On-site capture of critical waveforms at meter connection points

Presenter: Bas ten Have

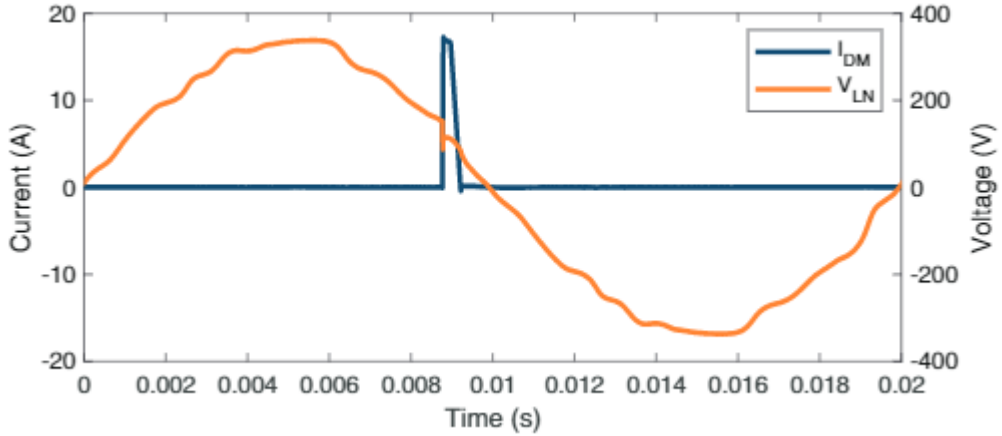
Affiliation: University of Twente

bas.tenhave@utwente.nl

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

Motivation

- Static energy meters showed errors caused by conducted electromagnetic interference (EMI).
- After consumer complaints, laboratory studies pinpointed several of these EMI cases [1].
- Interference signals showed pulsed currents with high crest factor, slope, and narrow pulse duration [2]:



- Limited information is available about general on-site situations.
- Determine the existence of similar critical waveforms in realistic situations.

[1] B. ten Have et al., "Faulty Readings of Static Energy Meters Caused by Conducted Electromagnetic Interference from a Water Pump", in *Renewable Energy and Power Quality Journal (RE&PQJ)*.
[2] B. ten Have et al., "Waveform Model to Characterize Time-Domain Pulses Resulting in EMI on Static Energy Meters," *IEEE Transactions on Electromagnetic Compatibility (Early Access)*.

