The certainty about measurement uncertainty during the assessment of harmonic emission

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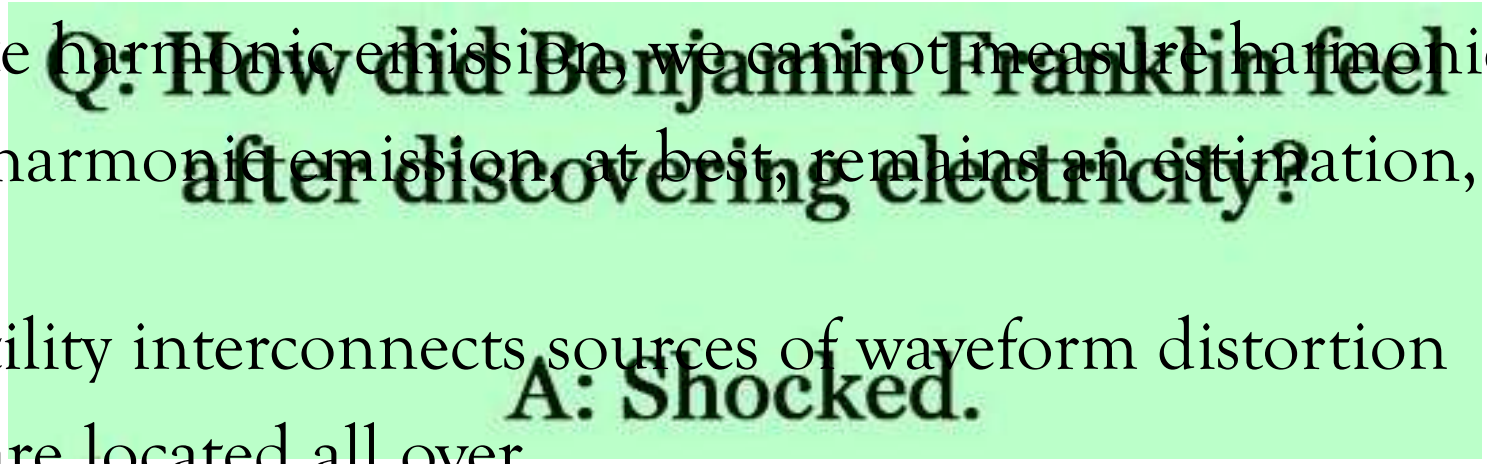
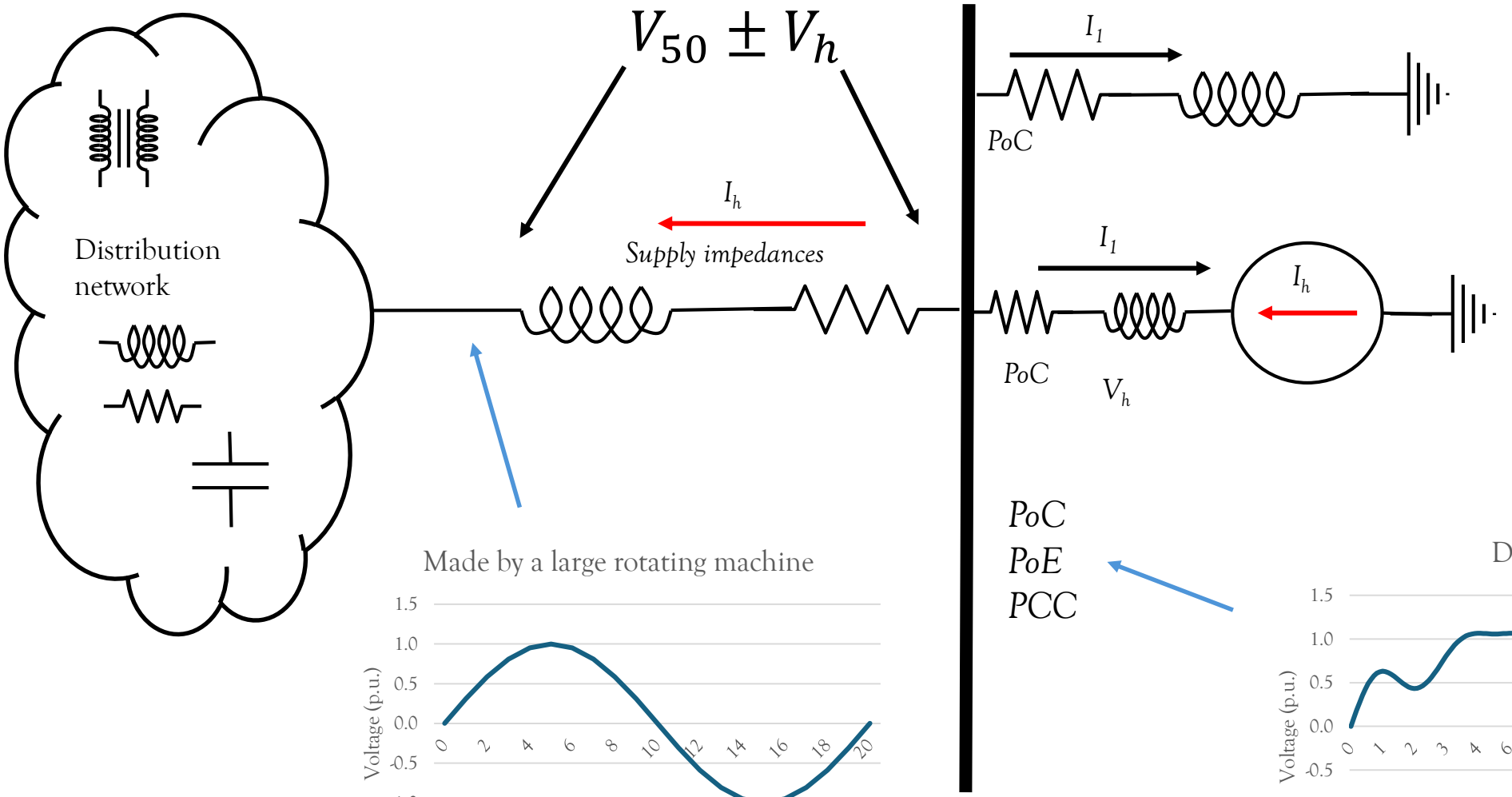
We cannot measure harmonic emission

