Power Quality challenges of new equipment

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Vladimir Ćuk, Assistant Professor, v.cuk@tue.nl

Electrical Engineering, Electrical Energy Systems

TKI URBAN ENERGY
Topsector Energie

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

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Effect of supraharmonic on smart meters

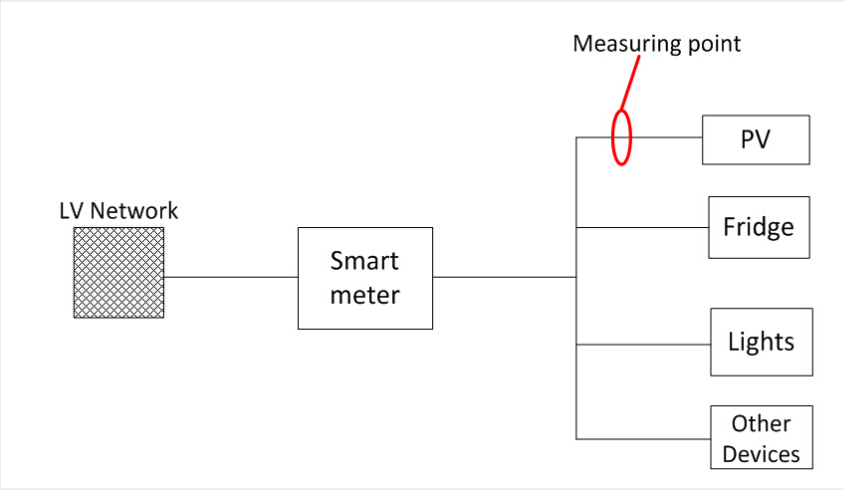
Smart meters and supraharmonics - Introduction

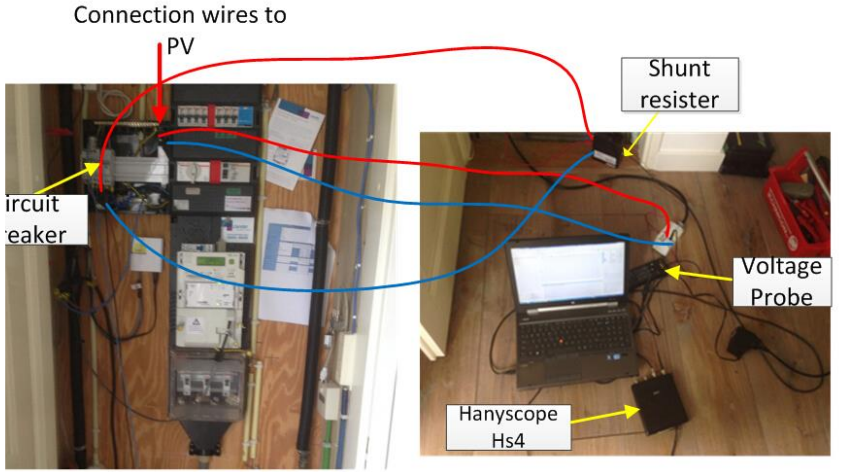
- Smart meter found to have wrong readings in a home
- “Suspicious” equipment – PV inverter
- Very large deviations of the readings assumed – in the order of 50 % from expected consumption/generation

Reference: MSc thesis of Liang Jiang, TU Eindhoven, 2014

Field and Laboratory tests of PV inverter emission

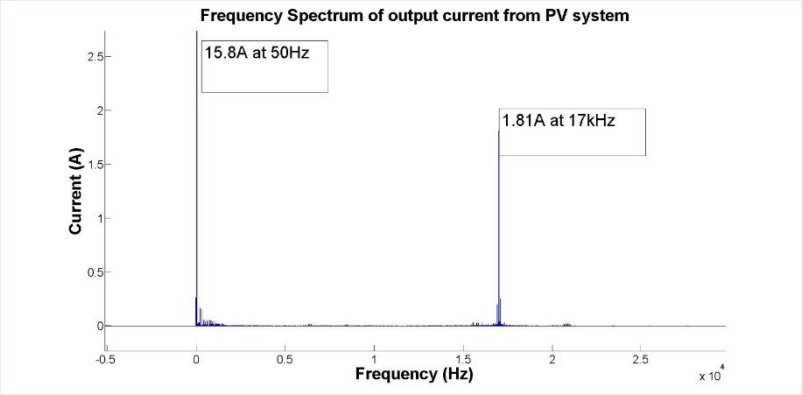
- Field measurements showed a strong 17 kHz component (both I and V)
- Component not present with the PV system switched off

