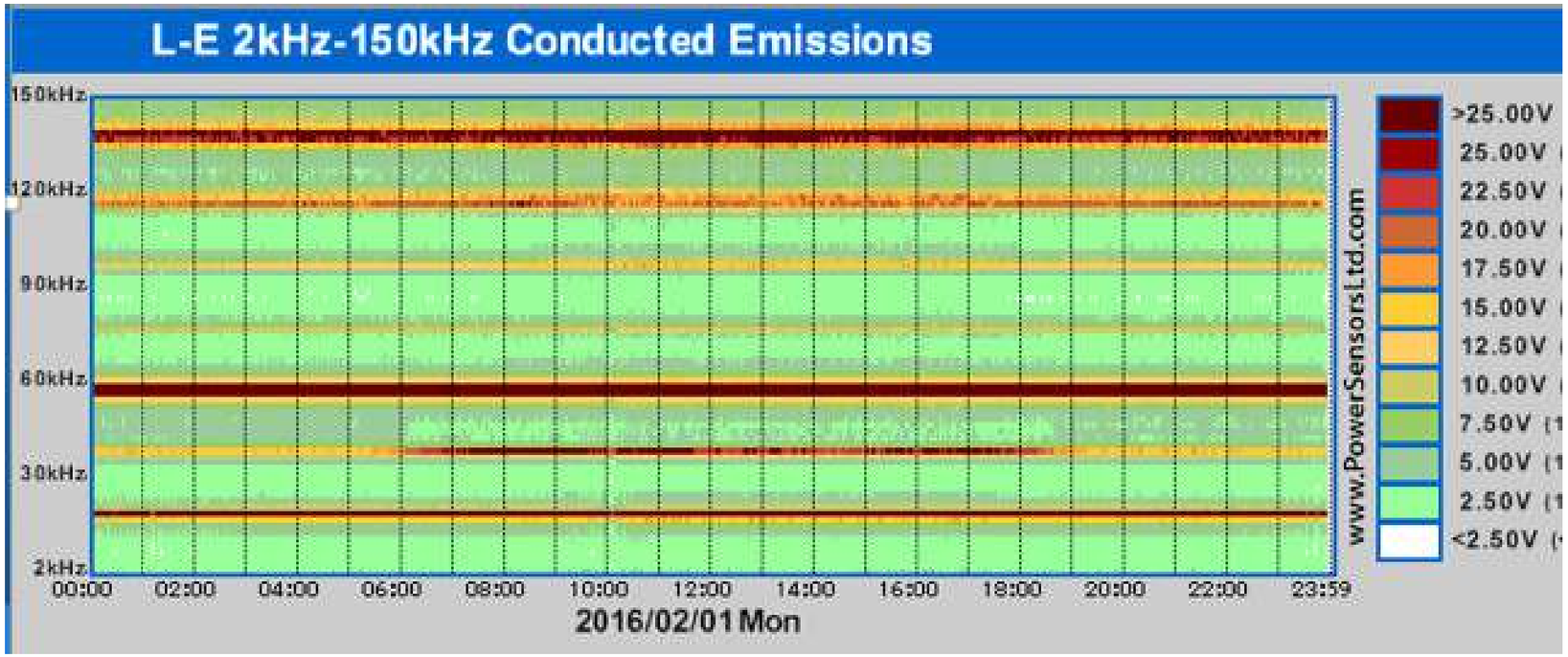
Measurements:
Voltage conducted emissions
MHz sampling
0 ~60 Vpk amplitude
5% accuracy