- We can estimate harmonic emission, we cannot measure harmonic emission
- Assessment of harmonic emission, at best, remains an estimation, quantum is unknown.
- An electrical utility interconnects sources of waveform distortion
- These sources are located all over.
- Distribution networks host many types of distorting sources, with renewable generation potentially, a significant role-player
- A solid-state interface to inject, or to absorb, electrical energy.
- Non-linear principle of operation
- Ability to exchange harmonic active power between non-linear sources



Considerations on harmonic emission

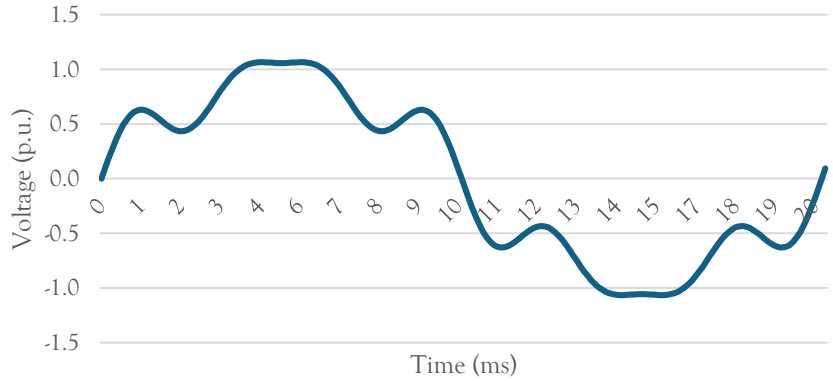


Linear loads only consume current

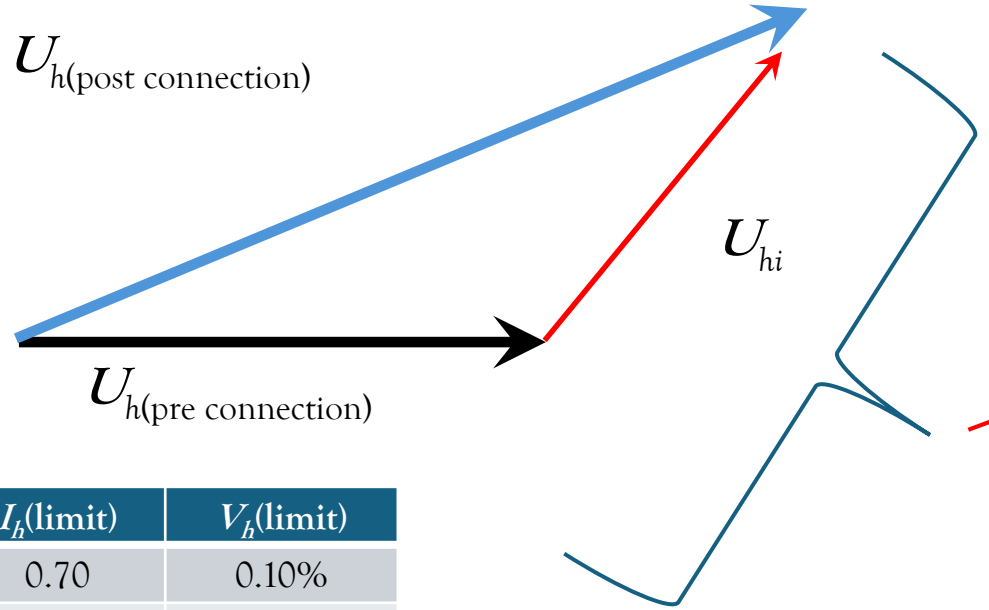
Non-linear loads consume 50 Hz current, convert some of the energy into higher frequencies, and then inject them – PV/Wind farm inject both 50 Hz and harmonic currents

