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

Challenges in the application of measurement methods in grid measurements

Victor Khokhlov, Jan Meyer, Technische Universität Dresden

SupraEMI M36 Workshop, April 2022

Outline

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

- **Introduction**

  Objectives and challenges of grid measurements

- **Methodology**

  Measurements in frequency ranges below and above 9 kHz

- **Application of measurement methods**

  On-site measurements and measurement results

- **Conclusions**

  Practical experience and further steps

Introduction

Objectives and challenges of grid measurements

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

Objectives

- Reproducible measurements (e.g. for study of propagation, source identification)
- Comparison of disturbance levels with compatibility levels

Compatibility levels according to IEC 61000-2-2

Frequencies	Basis	Rationale
below 9 kHz	U_{RMS}, IEC 61000-4-7	Reflecting thermal stress and equipment malfunction
9-150 kHz	U_{QP}, CISPR 16-1-1	Reflecting impact on radio transmission

Challenges

- Consistency of methodology below and above 9 kHz
- Compliance with established standardization framework (U_{QP} for comparison with IEC 61000-2-2 above 9 kHz)
- Representation of relevant interference mechanisms (thermal stress, equipment malfunction)
- Reasonable computational requirements

Methodology

Measurements in frequency range below 9 kHz

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

	Harmonics and interharmonics	Frequencies in the range 2-9 kHz
Measurement		
Interval	10/12 cycles	200 ms
Results	$U_{\mathrm{RMS}}^{(h,ih)}$, $I_{\mathrm{RMS}}^{(h,ih)}$, $\mathrm{THD_U}$, $\mathrm{THD_I}$	$U_{\mathrm{RMS}}^{(b)}$, $I_{\mathrm{RMS}}^{(b)}$, TSHV, TSHC
	Group, subgroup values	200-Hz bands
Aggregation		
Common Intervals	150/180 cycles, 10 min	3 s, 10 min
Method	RMS and Maximum	
	RMS aggregation: thermal stress of circuit components Maximum aggregation: perceptible malfunctions	
Evaluation	Comparison of weekly 95th percentile of 10-minute values Comparison of daily 99th percentile of 3-s values	

Methodology

Measurements in frequency range 9-150 kHz

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

SupraEMI: two proposals for a normative framework

Digital CISPR 16

Selected implementation based on
CISPR 16-1-1 and CISPR/TR 16-3

Benefits:

- Compliance with IEC 61000-2-2 above 9 kHz

Drawbacks:

- Laboratory setup
  with EUT-specific measurement procedure
- Questionable representation
  of relevant interference mechanisms
- High computational requirements

Light Quasi-Peak

New method based on adaptation of the method for 2-9 kHz
IEC 61000-2-2, Annex B

Benefits:

- Consistent methodology below and above 9 kHz
- Comparability with IEC 61000-2-2 above 9 kHz
- Representation of relevant interference mechanisms
- Reasonable computational requirements

Drawbacks:

- Lack of experience
  in comparison with IEC 61000-2-2 above 9 kHz

Application of measurement methods

Framework based on SupraEMI proposals

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

Digital CISPR 16

Measurement interval:	20 ms, 90 % time overlap
Measurement quantity:	U_{QP} every 2 ms
Aggregation:	maximum aggregation over the entire measurement time
Measurement results:	maximum U_{QP} values

Light Quasi-Peak

Measurement interval:	20 ms, no time overlap
Measurement quantity:	U_{RMS} every 20 ms, U_{QP} every 3 s
Aggregation:	RMS and maximum aggregation over 3 s, 10 min
Measurement results:	95th, 99th percentiles of aggregated U_{RMS} values, maximum U_{QP} values

Application of measurement methods

Grid measurements

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

Approach: continuous acquisition of voltage waveform and post-processing

Measurement sites: POC in public low voltage grids in Germany and Austria

Disturbance sources: PV inverters, EV chargers, PLC systems

Measurement duration: short (25-120 minutes), long (daily, weekly)