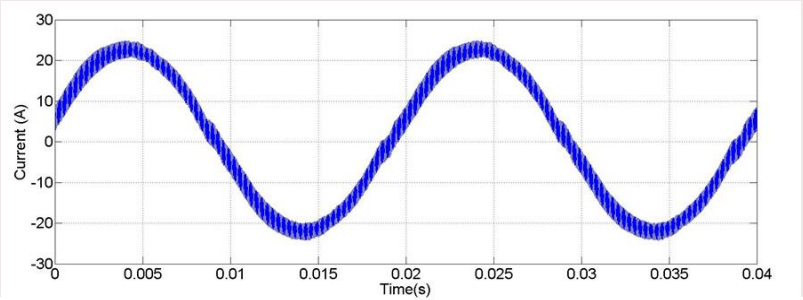




Emission results – lab testing

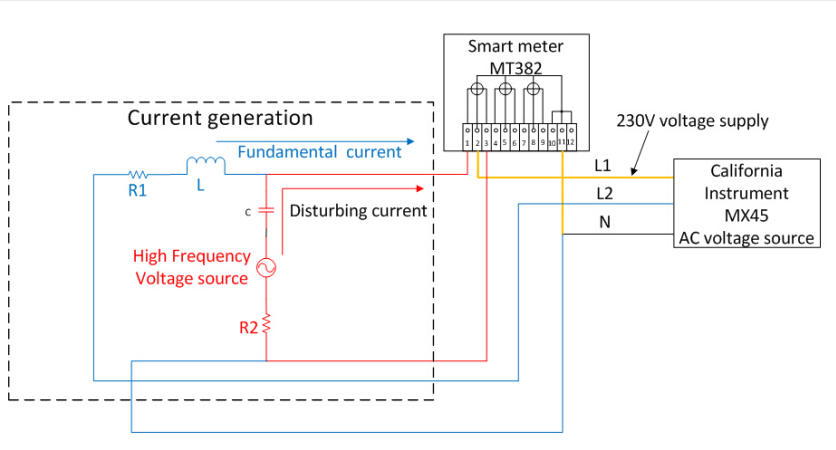
- Current THD measured up to 2kHz < 5 % - complies with emission requirements
- Current component at 17kHz ~ 2 A (~11 %, passed compliance testing)!





Immunity testing of a Smart Meter

- Susceptibility of the meter tested in the lab
- HF injection added to the current measurement
- Controllable injections up to 20 kHz, next to a 50 Hz signal



Results of immunity measurements

- Measurements not affected significantly by LF emissions (<2 kHz)
- Supraharmonic emissions can lead to very significant deviations

Fundamental current		2 A disturbing current at 5 kHz		2 A disturbing current at 10 kHz		2 A disturbing current at 15 kHz		2 A disturbing current at 17 kHz		2 A disturbing current at 20 kHz	
Various values (A)	Expected power (kW)	Registered power (kW)	Deviation (%)	Registered power (kW)	Deviation (%)	Registered power (kW)	Deviation (%)	Registered power (kW)	Deviation (%)	Registered power (kW)	Deviation (%)
5A	1.158	0.88	-35,4%	0.88	-35,4%	0,69	-40,4%	0.85	-26,6%	0.77	-33,5%
10A	2.29	1.76	-23.1%	1.76	-23.1%	1.34	-41.5%	1.44	-37.1%	1.59	-30.6%
15A	3.48	3.36	-3.41%	2.05	-41.1%	1.71	-50.8%	1.82	-47.7%	2.49	-28.4%

Conclusions of the study

- Current probe linear in the range < 2 kHz, requires filtering for higher frequencies
- Current testing of Smart Meters does not cover such interferences
- Does not occur with all energy meters and/or PV inverter
- Large current rate of change dI/dt can lead to errors with Rogowski coils
- Problem solvable with filtering/software, it is most important to be aware of the possible interference