2 kHz -9 kHz <-> 200 Hz bins
8 kHz -150 kHz <-> 2000 Hz bins

Recordings:
1 min interval
average & max values

Example: near PV Generation Site in South Africa





Example: EV Battery Charging Station in Germany

PSL PQube 3 Power Analysis

Trends/Statistiken
Trends/Statistics

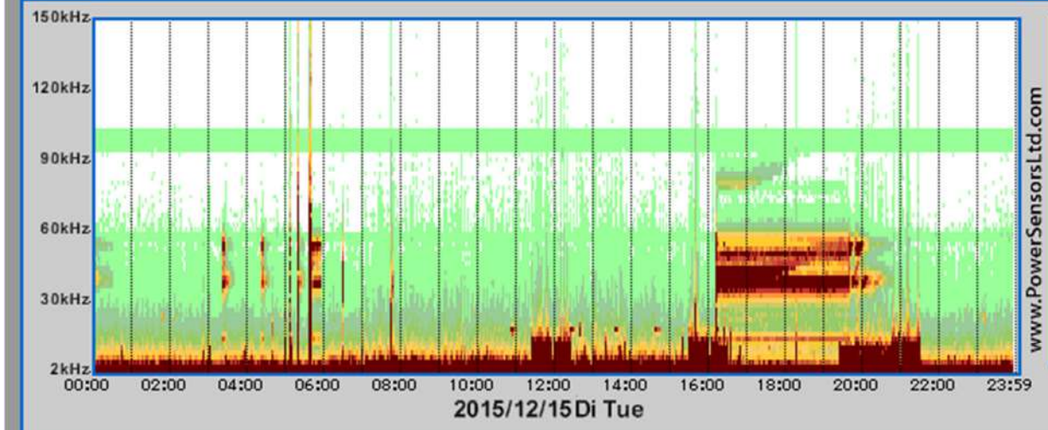
	Start Start	Ende End
	2015/12/15Di Tue	2015/12/15Di Tue
2015/12/15	00:00	23:59

230/400V
50Hz

Test
(note not set)
(note not set)

Erfasst 100.0%

L-E 2kHz-150kHz Conducted Emissions



>0.50V (>114dBµV)
0.50V (114dBµV)
0.45V (113dBµV)
0.40V (112dBµV)
0.35V (111dBµV)
0.30V (110dBµV)
0.25V (108dBµV)
0.20V (106dBµV)
0.15V (104dBµV)
0.10V (100dBµV)
0.05V (94dBµV)
<0.05V (<94dBµV)

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Max Values	
9kHz - 150kHz	5.82Vpk (135dBµV) 10kHz L1-E 5:41
	4.35Vpk (133dBµV) 18kHz L1-E 5:41
	3.40Vpk (131dBµV) 14kHz L1-E 5:40
2kHz - 9kHz	10.86Vpk (141dBµV) 2kHz L3-E 7:01
	7.95Vpk (138dBµV) 4kHz L1-E 5:40
	7.76Vpk (138dBµV) 6kHz L1-E 5:40

