



Traceability and legal standards in PQ metrology

Final dissemination workshop of EMPIR 15RPT04 TracePQM project
27-28 May 2019

Věra Nováková Zachovalová

Czech Metrology Institute Brno

Department of primary metrology of DC/LF electrical quantities

Okružní 31, 638 00 Brno, Czech Republic

vnovakovazachovalova@cmi.cz



Part I: Traceability in PQ metrology



Basic terms



- **Traceability** = property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty
- **Calibration** is a set of operations that under certain conditions establish relations between values indicated by a measuring instrument or system, or values represented by a materialised measure or reference material, and values realised by measurement standards
- **Standard** is realization of the definition of a given quantity, with stated quantity value and associated measurement uncertainty, used as a reference



Introduction to electrical quantities



- Metrology of EM quantities:

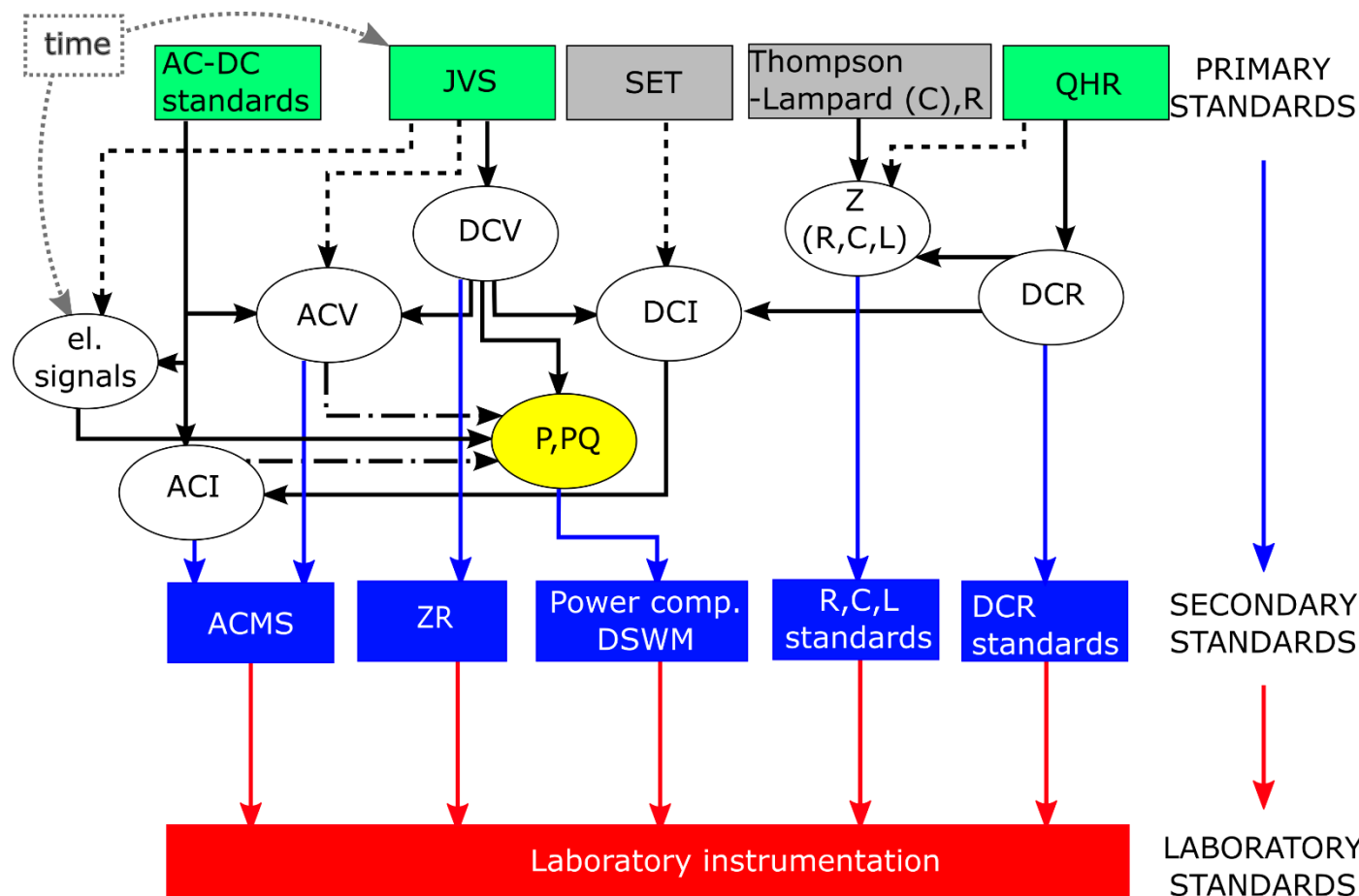
- DC (V,I,R – Quantum metrology)
- LF (AC/DC difference, Impedance)
- Power (electrical power and energy, power quality)