Results from UTwente and VSL

- 16 types of meters from 10 manufacturers tested
- Test includes also on-site measured waveforms
- Errors as large as several hundreds of % found in some cases
- Clear need for including certain new test waveforms in compliance testing of meters

References:

- H. van den Brom et.al., “EMC Testing of Electricity Meters Using Real-World and Artificial Current Waveforms”, IEEE Trans. on EMC, VOL. 63, NO. 6, December 2021.
- T. Hartman et.al.,” Susceptibility of Static Energy Meters Due to Amplifier Clipping Caused by a Rogowski Coil”, IEEE Trans. on EMC, Early Access Article, 2022.

Voltage flicker due to LED-dimmer interactions

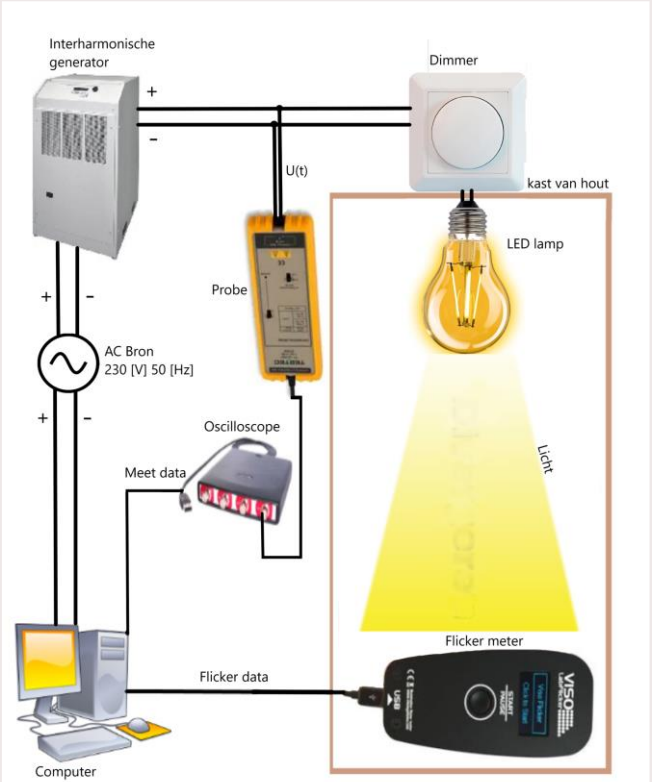
Introduction

- Flicker complaints registered in the Eindhoven region
- Voltage measurements showed compliance to EN 50160
- Correlation to Ripple Control Signals noticed – mains signalling on 492Hz and 1042Hz
- Enexis (DSO) narrowed down the problems to specific LED + dimmer combinations, with all devices compliant to flicker requirements

Project: “Flicker of LED lamps with Dimmers due to Ripple Control Signals”, T.E. Castelo de Oliveira, V. Cuk (TU/e), S. Bhattacharyya and W. Oldenburg (Enexis), December 2020.

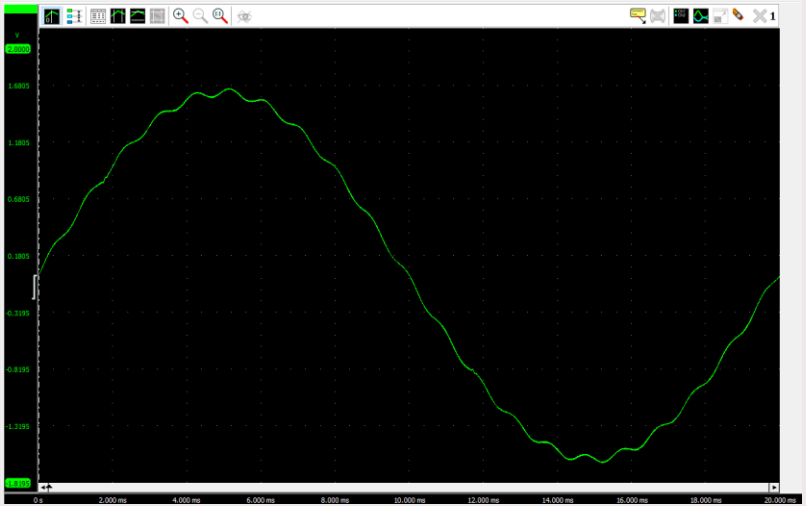
Laboratory testing

- Testing done based on visible flicker (not electrical measurements)
- Interharmonic voltages superimposed to the 50 Hz supply
- 5 V and 10 V levels used < mains signalling levels
- 15 lamp-dimmer combinations tested