Made by a large rotating machine

Distorted waveform



The IEC 61000-3-6 on harmonic emission



h	I_h(limit)	V_h(limit)
2	0.70	0.10%
3	0.47	0.10%
4	0.44	0.10%
5	0.61	0.22%
6	0.44	0.10%
7	0.44	0.22%
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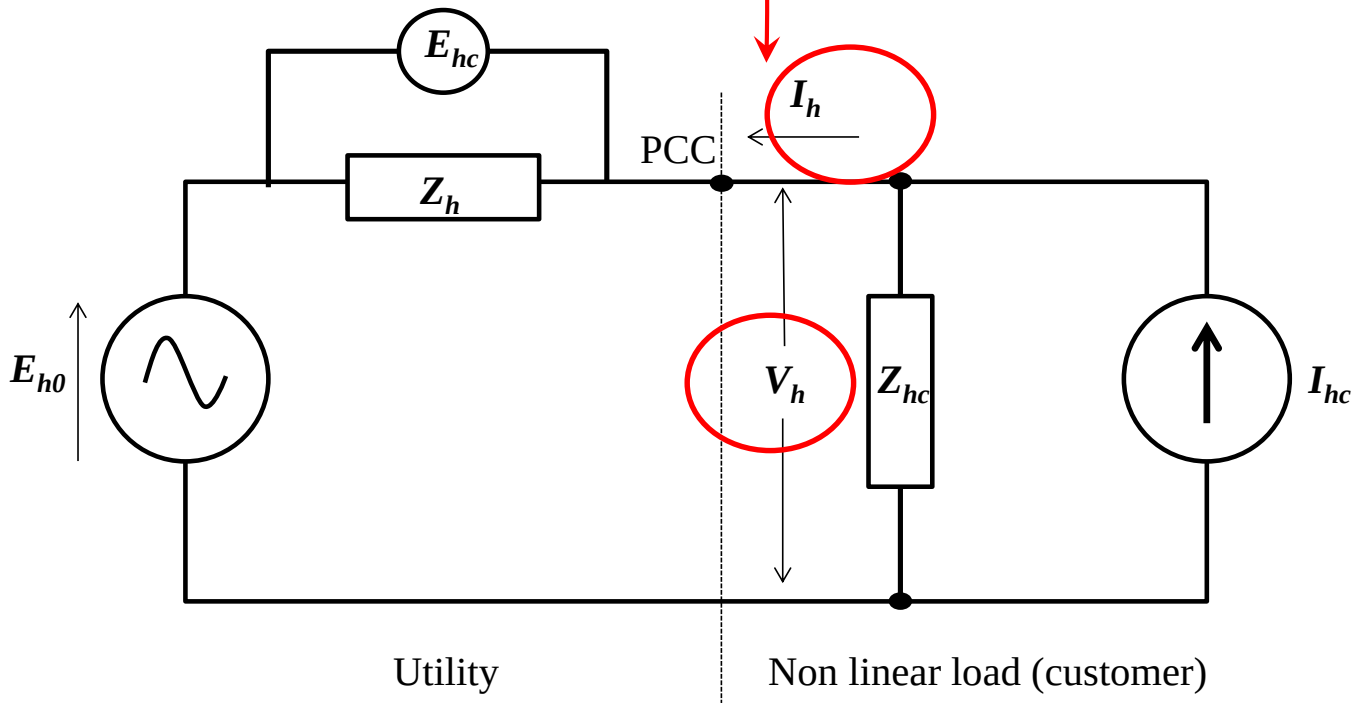
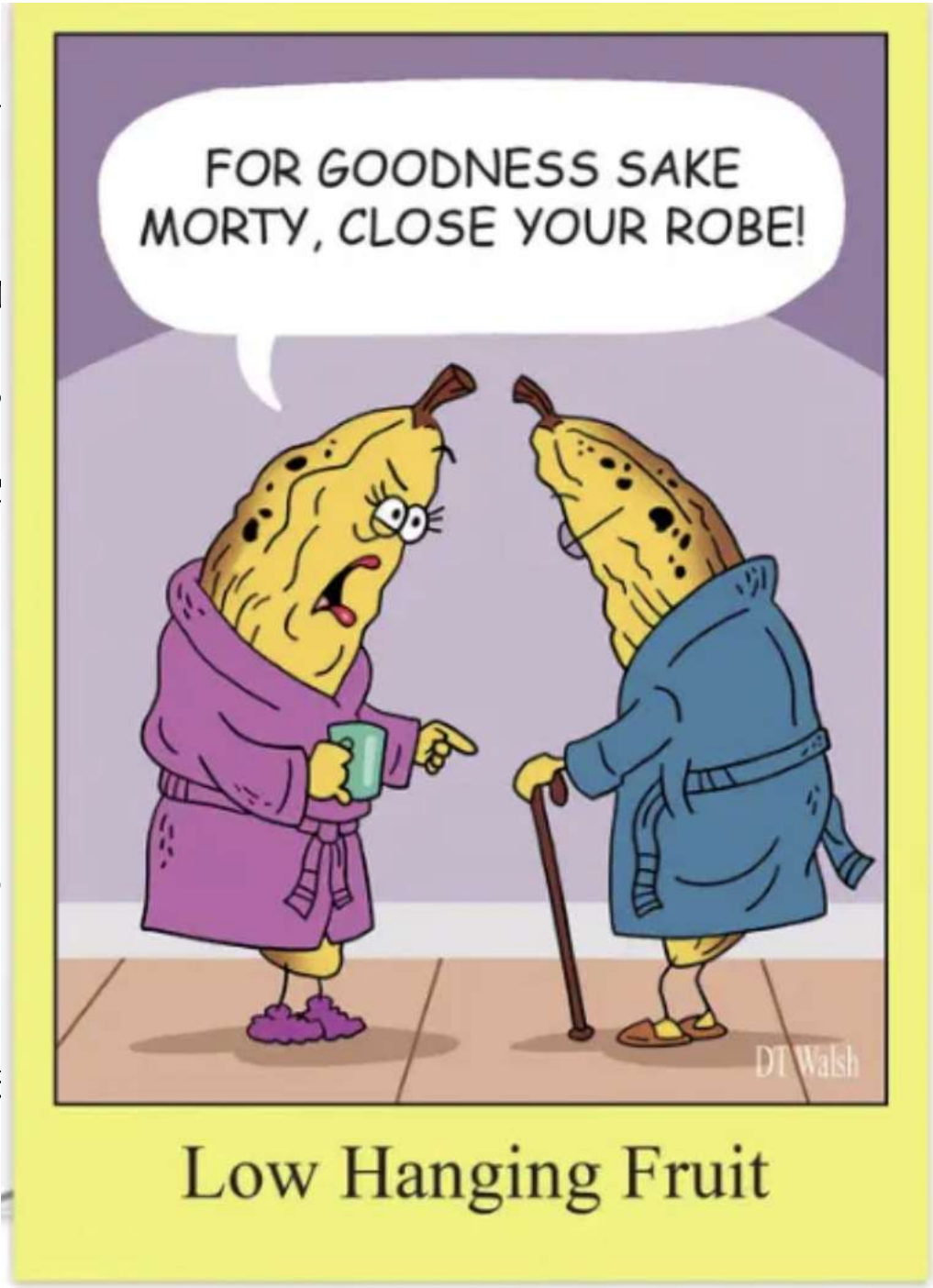