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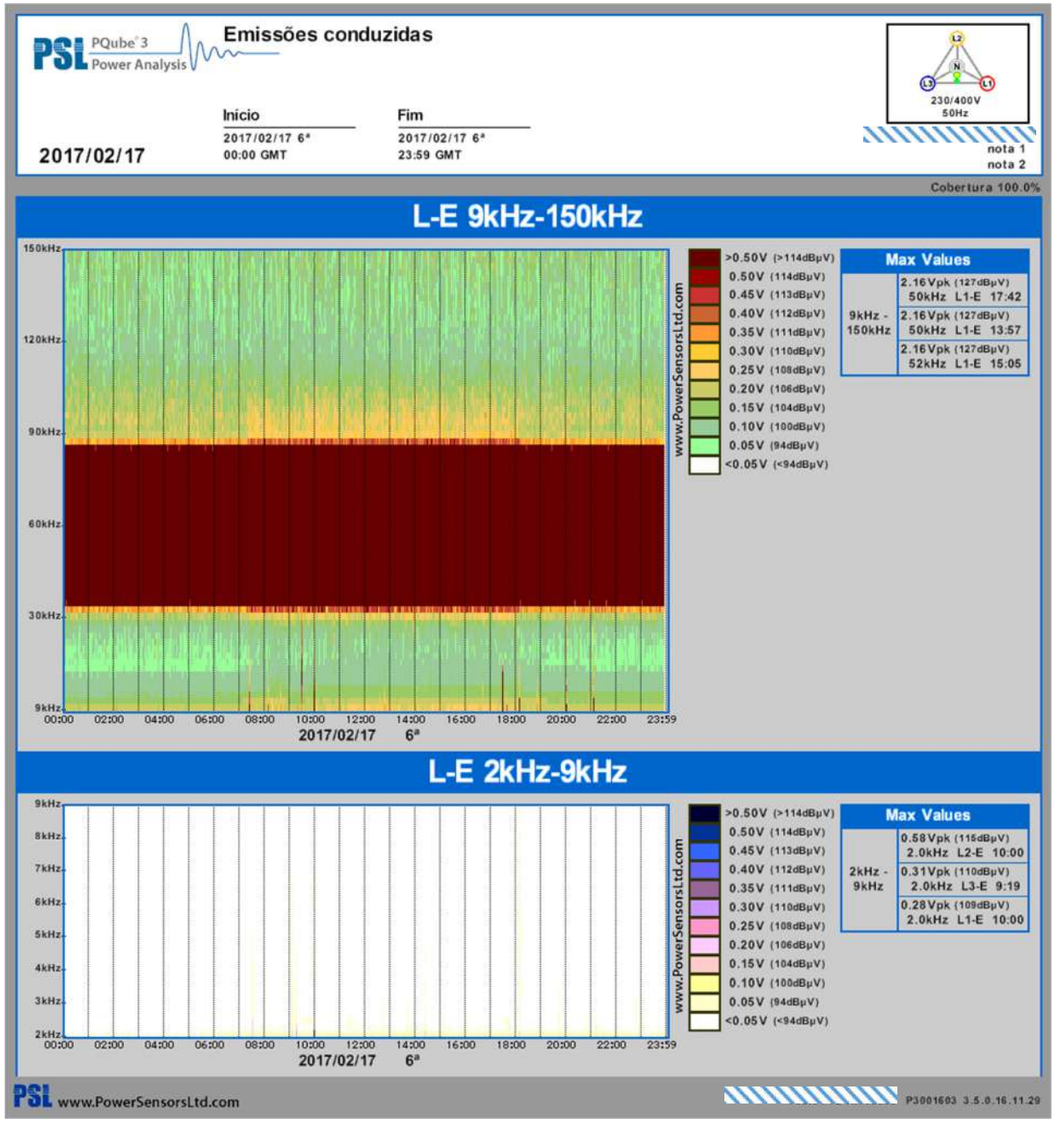
