From complex “real-world” waveforms to Artificial Test Waveforms:
A time-domain modelling approach

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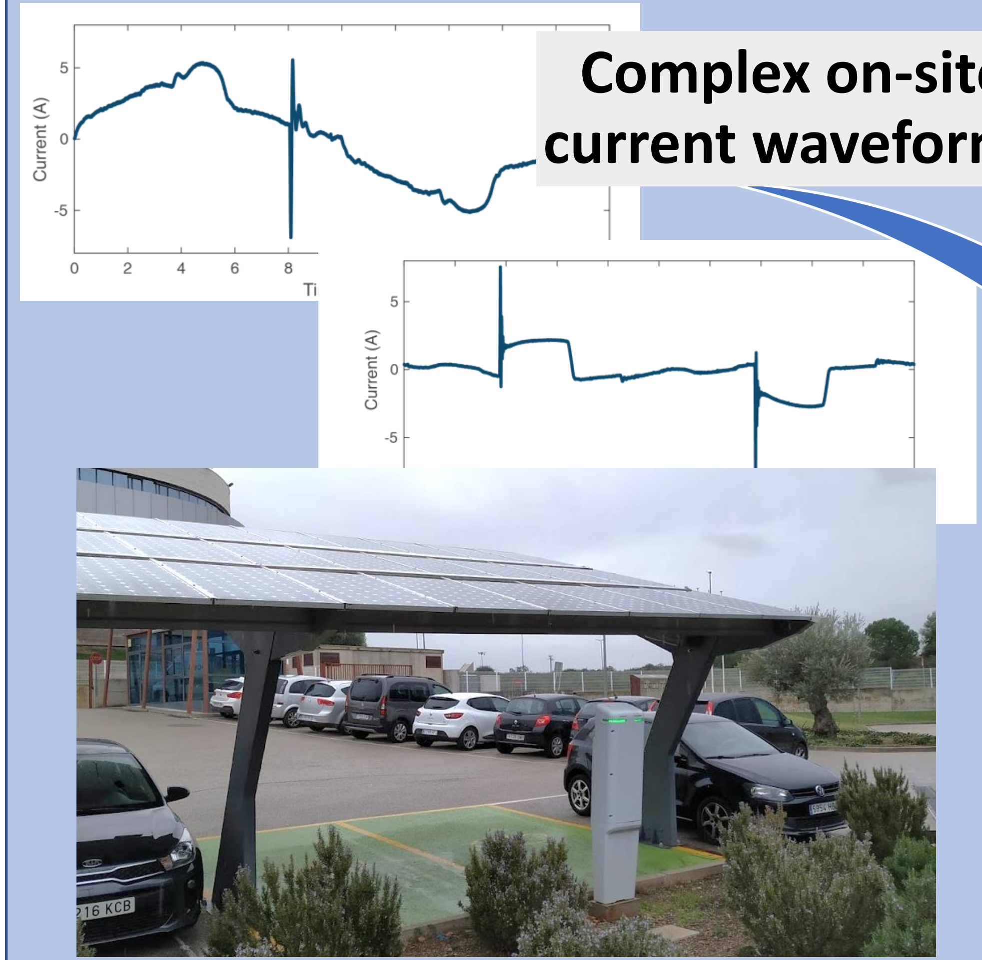
Objective