Containing the pollution: limits on emission

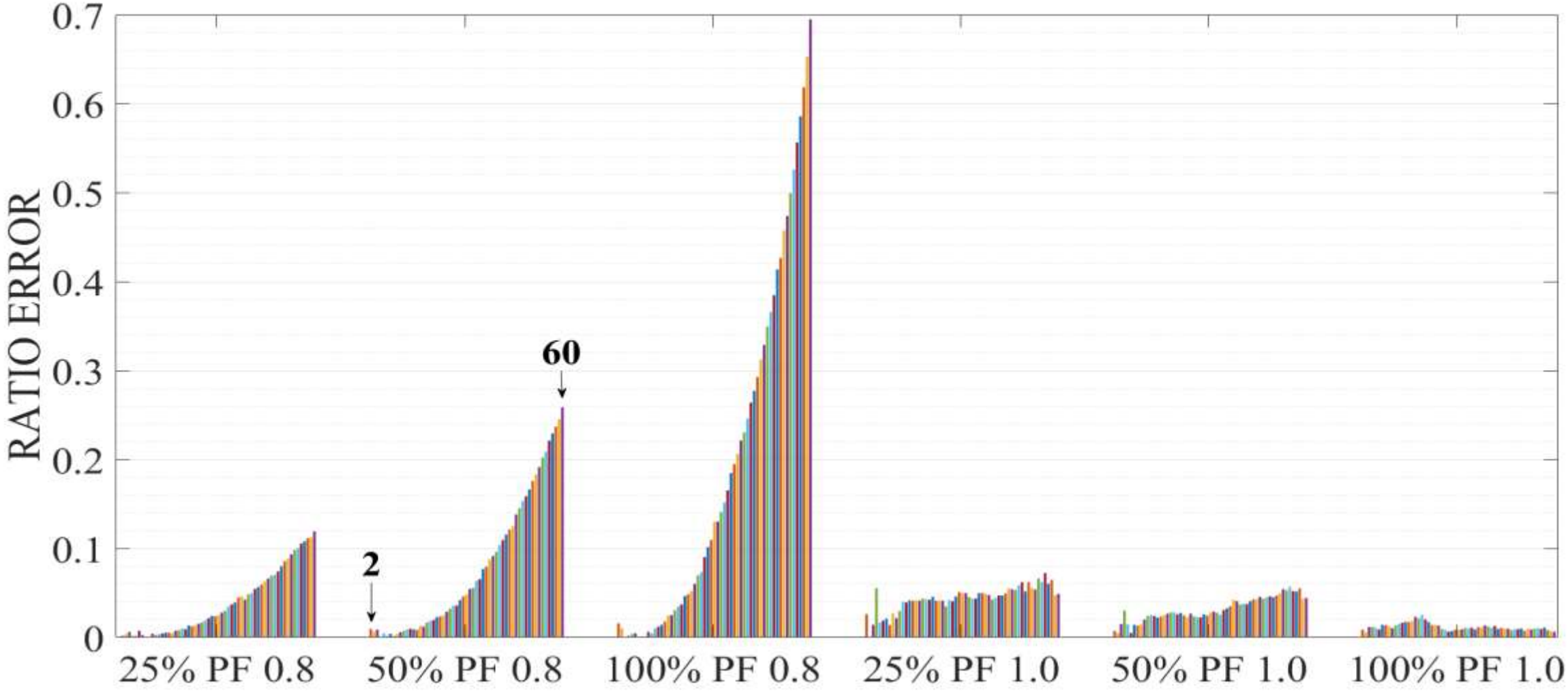
- Limits on the injection of harmonic currents – a contract between the user of the network and the owner of the network
- Owner calculates ”how much” harmonic currents can be tolerated at a PCC
- Process of apportioning- fundamental network principles – Ohm’s law
    - *Resistance is futile… unless you’re an electrical circuit!*
- IEC and other standards set guidelines - to be used in a contract
- How do you know that the user respect the contracted agreement?
- By the assessment of harmonic emission: ESTIMATION of what a single source contributes – cannot be MEASURED.

We can only remain uncertai

- Because we can only estimate, not measure har
- Current emission is the "cause" to voltage emis
  - *Sherlock Ohms is neede*
    - *"It is*
- Instruments are needed to measure current
- Digital data, to be analysed digitally
- From the real world – to the measurand in Exc
- Have not included the performance of the CT
- *All components in the measurement chain contribute*
- Let's focus on the low-hanging fruit