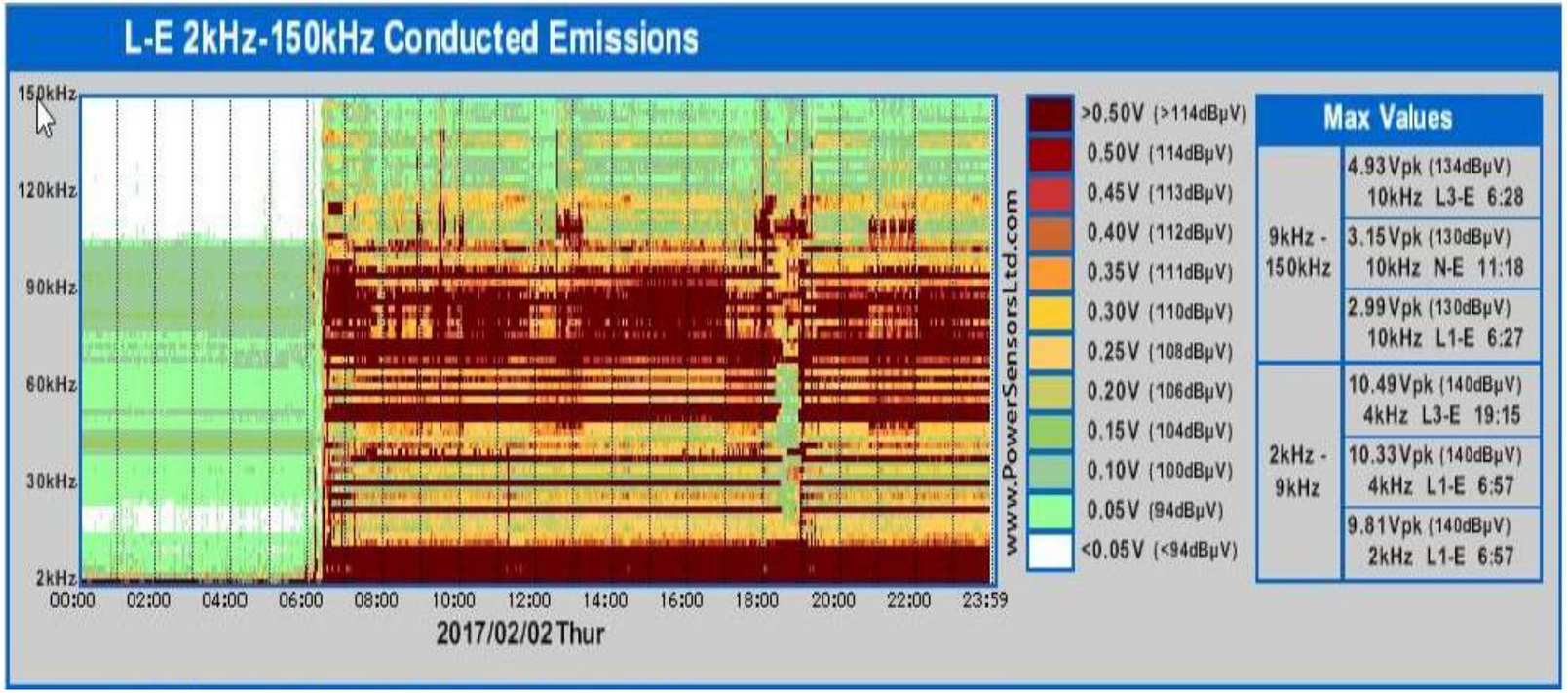
MMR PQ3_1 P3001812 3.3.5F.15.10.23