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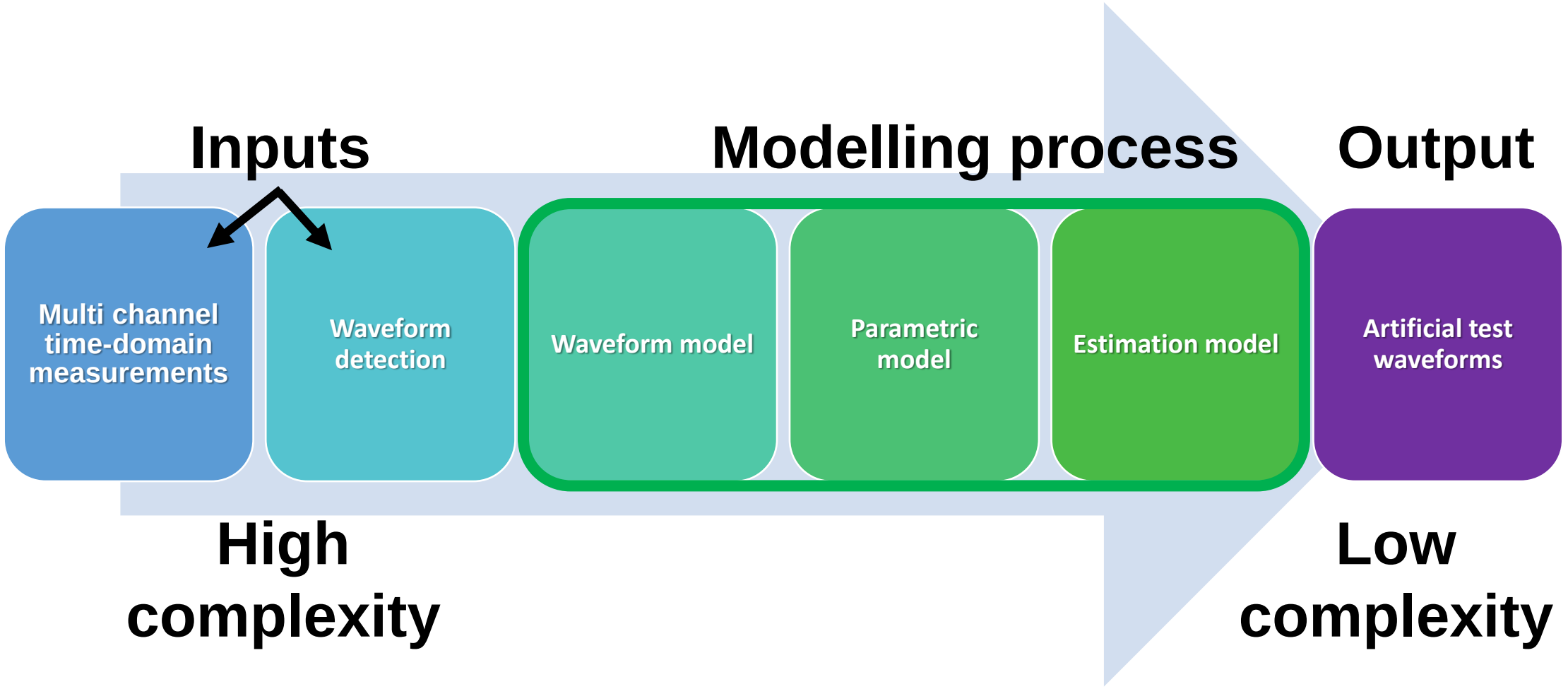
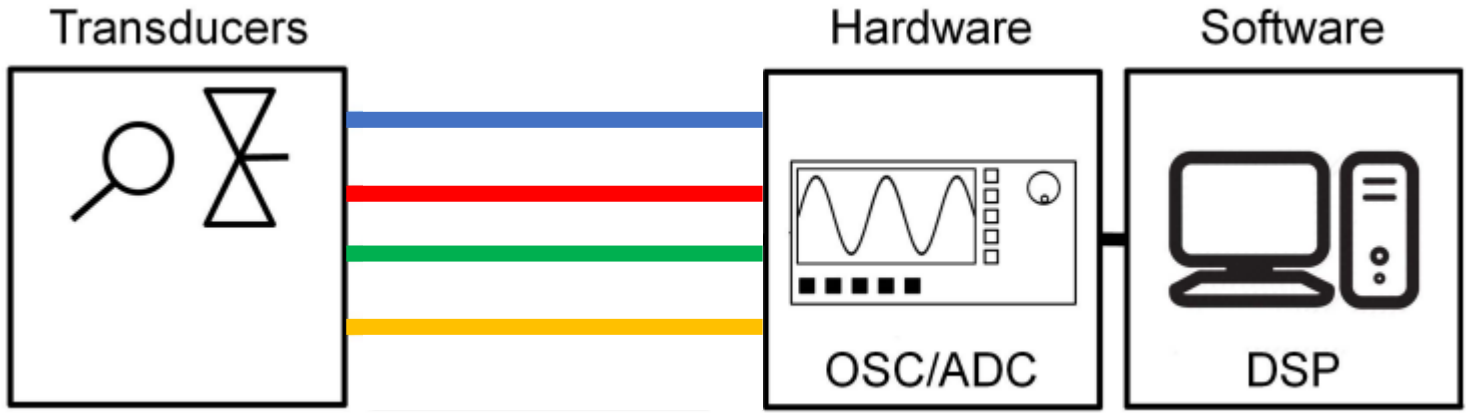
Overview


Inputs
Modelling process
Output
Multi channel time-domain measurements
Waveform detection
Waveform model
Parametric model
Estimation model
Artificial test waveforms
High complexity
Low complexity

Measurement method

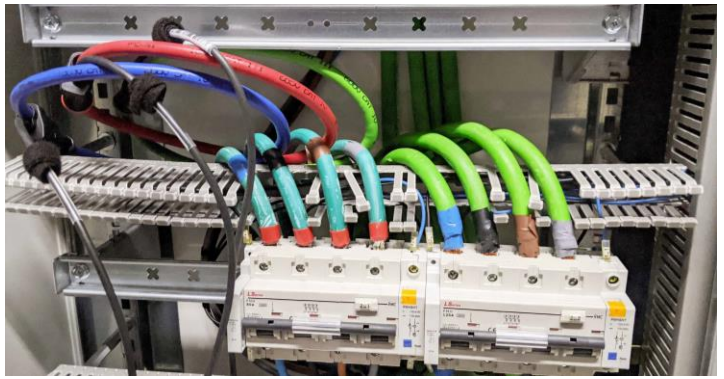
- Measurements at meter connection point.
- Waveforms are captured for 10 days (per site).
- Smart triggering software is used to only capture pulsed currents of interest [3], [4].
- Flexible current probes.
- Multi channel synchronous time-domain EMI measurement and processing system [5]:



[3] T. Hartman et al., "On-site Waveform Characterization at Static Meters Loaded with Electrical Vehicle Chargers," *EMC Europe 2019.*
[4] B. ten Have et al., "On-Site Waveform Survey in LV Distribution Network using a Photovoltaic Installation," *EMC Europe 2020.*
[5] M. A. Azpúrua et al., "Waveform Approach for Assessing Conformity of CISPR 16-1-1 Measuring Receivers," *IEEE Transactions on Instrumentation and Measurement.*

Measurement locations

- Measurements are performed at a representative range of installations in different countries.
- Measured sites:
    1. Site 1: Spain
        - Photovoltaic installation
    2. Site 2: Spain
        - Electric vehicle charging station
    3. Site 3: The Netherlands
    4. Site 4: Norway
        - Photovoltaic installation
    5. Site 5: Norway
    6. Site 6: Norway
        - Photovoltaic installation & electric vehicle charging station



Estimation of critical waveforms

- A total of 25,717 waveforms was captured → post-processing to select critical waveforms.
- Detect on-site surveyed waveforms with similar characteristics as waveforms in lab experiments.

Reference data set

- Laboratory experiments of which the static energy meter errors are accurately known.
- Data set contains the waveform parameters [2] and measured static energy meter error:

$$\left\{CF_1 ; \frac{\Delta I_1}{\Delta t} ; t_{\text{duration},1}\right\} \quad e_1$$
$$\left\{CF_2 ; \frac{\Delta I_2}{\Delta t} ; t_{\text{duration},2}\right\} \quad e_2$$
$$\vdots \qquad \vdots$$
$$\left\{CF_n ; \frac{\Delta I_n}{\Delta t} \; t_{\text{duration},n}\right\} \quad e_n$$

On-site surveyed waveforms

- Characterized by parameters, but unknown error.

$$\left\{CF_u ; \frac{\Delta I_u}{\Delta t} ; t_{\text{duration},u}\right\} \qquad e_u = ?$$

Estimator

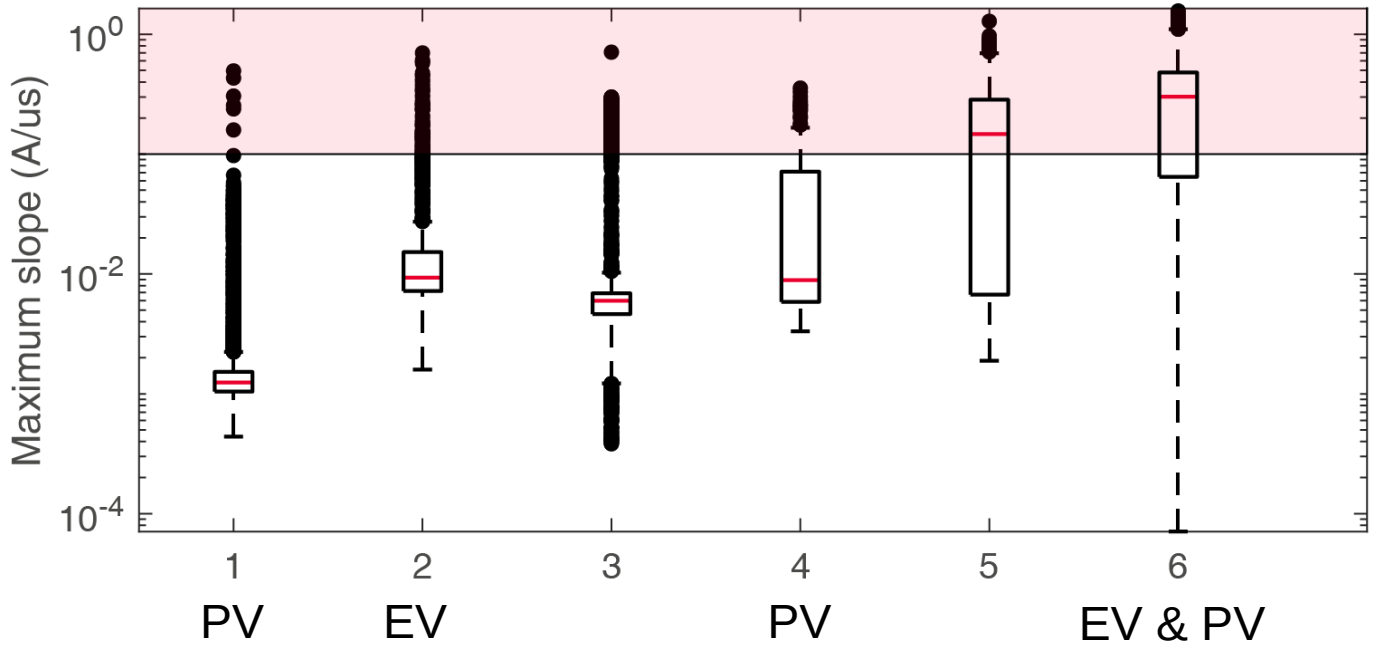
- Similar waveforms result in similar errors.
- Interpolate the on-site parameters to reference data set to estimate the EMI.