Influence of burden or error (PF 1.0 & PF 0.8) – 200/1, 22 kV



Harmonic emission - limits @ PoE, PoC, PCC

h	I_h(limit)	V_h(limit)
2	0.70	0.10%
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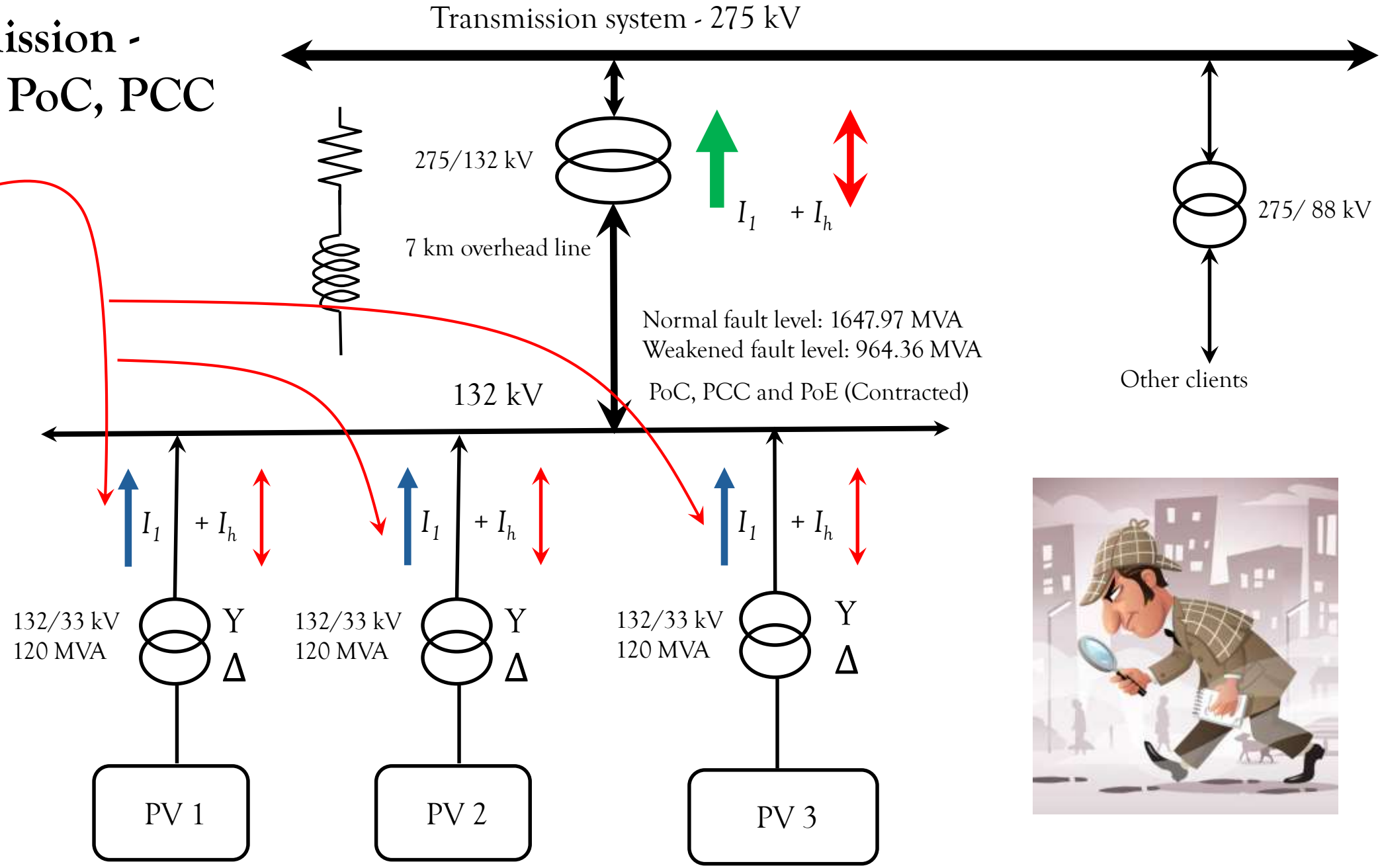
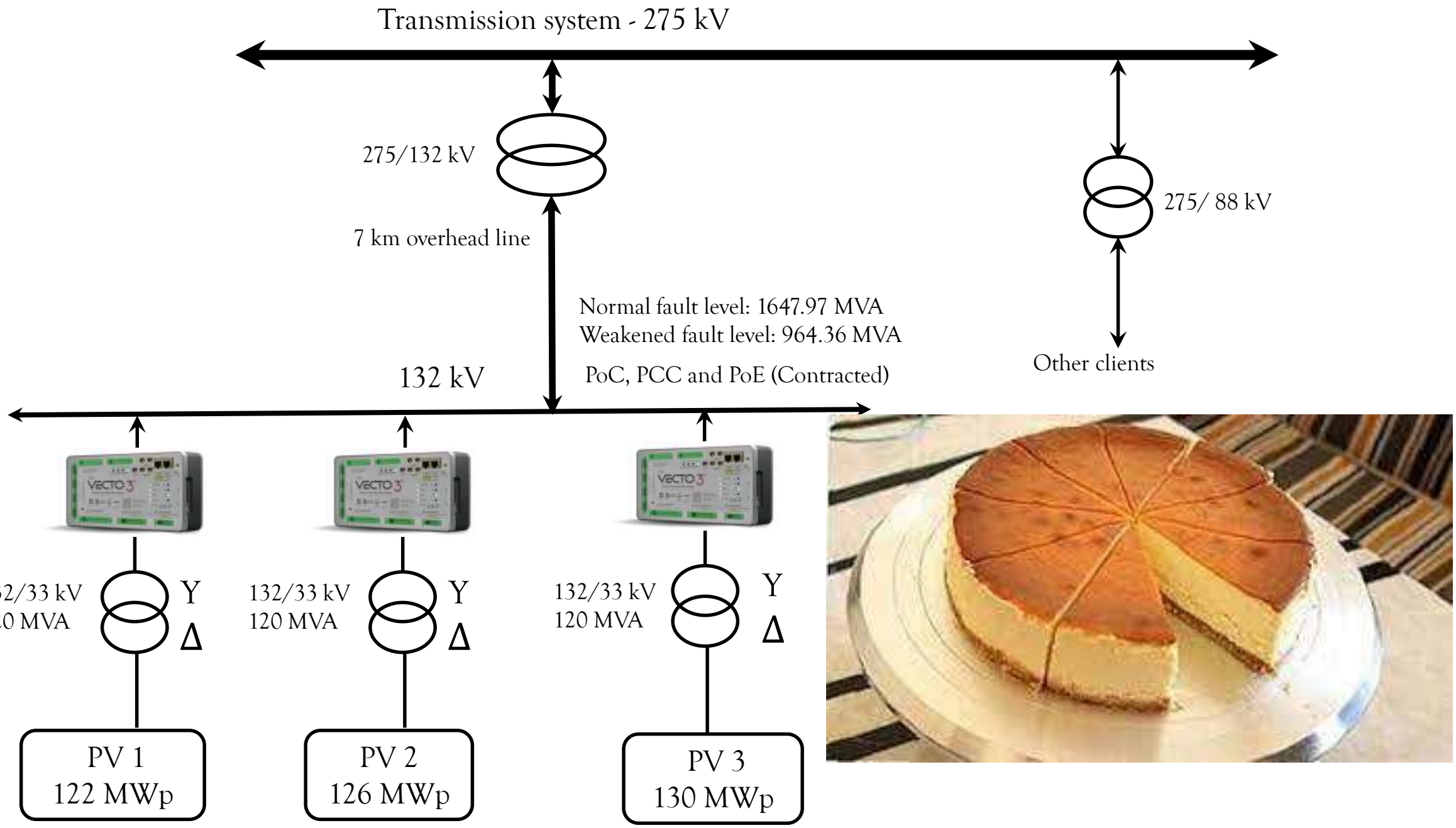
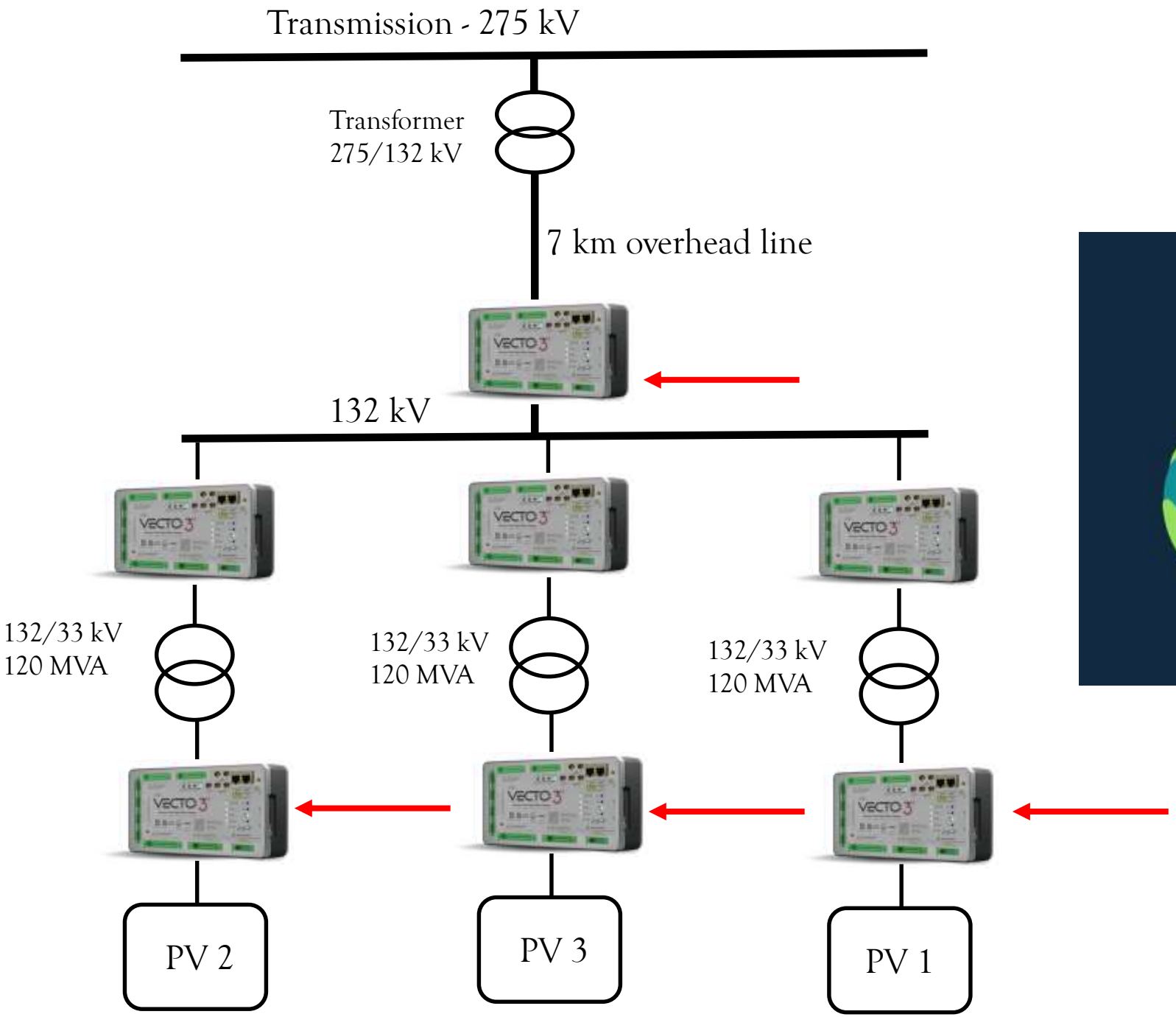
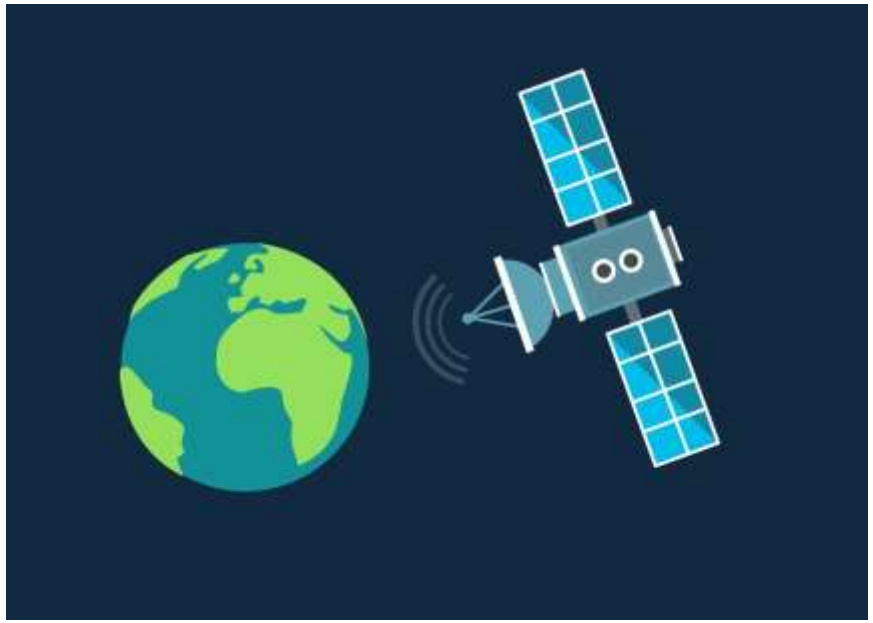