Complex on-site current waveforms


INTERNATIONAL STANDARD

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BASIC EMC PUBLICATION
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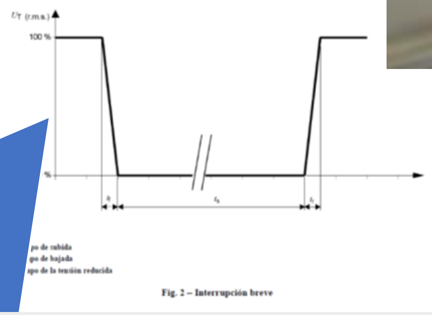
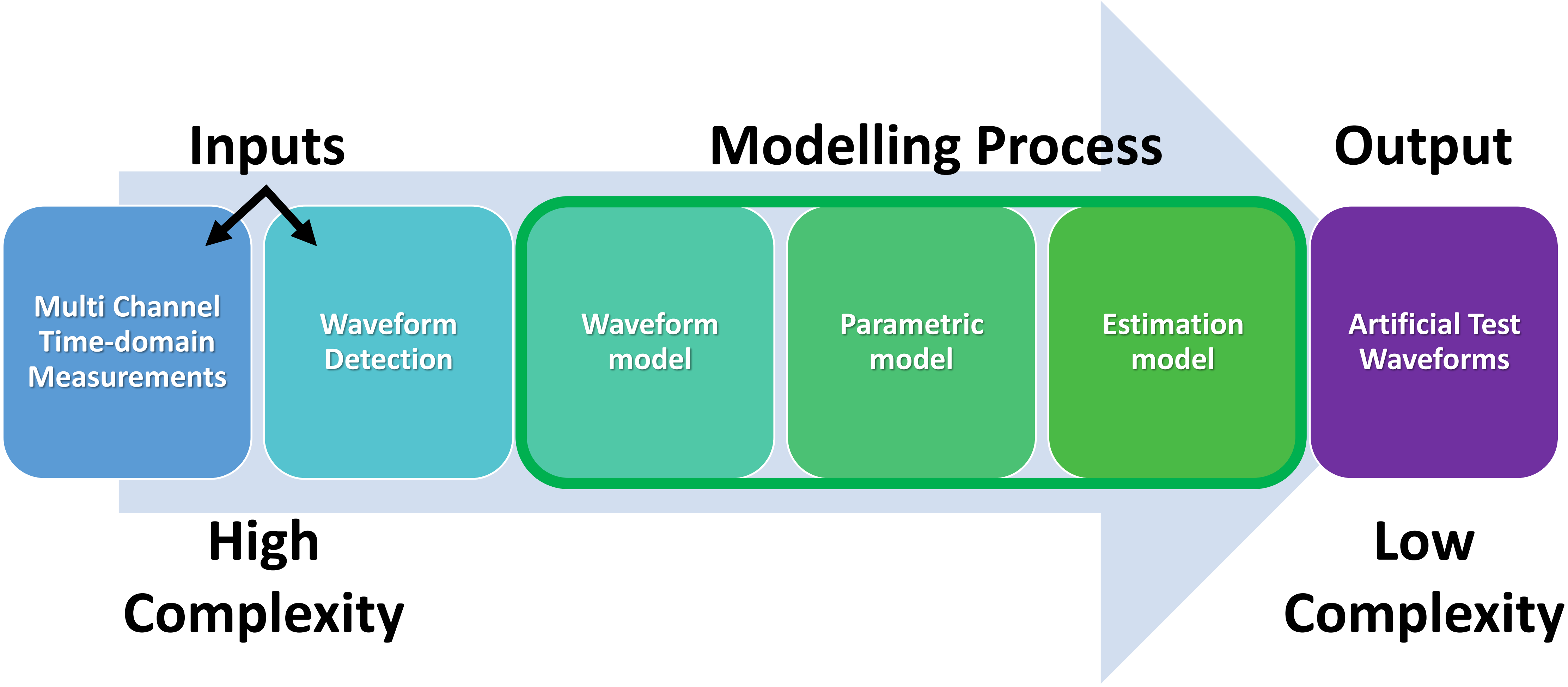
AMENDMENT 1
AMENDEMENT 1