Applied ripple control signals

5 V @ 492 Hz



5 V @ 1042 V

Results

- Flicker index, SVM and PstLM are characteristics of light intensity variations (not a part of Pst measurement)
- Case 1 – 5V, 1042 Hz, 100 % intensity
- Case 2 – 10V, 1042 Hz, 100 % intensity
- Case 3 – 5V, 1042 Hz, 50 % intensity
- Case 4 – 10V, 1042 Hz, 50 % intensity

Combinations	Case	Flicker Index	SVM	PstLM	Observed Naked eye Fliker
1st	1	0.04	0.44	0.73	1
	2	0.03	0.42	1.36	1
	3	0.03	0.4	1.55	2
	4	0.12	1.5	5.19	2
2nd	1	0.01	0.09	0.81	1
	2	0.01	0.09	2.39	2
	3	0.01	0.06	0.49	1
	4	0	0.06	2.85	2
3rd	1	0.08	0.92	0.34	1
	2	0.07	0.92	0.76	1
	3	0.11	1.33	13.8	4
	4	0.07	0.92	0.76	5
4th	1	0	0.01	0.21	1
	2	0	0.01	0.16	1
	3	0	0.01	0.51	1
	4	0	0.05	2.47	1
5th	1	0.06	0.79	0.06	1
	2	0.06	0.76	1.01	1
	3	0.07	0.87	0.63	1
	4	0.07	0.83	3.8	2
6th	1	0.01	0.04	2.13	1
	2	0	0.04	2.14	1
	3	0	0.01	0.14	1
	4	0	0.01	0.28	2
7th	1	0.01	0.1	0.71	1
	2	0.01	0.09	0.99	1
	3	0.01	0.08	0.47	1
	4	0.01	0.06	3.33	1
8th	1	0.05	0.6	0.15	1
	2	0.05	0.59	0.32	1
	3	0.12	1.35	11.92	3
	4	0.12	1.33	30.33	5
9th	1	0.03	0.36	1.46	1
	2	0.04	0.46	1.43	1
	3	0.03	0.37	1.6	1
	4	0.03	0.39	3.14	2
10th	1	0	0	1.54	1
	2	0	0	0.3	1
11th	1	0.02	0.23	0.38	1
	2	0.03	0.4	0.24	1
12th	1	0.01	0.08	0.14	1
	2	0.01	0.08	0.16	1
13th	1	0.05	0.59	0.65	1
	2	0.05	0.59	0.82	1
14th	1	0	0.01	0.02	1
	2	0	0.01	0.02	1
15th	1	0.05	0.59	0.65	1
	2	0.04	0.49	0.16	1

Conclusions

- In some LED-dimmer combinations, voltage complying to Pst and mains signalling requirements leads to visible (or measured) flicker
- Power line communication (ripple control) triggers the interaction
- The key is in test conditions, lamps/dimmers from other manufacturers lead to LF oscillations not seen from the same brand