Considerations on the metrology

- Up to 132 kV, magnetic VT's – capacitive VT's – poorer f-response
- Measurement Class - CT and VT, Class 0.2 is common for instrumentation
- 0.2% Error at rated conditions (50 Hz, 5% - 120%) - IEC 61869-2
- 1 A rated secondary circuits increasingly exists.
- Instruments needs to produce useful data (certified, accurate and and)
- IEC 61000-4-30 Class A – Edition 4 on current - forensic quality data.
- The real world has to be translated into the digital world
- Analog to Digital conversion, subjected to measurement rules – 200 ms, filters – signal processing rules and and – to generate measurand visible in Excel


Transmission system - 275 kV
275/132 kV
7 km overhead line
275/ 88 kV
Other clients
Normal fault level: 1647.97 MVA
Weakened fault level: 964.36 MVA
PoC, PCC and PoE (Contracted)
132 kV
VECTO 3
VECTO 3
VECTO 3
132/33 kV
120 MVA
Y
Δ
132/33 kV
120 MVA
Y
Δ
132/33 kV
120 MVA
Y
Δ
PV 1
122 MWp
PV 2
126 MWp
PV 3
130 MWp


Transmission - 275 kV
Transformer
275/132 kV
7 km overhead line
132 kV
132/33 kV
120 MVA
132/33 kV
120 MVA
132/33 kV
120 MVA
PV 2
PV 3
PV 1



Resolution of measurement (1)