Electromagnetic compatibility (EMC) –



Artificial Test Waveforms for standards

Overview



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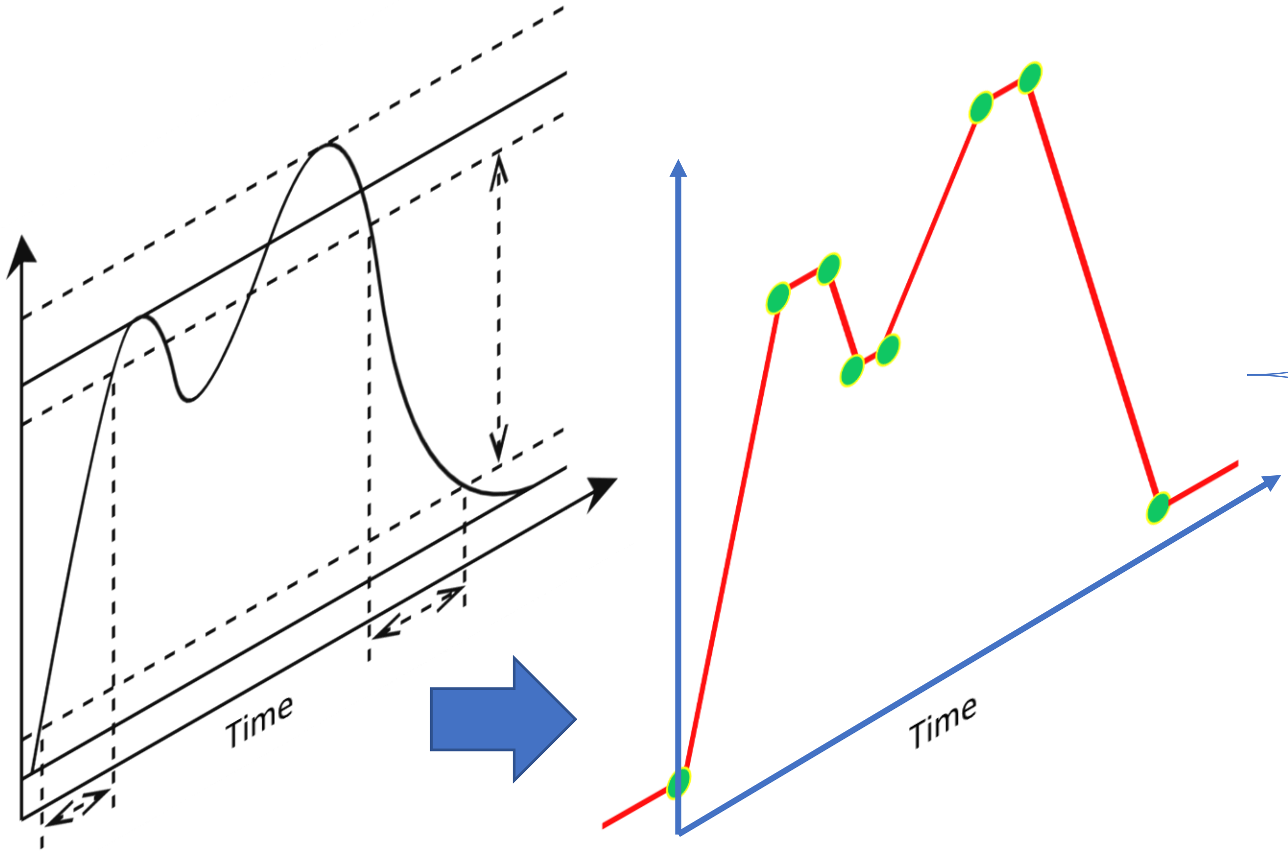
Methodology: Modelling

Third step: Developing a waveform model that accurately represent such interfering waveforms with a reduced number of features.



Waveform Model Algorithm [3]

Decomposition: Pulsed events are extracted from the measured waveforms.

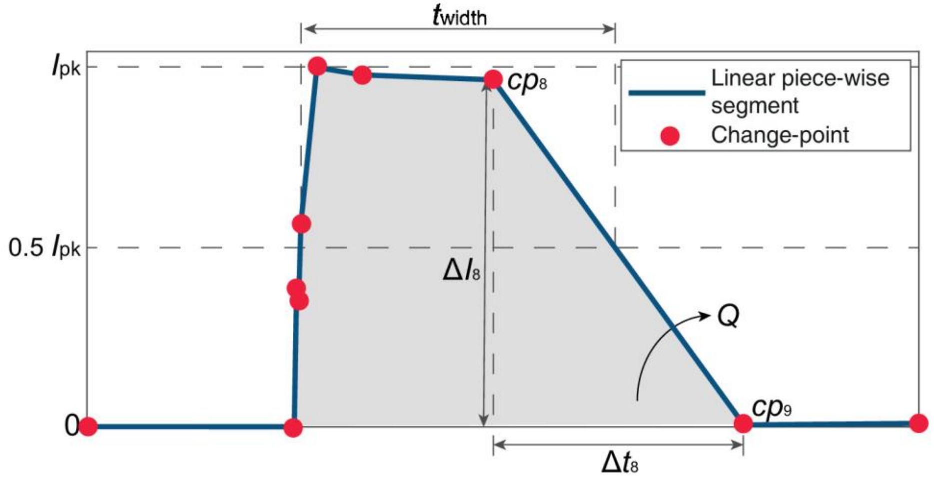
Fitting: The pulses are modelled through optimum piece-wise linear segments defined in between change points .