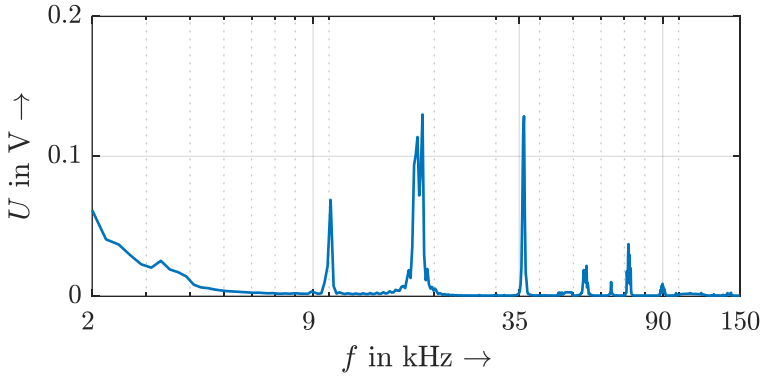
Application of measurement methods

Grid measurement A

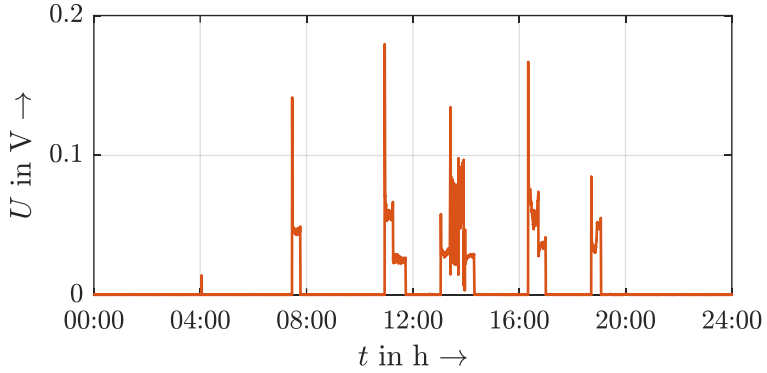
The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

Measurements – POC of central charging infrastructure (one day)

Measured disturbance levels



Variation of disturbance level at 36 kHz



Disturbances:

- 10 kHz – switching frequency of an AC charger
- 18 kHz – switching frequency of a DC charger, 36 kHz – 2nd harmonic of switching frequency

Characteristics:

- strong variation of disturbance level during the day
- five non-simultaneous charging processes with overall duration of 200 min

Application of measurement methods

Grid measurement A

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

Measurement results – individual frequency bands

		10 kHz	18 kHz	36 kHz
Digital CISPR 16	U_{QP}, mV	87 *(100 %)*	187 *(100 %)*	243 *(100 %)*
Light Quasi-Peak	U_{QP}, mV	91 *(104 %)*	186 *(100 %)*	237 *(98 %)*
99th percentile	U_{RMS}, mV	69	117	126
	U_{max}, mV	70	129	143
Compatibility levels	U_{QP}, V	2.8	2.1	1.1

- Relative low disturbance levels compared to compatibility levels
- High comparability between the proposals in terms of quasi-peak values
- Possible misinterpretation of relevant interference mechanisms with Digital CISPR 16 proposal

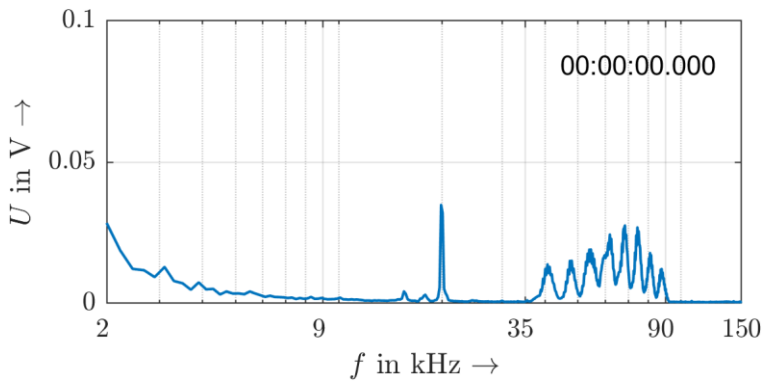
Application of measurement methods

Grid measurement B

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

Measurements – POC of PV inverter with PLC system (25 minutes)

Measured disturbance levels



Disturbances:

- 20 kHz – switching frequency of a PV inverter
- 35-90 kHz – operating range of a PLC system

Characteristics:

- narrowband, fairly constant emission of PV inverter
- broadband, fast varying emission of PLC system

Application of measurement methods

Grid measurement B

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

Measurement results – integral values (35-90) kHz

Integral values of disturbances (TSHV) represent signal power in a certain frequency range

$$\mathrm{TSHV} = \sqrt{\sum_{B=1}^{N} U_B^2}$$

Use case: reflecting relevant interference mechanisms (thermal stress)

Digital CISPR 16: calculation based on U_{QP} (U_{AVG}) with an overlap compensation factor

Light Quasi-Peak: calculation based on U_{RMS}

95th percentile of non-aggregated 200-ms-values

		35-90 kHz
Digital CISPR 16	TSHV, mV	251 (163)
Light Quasi-Peak	TSHV, mV	210

- Large deviation between the proposals
- Large deviation between the approaches for digital CISPR 16
- Possible misinterpretation of relevant interference mechanisms with digital CISPR 16

Conclusions

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

Summary

Experience in practical application of SupraEMI proposals for a normative framework

Digital CISPR 16

- Different methodology below and above 9 kHz
- Compliance with IEC 61000-2-2 above 9 kHz
- Possible misinterpretation of relevant interference mechanisms
- High computational requirements compared to the present generation of measurement instruments

Light Quasi-Peak

- Consistent methodology below and above 9 kHz
- Comparability with IEC 61000-2-2 above 9 kHz
- Accurate representation of relevant interference mechanisms
- Significantly lower computational requirements compared to Digital CISPR 16

Further steps

- IEC SC77A WG9: final decision on the normative method and circulation of IEC 61000-4-30, CD
- SupraEMI team: experience in practical application and further validation of research proposals

Thank you
for your attention!

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

Measurement of audible noise

Measurement of thermal stress

Immunity assessment

Technische Universität Dresden

Institute of Electrical Power Systems and High Voltage Engineering

Power Quality Research Team

E-mail: victor.khokhlov@tu-dresden.de