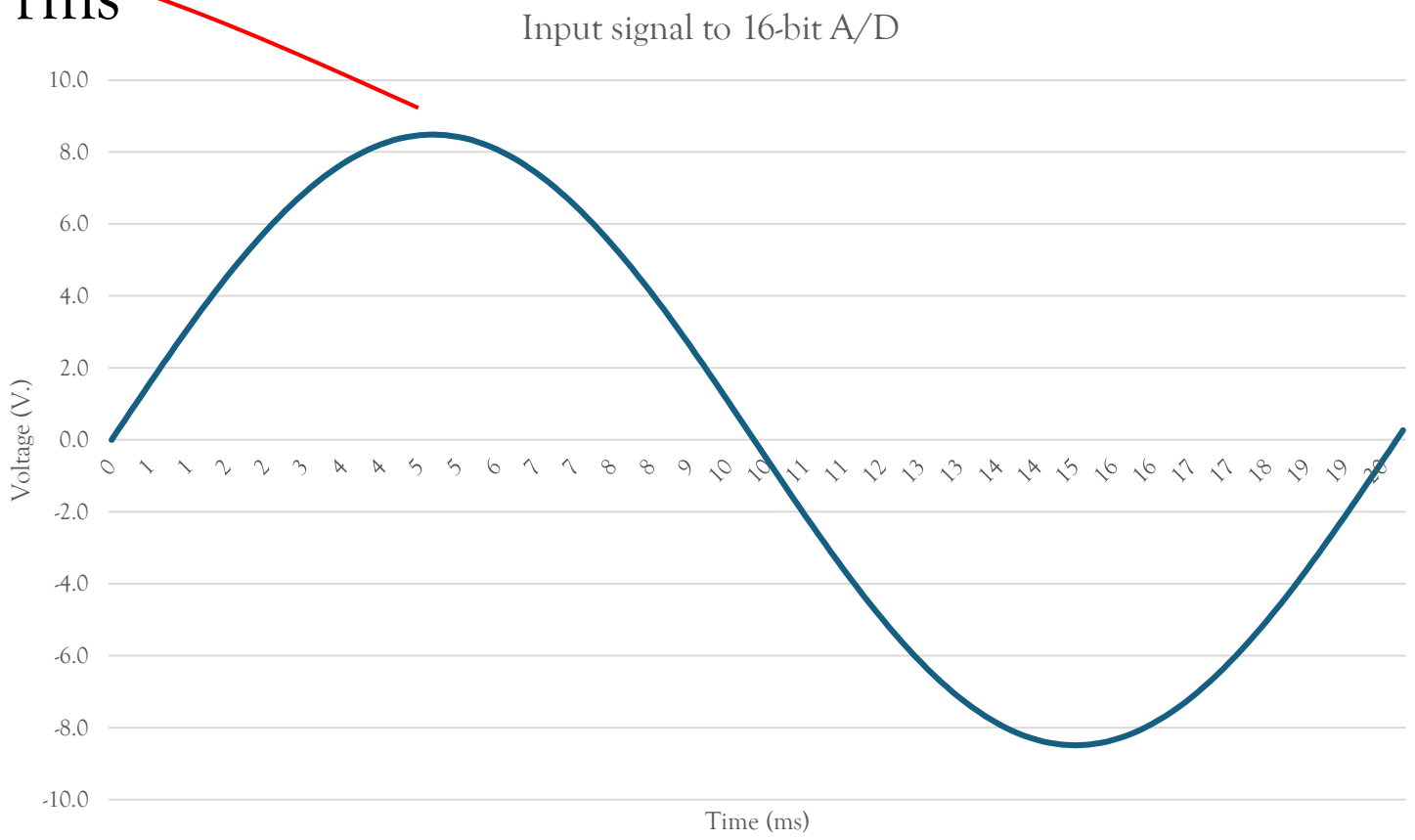
- Certified PQ instrument designed for 6 A (rms) secondary CT measurement
- 600:1 A CT
- 16-bit converter measuring 6 A rms