Simplification: A minimum number of change points are selected to preserve the waveform shape.

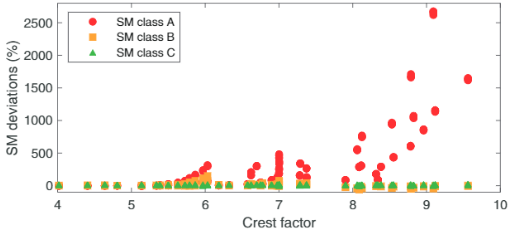
[3] B. ten Have et al., "Waveform Model to Characterize Time-Domain Pulses Resulting in EMI on Static Energy Meters," IEEE Transactions on Electromagnetic Compatibility (Early Access).

Methodology: Modelling

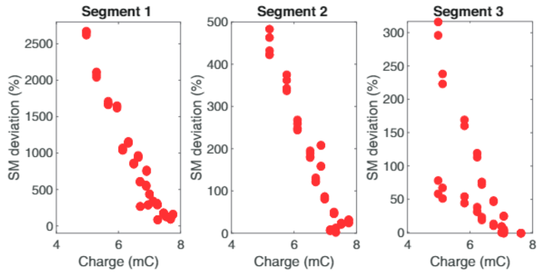
Fourth step: Defining a reduced set of waveform parameters that can be calculated for the modelled waveform and that are strongly correlated to interferences in static meters.



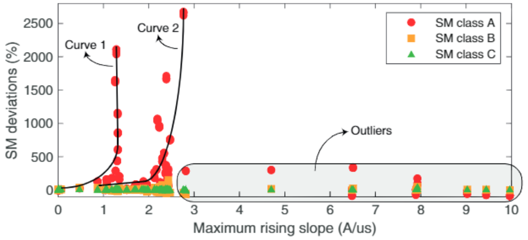
Crest factor



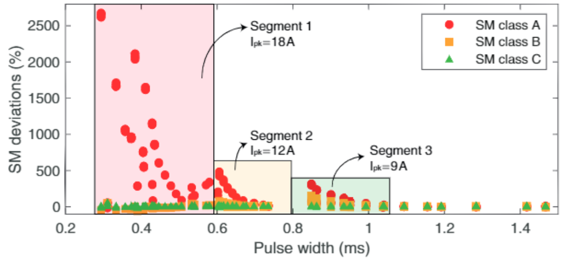
Charge



Max. Slope



Pulse duration



Narrow, fast rising, pulses, where, on average, higher crest factor, narrower pulse width, higher peak amplitude, less charge, and higher slopes, will contribute to an increase in the metering error [3].

[3] 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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Methodology: Modelling

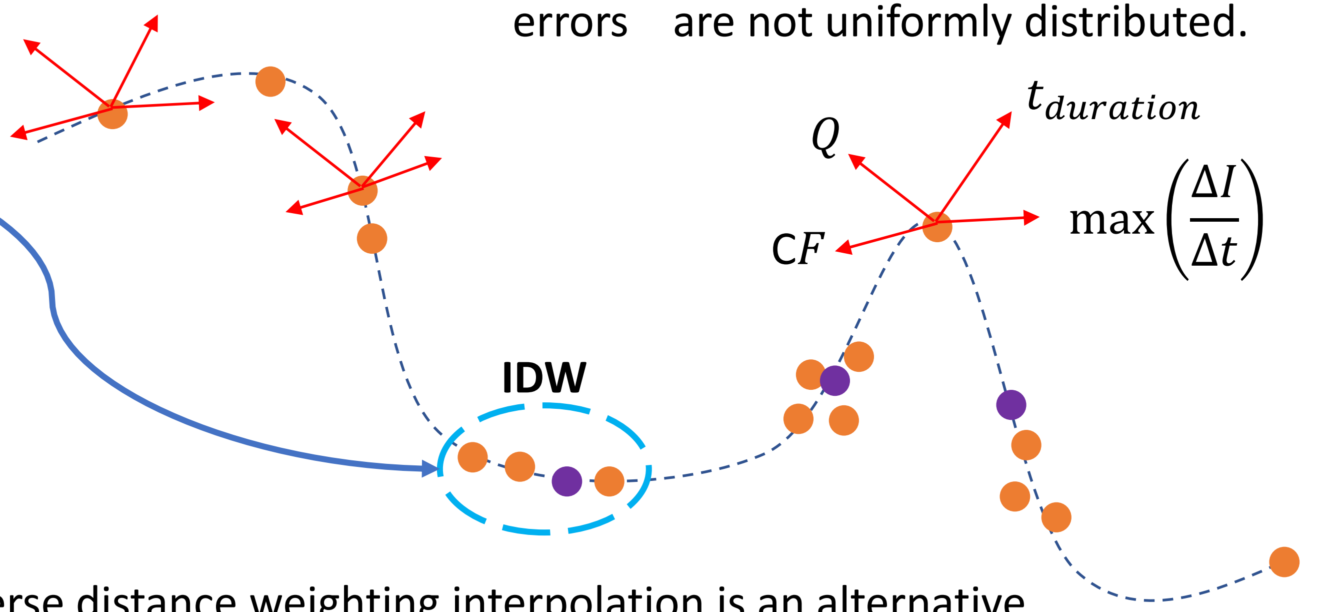
Fifth step: Estimate the metering errors produced by the interfering waveforms measured in the onsite scenarios.