→ Detect similar waveforms.

[2] B. ten Have et al., "Waveform Model to Characterize Time-Domain Pulses Resulting in EMI on Static Energy Meters," *IEEE Transactions on Electromagnetic Compatibility (Early Access).*

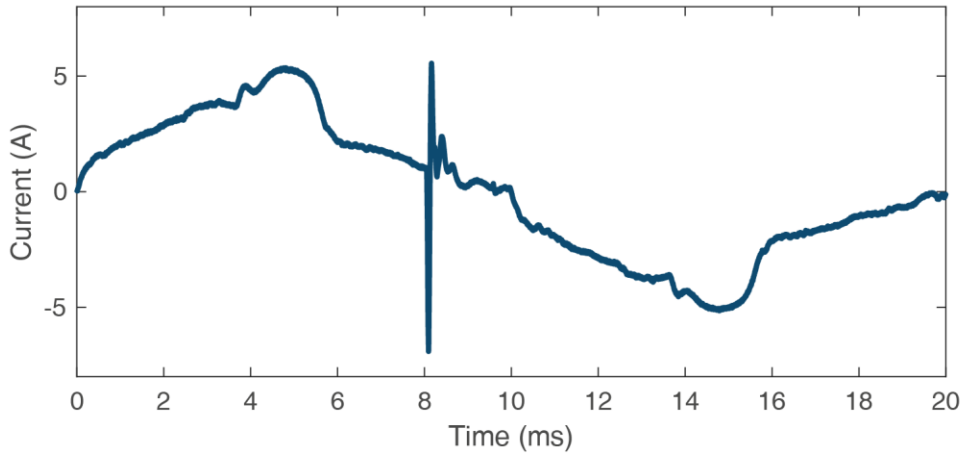
Results

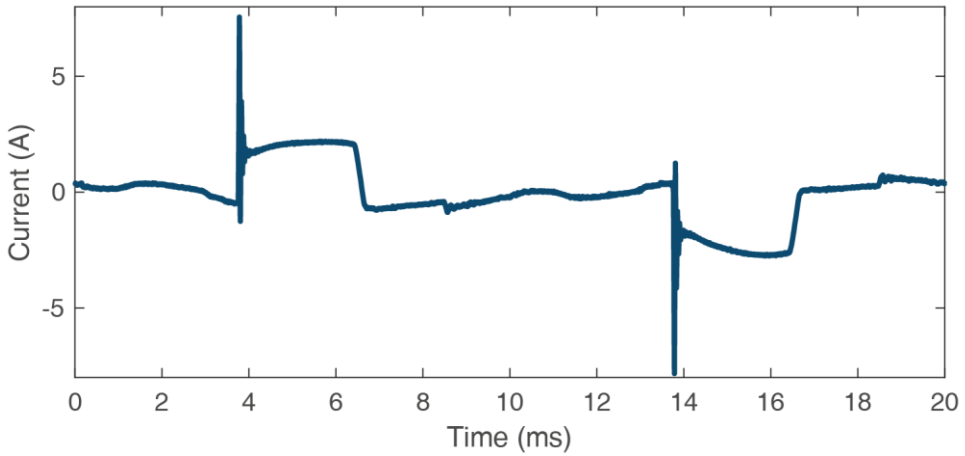
- The slope was indicated as one of the main causes of the EMI.
- Red zones indicate the critical range that causes EMI on static energy meters.
- Statistical visualization of the slope shows many data points inside the red zone:



Results

- In 74% of the on-site waveforms, parameters inside the critical interference range are found.
- Estimated errors range from -35% to 925%.
- Similar pulses were found in the on-site waveforms.
- Furthermore, the waveforms have a large harmonic distortion.
- The pulses resemble inrush currents from connected equipment.





MeterEmi
EMPIR
EURAMET
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Conclusion

- Pulses similar to lab experiments are found in on-site surveyed data.
- On-site situation contains critical non-linearities in relation with EMI on static energy meters.

Thanks for your attention!

Contact information:

bas.tenhave@utwente.nl

linkedin.com/in/bas-ten-have-758677119/

research.utwente.nl/en/persons/bas-ten-have/publications

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