$$Resolution = 3 \times \left({}^{8.49}/_{2^{15}}\right)$$

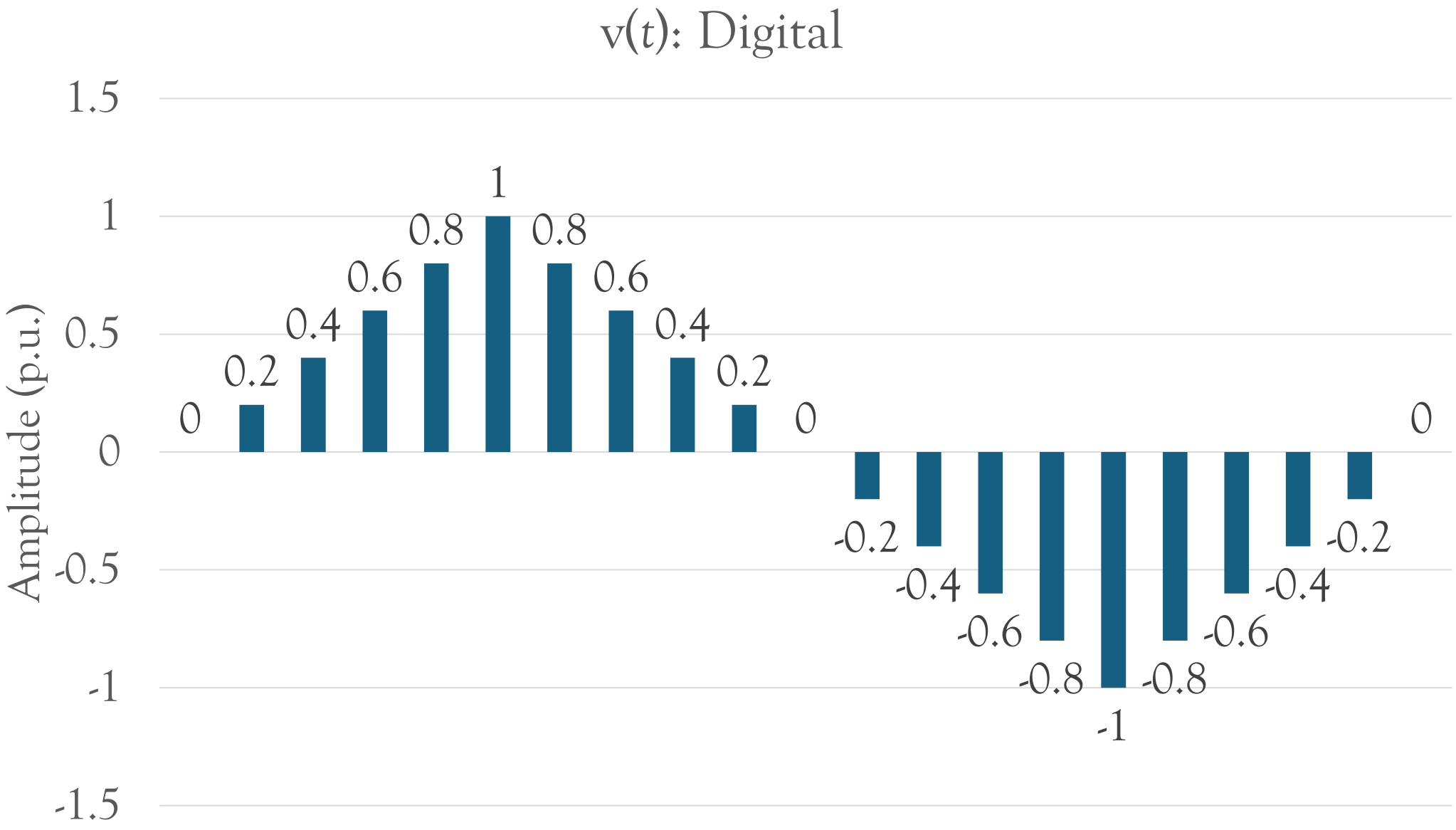
= 2.3 mA into instrument

= 0.47 A in primary circuit

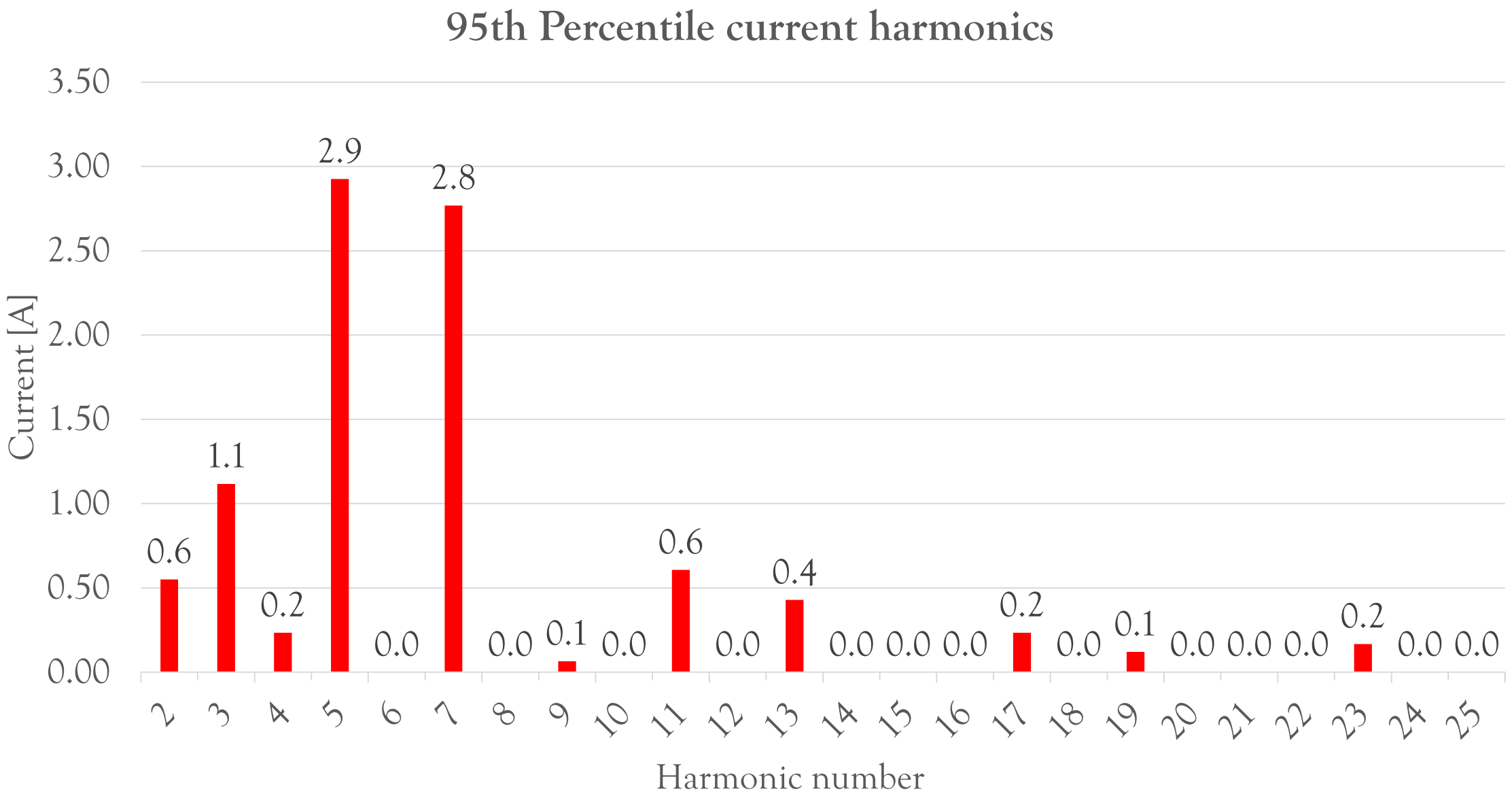
(0.0023 x 600)



Resolution of measurement (2)



Harmonic currents – 100 MW PV farm



Harmonic emission limits: measurement resolution

h	$I_{h(limit)}$	$I_{h(95\%)}$	$V_{h(limit)}$	$V_{h(95\%)}$
2	0.70	0.73	0.10%	0.05%
3	0.47	1.78	0.10%	0.23%
4	0.44	0.23	0.10%	0.00%
5	0.61	2.93	0.22%	0.88%
6	0.44	0.01	0.10%	0.00%
7	0.44	2.77	0.22%	0.49%
8	0.44	0.04	0.10%	0.00%
9	0.44	0.18	0.22%	0.06%
10	0.44	0.00	0.10%	0.00%
11	0.46	0.61	0.36%	0.19%
12	0.44	0.00	0.10%	0.00%
13	0.44	0.47	0.36%	0.29%
14	0.44	0.00	0.10%	0.00%
15	0.44	0.00	0.10%	0.00%
16	0.44	0.00	0.10%	0.00%
17	0.44	0.23	0.24%	0.14%
18	0.44	0.00	0.10%	0.00%
19	0.44	0.16	0.24%	0.20%
20	0.44	0.00	0.10%	0.00%

h	$I_{h(limit)}$	$I_{h(95\%)}$	$V_{h(limit)}$	$V_{h(95\%)}$
2	0.70	0.26	0.10%	0.05%
3	0.47	1.31	0.10%	0.22%
4	0.44	-0.23	0.10%	0.00%
5	0.61	2.45	0.22%	0.86%
6	0.44	-0.46	0.10%	0.00%
7	0.44	2.30	0.22%	0.48%
8	0.44	-0.42	0.10%	0.00%
9	0.44	-0.29	0.22%	0.05%
10	0.44	-0.47	0.10%	0.00%
11	0.46	0.14	0.36%	0.18%
12	0.44	-0.47	0.10%	0.00%
13	0.44	0.00	0.36%	0.28%
14	0.44	-0.47	0.10%	0.00%
15	0.44	-0.47	0.10%	0.00%
16	0.44	-0.47	0.10%	0.00%
17	0.44	-0.23	0.24%	0.14%
18	0.44	-0.47	0.10%	0.00%
19	0.44	-0.30	0.24%	0.20%
20	0.44	-0.47	0.10%	0.00%

So, we cannot assess compliance to harmonic emission?

- It is possible, sort of, yes, IF:
- You use an instrument, certified to IEC 61000-4-30, Class A + Edition 4 (or 3) BUT for both V&I
- That instrument at least a 16-bit A/D
- Realistic harmonic limits: apportioning (mathematics) to calculate limits > spreadsheet – pragmatic
- And, if you know what method to apply
- To identify those current harmonics that increase the network (background) voltage harmonic
- And, < harm no 17
- Then, sort of possible.....
- Yes, because: *Results(t)* – *The Truth is NOT Social*