Hypothesis:

<u>Similar interfering waveforms will result in similar errors.</u>

Similar waveforms are those that are close (Euclidean distance) in terms of their parametric model.

The know set of waveform parameters ● and their associated errors are not uniformly distributed.



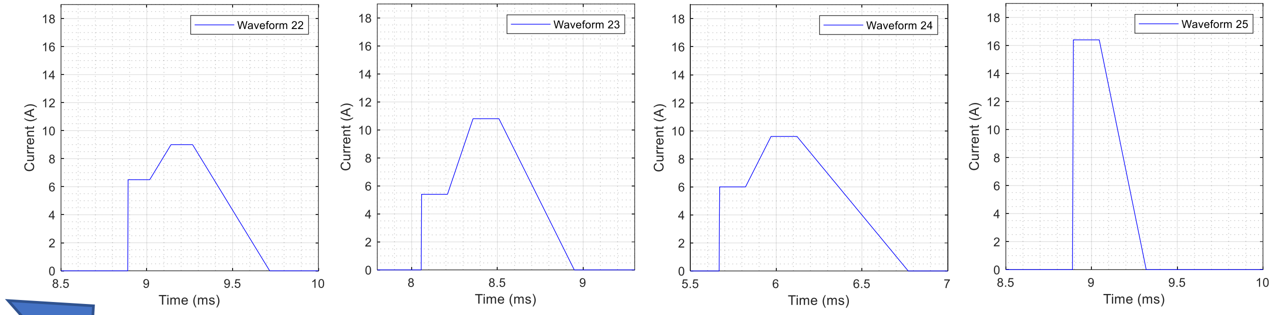
Inverse distance weighting interpolation is an alternative to estimate the unknown errors ● based on the modelled waveform parameters [4].

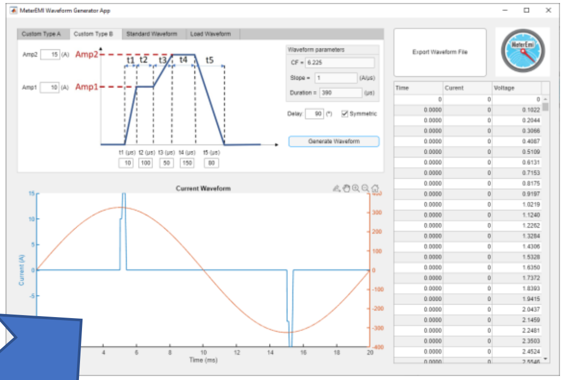
[4] B. ten Have et al., “Estimation of Static Energy Meter Interference in Waveforms Obtained in On-Site Scenarios ,” IEEE Transactions on Electromagnetic Compatibility (Submitted).