- High current, high voltage
- RF/MW (radio frequency, microwave)
- Magnetism

**Metrology of DC/LF
electrical quantities**



Traceability of DC/LF electrical quantities





Traceability for power and PQ



- No primary intrinsic standard for power and PQ
- The quantity is derived from:
 - Primary standards of AC-DC difference, DCV (traditional, especially for power)
 - Primary standards of DCV and time (sampling techniques, PQ)



Traceability levels for power and PQ



LEVEL	Standards	Uncertainty level (50 Hz, $\cos\varphi = 1$)
AC-DC difference + DCV DCV + time (sampling)	Power comparator sampling wattmeter	from 0,01 % from 0,001 %
Transfer to laboratory standards	Standard meters, Power calibrators	~ 0,05 % from 0,02 %
Transfer to customers instruments	electricity meters, PQ meters	Accuracy class 0,2 % ; 0,5 %; 1 %; 2 % Class A (0,1%) and S (0,5%)



Definitions of power and PQ



- **DC power** = multiplication of voltage and current:

$$P = UI$$

- **AC power** = multiplication of RMS values of voltage and current and phase angle

$$P = U_{ef} I_{ef} \cos \varphi$$

- **Power Quality**: describes quality of energy distributed in the grid, is comprised of number of parameters (not just a one equation!)



Power quality parameters



- **Basic PQ parameters (from IEC 61000-4-30):**

Frequency

Magnitude of supply voltage

Flicker

Supply voltage dips and swells

Voltage interruptions

Transient voltages

Supply voltage unbalance

Voltage harmonics and interharmonics

Mains signalling on the supply voltage

Rapid voltage changes

Current measurement (mag., unbal., harm.,...)

- Informative: Under- and overdeviations,
Emissions in 2 -150 kHz

- definitions are based on the signal shape and described in international standards



Part II: Legal standards in PQ metrology



Introduction to IEC standards in Power Quality



- Measurement methods and ranges implemented in PQ meters need to be verified
- Measurement methods implemented in PQ meters as well as functional test methods are covered by relevant IEC standards
- **More than 100 test methods + flicker**
- **it is not easy to maintain the traceability for all of them**



IEC standards for PQ



- **Basic: IEC 61000-4-30: Power quality measurement methods**
- **Edition 3, April 2015**
- **Important links to:**
 - IEC 62586 Power quality measurement in power supply systems
 - IEC 61000-4-7 EMC General guide on harmonics and interharmonics....
 - IEC 61000-2-4 EMC Compatibility levels in industrial plants for LF installations
 - IEC 61000-4-15 EMC Flickermeter



IEC 61000-4-30



- EMC Part 4-30: Testing and measurement techniques - Power quality measurement methods
- „...**defines the methods for measurement and interpretation of results for PQ parameters** in a.c. power supply systems with a declared fundamental frequency of 50 Hz or 60 Hz...”
- „...addresses measurement methods for **in-situ measurements**...”
- „..... measurement methods are described in terms of **reliable and repeatable results** regardless of the method’s implementation...”