Effect of supraharmonics on RCDs

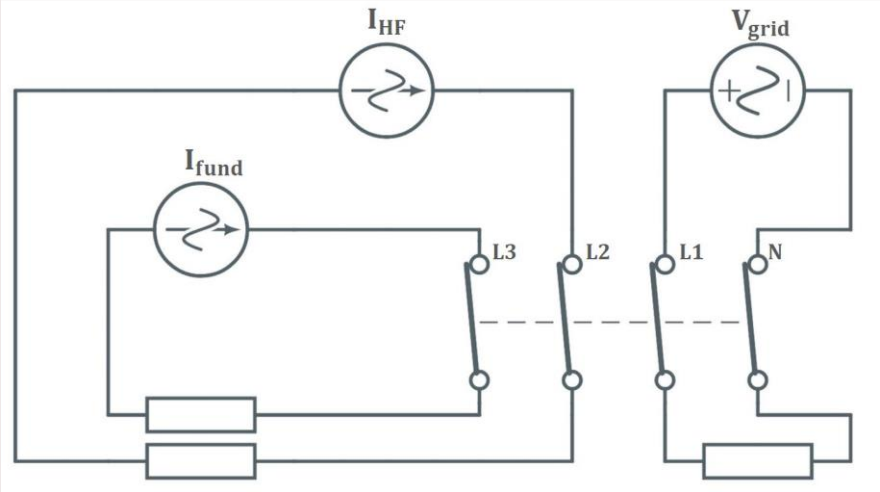
Introduction

- Residual Current Devices (RCDs) have test requirements defined for 50 Hz, pulsating and DC leakage currents
- Previously some negative effects were observed with LF harmonics included (reduced or increased sensitivity)
- The objective was to analyse the impact of supraharmonic currents on the operation of RCDs

Reference:
T. M. H. Slangen, B. R. F. Lustenhouwer, V. Ćuk and J. F. G. Cobben, “The Effects of High-Frequency Residual Currents on the Operation of Residual Current Devices”, in Proc. ICREPQ 2021

Laboratory testing

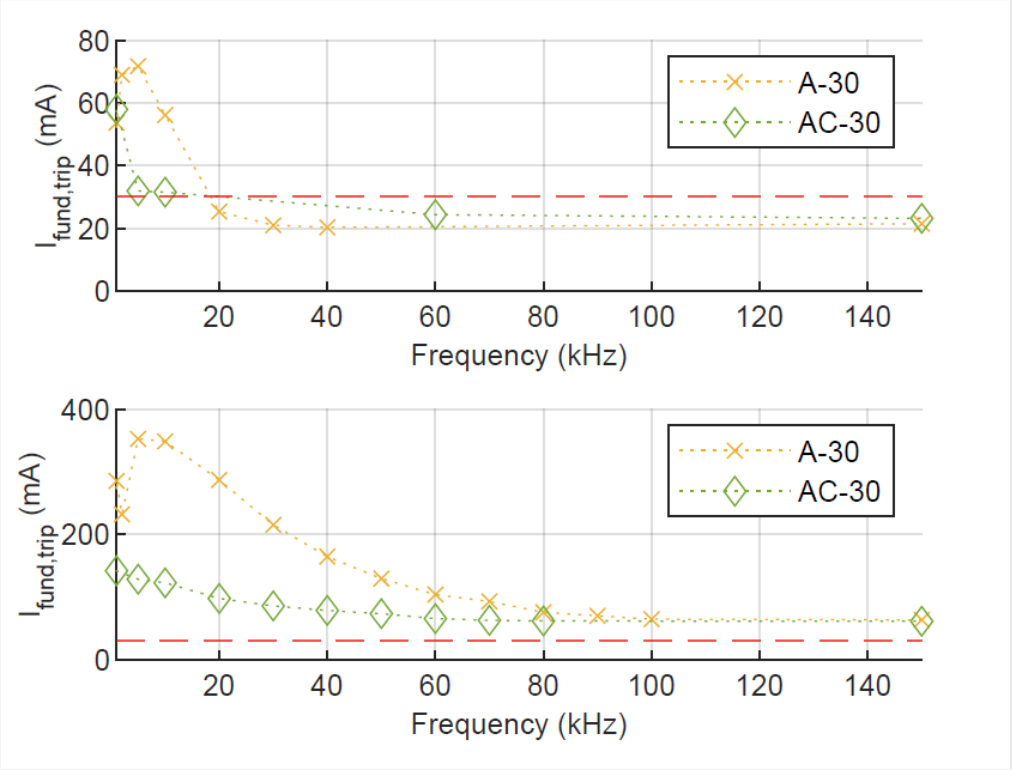
- Superposition of 50 Hz and supraharmonic fields created via different phases of the RCD
- Individual and both components can be injected
- 10 repetitions per test condition



Results

800 mA

1300 mA



Conclusions

- A-30 and AC-30 show a significant increase in fundamental tripping current in the presence of a high-frequency leakage current – safety risk!
- In general, a higher residual current is needed to operate the RCDs for higher frequencies ,exception is B-30 type with a reduction