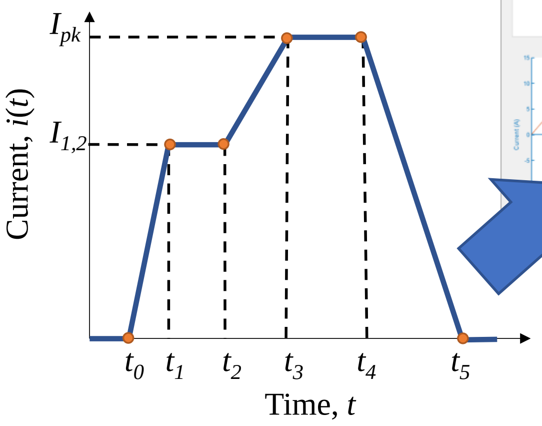
Results: Artificial Test Waveforms

Final step: Define a representative set of low complexity waveforms that could be used to test the immunity of static meters when subject to this type of interference.

Single trapezoidal pulses, or a combination of trapezoids, fitted to reproduce the critical waveform parameter correlated to interference in static meters







Waveform	Q (mC)	CF	dI/dt (A/us)	I_{pk} (A)	$t_{duration}$ (ms)	PA (degrees)
22	4.9	6.78	2.32	9	0.828	160
23	6.0	6.88	2.12	10.8	0.892	145
24	6.6	6.16	1.93	9.6	1.103	102
25	4.8	9.05	2.78	16.4	0.431	160

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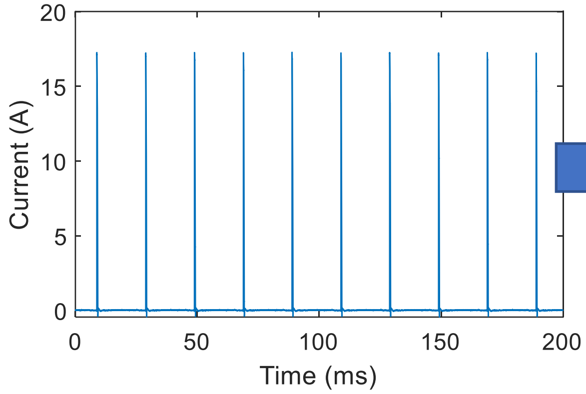
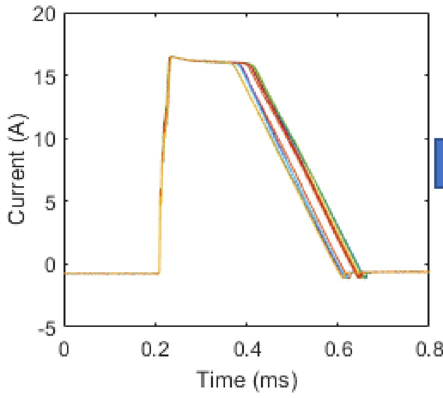
Conclusion

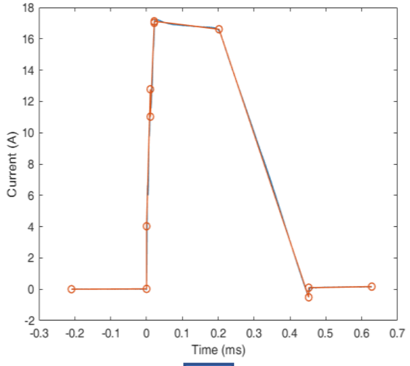
Complex raw data



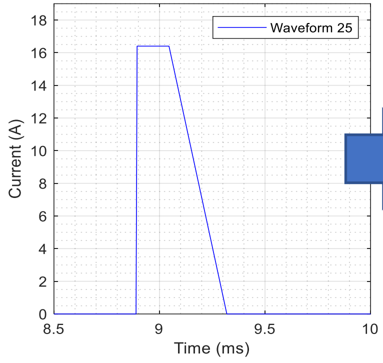
Detected waveforms



Modelled waveforms



Artificial test waveforms



- Interfering waveforms have been characterized in laboratory conditions. Their associated errors are accurately known.
- Parametric waveform models allowed to describe such waveforms accurately and reduced their complexity.
- Interfering waveforms have been encountered in the onsite.
- Artificial test waveforms based methodology presented have been defined for standardizing new immunity test for the static meters.

Parametric model

Charge	Q
Max. Slope	ΔI/Δt
Crest factor	CF
Peak current	I_{max}
Duration	$t_{duration}$
Pulse width	t_{width}

Estimation model

Parameter	Critical range
Charge	4-8 mC
Crest factor	> 5
Pulse width	0.2-1.2 ms
Rising slope	> 0.1 A/µs

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