IEC 61000-4-30



- **PQ parameters measurement considered** in this standard:
 - Frequency
 - Magnitude of supply voltage
 - Flicker
 - Supply voltage dips and swells
 - Voltage interruptions
 - Transient voltages
 - Supply voltage unbalance
 - Voltage harmonics and interharmonics
 - Mains signalling on the supply voltage
 - Rapid voltage changes
 - Current measurement
 - Informative: Under- and overdeviations, emissions in 2 -150 kHz



IEC 61000-4-30



- **Instruments:**

- Class A: more accurate as Class S
wider measurement range
- Class S: less accurate as Class A
not so wide measurement range as Class A
less methods implemented
- Class B: moved to informative annex and considered for future removal



IEC 61000-4-30



- **Relevant for:**

- Producers of PQ meters while developing of the new devices
- Energy producers and distributors to assist with interpretation of results (to ensure secure supply)
- „Test methods for verifying compliance with this standard can be found in **IEC 62586-2.**“

(in previous edition the tests were different and were part of EMC 4-30)



IEC 62586



- Power Quality Measurement in Power Supply System

Part 1: PQ instruments

- Edition 1: 2013
- Product and performance requirements for PQ instrumentation in power supply systems:
 - Safety requirements
 - EMC requirements,
 - Climatic requirements
 - Mechanical requirements

Part 2: Functional tests and uncertainty requirements

- **NEW EDITION 2:2017**
- Functional tests and uncertainty requirements for PQ instrumentation in power supply systems:
 - Functional testing procedures for verifying measurement methods implemented according to IEC 61000-4-30



IEC 62586-2



- **Functional tests considered** in this standard:
 - Power frequency
 - Magnitude of supply voltage
 - Flicker
 - Supply voltage interruptions, dips and swells
 - Supply voltage unbalance
 - Voltage harmonics and interharmonics
 - Mains signalling on the supply voltage
 - Underdeviation and overdeviation
 - Flagging
 - Clock uncertainty testing
 - Variation due to external influence quantities (temperature, power supply voltage)



IEC 62586-2



- **NEW EDITION: consider testing of current measurement methods!**
(magnitude, harmonics, interharmonic, unbalance)
- **More than 100 test methods + flicker tests** (according to IEC 61000-4-15)
- cca 200 test points for Class A + flicker testing !!!
- Latest date to be implemented at national level: 25 Feb 2018
- Latest date the previous national standards in conflict with this standard have to be withdrawn: 25 Aug 2020



IEC 62586-2 – how to work with?



- **Test description:**
 - target of the test
 - test points (Table 3)
 - complementary test conditions (influence quantities: description or link to Table 4-6)
 - test criterion (Table 7)
 - (Test duration)
- **Uncertainty requirements:** Table 16 (magnitude and frequency)
- **Calculation of uncertainties:** Annexes, link to EMC-4-30



IEC 62586-2 – example



- Magnitude of supply voltage:

6.2.2.2 Variations due to single influence quantities

Each test shall last at least 1 s.

N°	Target of the test	Testing points according Table 3	Complementary test conditions according to Table 4	Test criterion (if test is applicable)
A2.3.1	Measure influence of frequency on measurement uncertainty (for further calculations as required in 8).	P3 for Voltage magnitude	S1 for Frequency	---
			S3 for Frequency	---
			S4 for Frequency	---
A2.3.2	Measure influence of harmonics on measurement uncertainty (for further calculations as required in 8).	P3 for Voltage magnitude	S1 for Harmonics	TC10/12(unc) on ch1 compared to a reference voltage

3 test points !



IEC 62586-2: test points in Table 3



Table 3 – Testing points for each measured parameter

Measured parameter	Class	Testing point P1 ^a	Testing point P2 ^a	Testing point P3 ^a	Testing point P4 ^a	Testing point P5 ^a
Frequency 50 Hz ^b (covers 50 Hz)	A	42,5 Hz	50,05 Hz	57,5 Hz	50 Hz	N.A.
	S	42,5 Hz	50,05 Hz	57,5 Hz	50 Hz	N.A.
Frequency 60 Hz ^b (covers 60 Hz)	A	51 Hz	59,95 Hz	69 Hz	60 Hz	N.A.
	S	51 Hz	59,95 Hz	69 Hz	60 Hz	N.A.
Voltage magnitude	A	10 % U_{din}	45 % U_{din}	80 % U_{din}	115 % U_{din}	150 % U_{din}
	S	20 % U_{din}	45 % U_{din}	70 % U_{din}	95 % U_{din}	120 % U_{din}
Swells ^c	A	Threshold swell- ^d	Threshold swell+ ^d	110 % U_{din}	120 % U_{din}	200 % U_{din}
	S	Threshold swell- ^d	Threshold swell+ ^d	110 % U_{din}	120 % U_{din}	150 % U_{din}



IEC 62586-2 – example



- Magnitude of supply voltage:

6.2.2.2 Variations due to single influence quantities

Each test shall last at least 1 s.