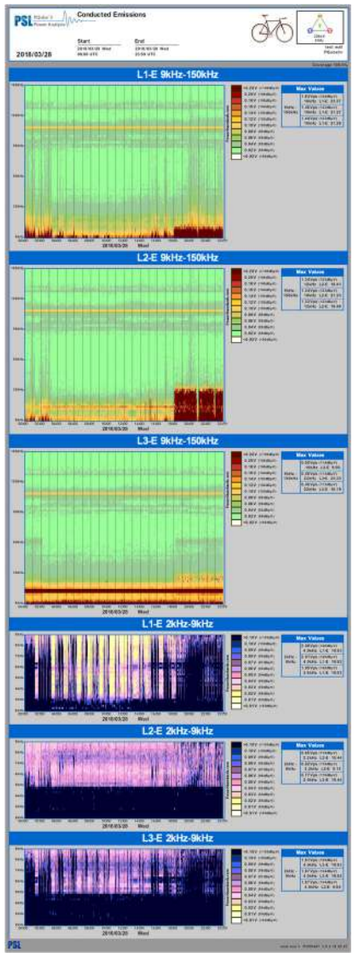
Example: Secondary Substation in Portugal



Example: Motor Factory in Vietnam

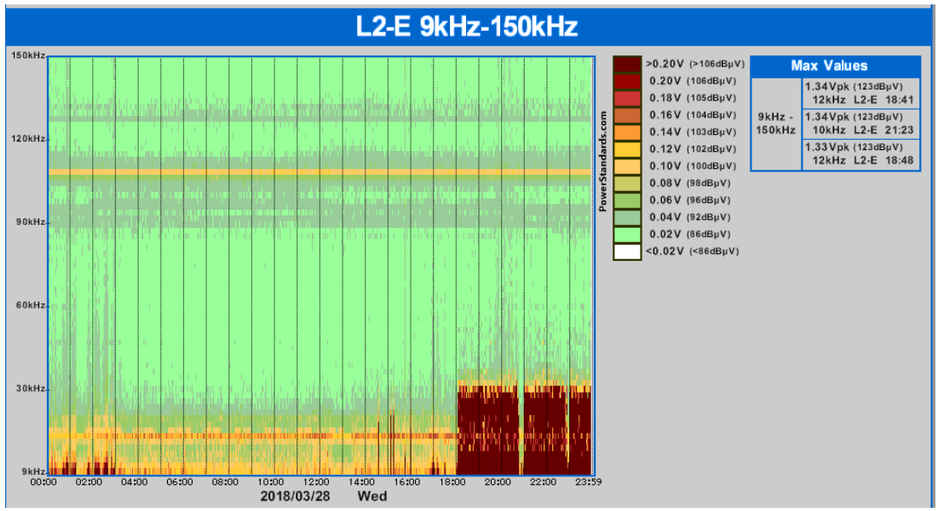


2kHz - 150 kHz Conducted Emissions: details & troubleshooting

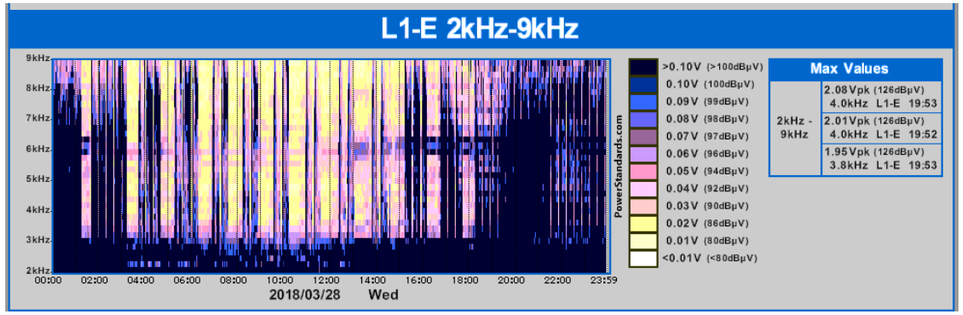


Phase by Phase view

L2-E channel



L1-E channel



New Standards, or Evolution of the Existing Standards

Compatibility levels for voltage distorsion & emissions : IEC 61000-2-2

2 kHz -30 kHz : Consensus in the frequency range
30k Hz-150kHz: No consensus , propositions circulated

Immunity type testing : IEC 61000-4-19 :2014

Testing immunity methods (type tests in labs) for equipment or revenue meters

Methods for measuring HF radio disturbances & immunity > 9 kHz: CISPR- 16

How to measure? IEC 61000-4-30 Ed3 (informative)

Provides guidance in methods in-situ measurements of 2kHz-150kHz emissions

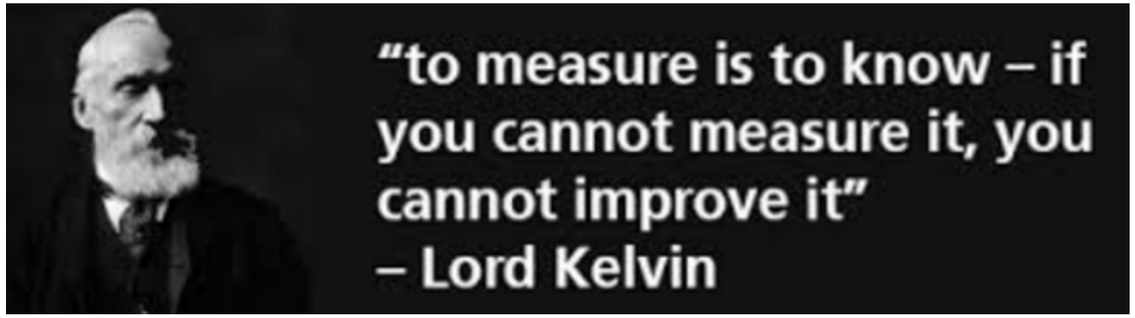
PQube®3 implements the measurement methods recommended for 2kHz-150kHz emissions

Conclusions

The amount of DERs in distribution grids and on the demand side brings opportunities, but also new challenges

The conducted emissions levels will get worse
Real time measurements are needed to control the (micro) grids stability

There are today instruments which do these new types of measurements



Thank you for your time!

Questions?

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