N°	Target of the test	Testing points according Table 3	Complementary test conditions according to Table 4	Test criterion (if test is applicable)
A2.3.1	Measure influence of frequency on measurement uncertainty (for further calculations as required in 8).	P3 for Voltage magnitude <div>A 80 % U_{din} S 70 % U_{din}</div>	S1 for Frequency	---
			S3 for Frequency	---
			S4 for Frequency	---
A2.3.2	Measure influence of harmonics on measurement uncertainty (for further calculations as required in 8).	P magnitude	S1 for Harmonics	TC10/12(unc) on ch1 compared to a reference voltage



IEC 62586-2: complementary condition in Table 4



Table 4 – List of single "power system influence quantities"

Power system influence quantities	Class	Testing state S1 ^a	Testing state S2 ^a	Testing state S3 ^a	Testing state S4 ^a
Frequency: 1) for instruments covering both 50 Hz and 60 Hz frequencies	A	42,5 Hz	50 Hz	55,75 Hz	69 Hz
	S	42,5 Hz	50 Hz	55,75 Hz	69 Hz
2) for instruments covering only 50 Hz frequency	A	42,5 Hz	50 Hz	57,5 Hz	---
	S	42,5 Hz	50 Hz	57,5 Hz	---
3) for instruments covering only 60 Hz frequency	A	51 Hz	60 Hz	69 Hz	---
	S	51 Hz	60 Hz	69 Hz	---
Voltage magnitude	A	10 % U_{din}	---	200 % U_{din}	---
	S	10 % U_{din}	---	150 % U_{din}	---
Harmonics (in addition to the	A	^{c d}	---	---	---



IEC 62586-2



- Links to other standards where relevant
- To specify the test points
- **Links to:**
 - IEC 61000-4-15: Flickermeter
 - IEC 61000-4-7: General guide on harmonics and interharmonics...
 - IEC 61000-2-4: Compatibility levels in industrial plants for LF installations



IEC 61000-4-15



- **EMC Part 4-15:** Testing and measurement techniques – Flickermeter – Functional and design specification
- **Linked in EMC 4-30:**
 - Requirements on measurement methods.
- **Linked in IEC 62586-2:**
 - Tests shall be performed according to testing requirements described in EMC 4-15



IEC 61000-4-7



- **EMC Part 4-7:** Testing and measurement techniques- General guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected thereto
- **Linked in EMC 4-30:**
 - Definition of basic measurement method and uncertainty of voltage harmonics of Class A and S,
 - Calculation of THD of Class A and S,
 - Definition of basic measurement method and uncertainty of voltage interharmonics harmonics of Class A,



IEC 61000-2-4



- **EMC Part 2-4:** Environment – Compatibility levels in industrial plants for LF conducted disturbances
- **Linked in EMC 4-30:**
 - To specify measuring range of voltage harmonics and interharmonics of Class A and Class S instrument
- **Linked in IEC 62586-2:**
 - To specify testing points for harmonics and interharmonic



Conclusion



- **No primary intrinsic standard for power and PQ**
- The quantity **is derived** from:
 - I. Primary standards of AC-DC difference, DCV (traditional, especially for power)
 - II. Primary standards of DCV and time (sampling techniques, PQ)
- Important **PQ legal standards**:
 - IEC 61000-4-30: PQ instruments requirements
 - IEC 62586: Product and performance requirements and PQ functional tests
 - IEC 61000-4-15: Flickermeter
 - IEC 61000-4-7: Guide on harmonics and interharmonics
 - IEC 61000-2-4: Compatibility levels (harmonics and interharmonics)
- **Weak points** of legal standards: unclear paragraphs, errors



Thank you for your attention!