21 April 2021 MeterEMI Final Workshop

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Electromagnetic Interference on Static Electricity Meters

A benchmark meter for settling customer complaints

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Dutch Metrology Institute

About VSL

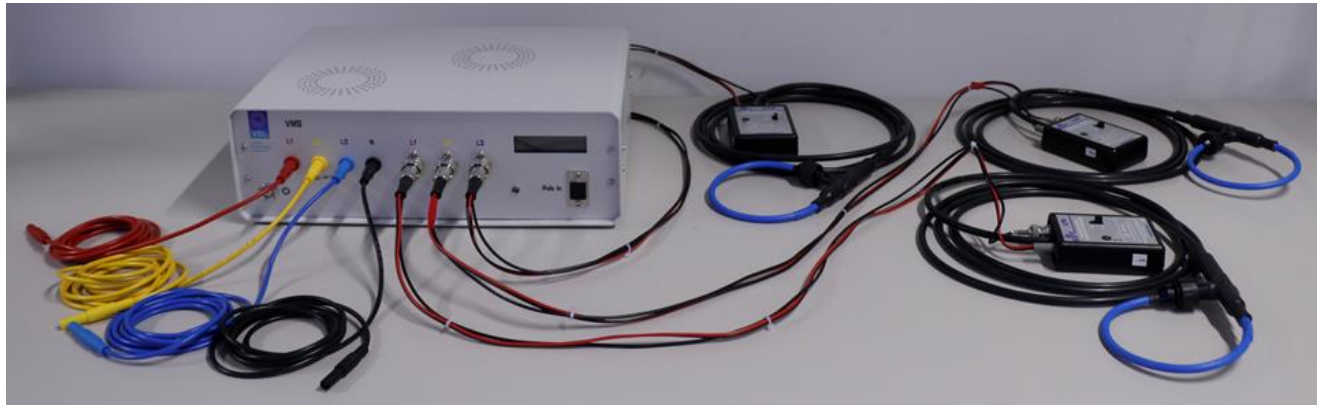
- National Metrology Institute of the Netherlands
- Company with a public task
- 100 fte, 40 % MSc or PhD
- Calibrations, reference materials, R&D, consultancy, training
- Focus on energy and industry
- Located in Delft, the Netherlands

VSL waveform recorder

- Used to record on-site waveforms at potentially EMI-distorted **metered supply points**

- 3-phase *V* & *I* **waveform recorder**:
  - Rogowski coils, 120 A or 1200 A peak, 0.3 Hz – 1 MHz
  - Resistive/capacitive dividers, DC – 100 kHz
  - 8-channel, 16-bit, 1 Msa/s digitizer
  - Optical sensor, 1000 pulses per kWh
  - Minicomputer with dedicated home-built software
  - 4G-connection

- Measure for 1-2 weeks:
  - 200 ms blocks
  - Every minute
  - Triggered by dI/dt or CF



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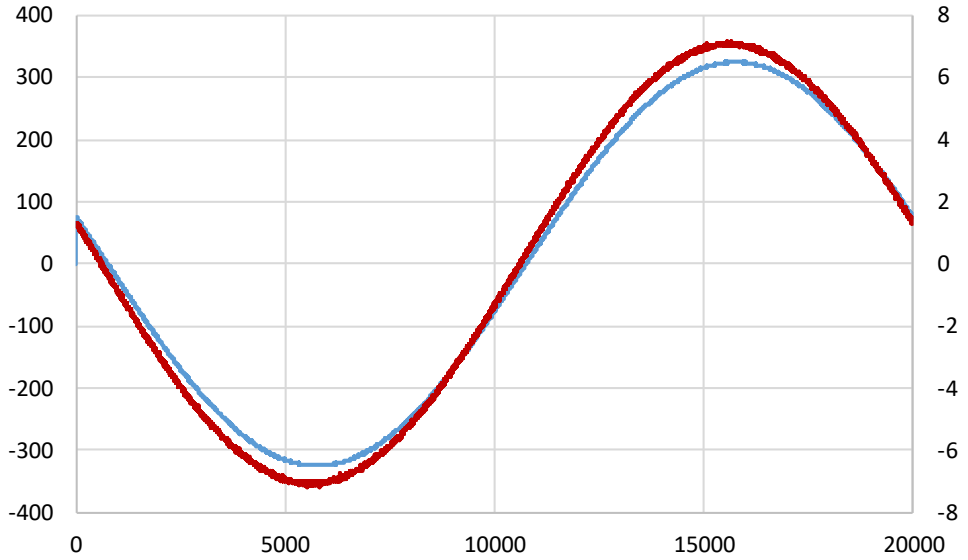
Energy measurement

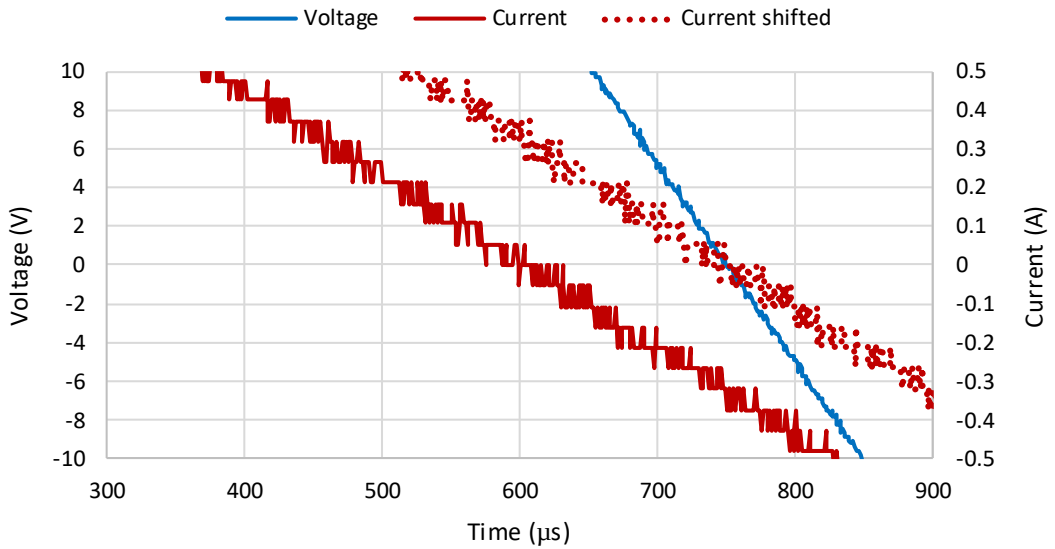
- Determination of energy *E(T):*

$$E(T) = \int_0^T V(t) \cdot I(t)\, dt$$

- Different **input stages** for *V* and *I*:
  - High-ohmic voltage dividers for *V*
  - Rogowski coils for *I*

- **Conventional** compensation method:
  - Time shifting
  - Works **perfectly** for sine waves





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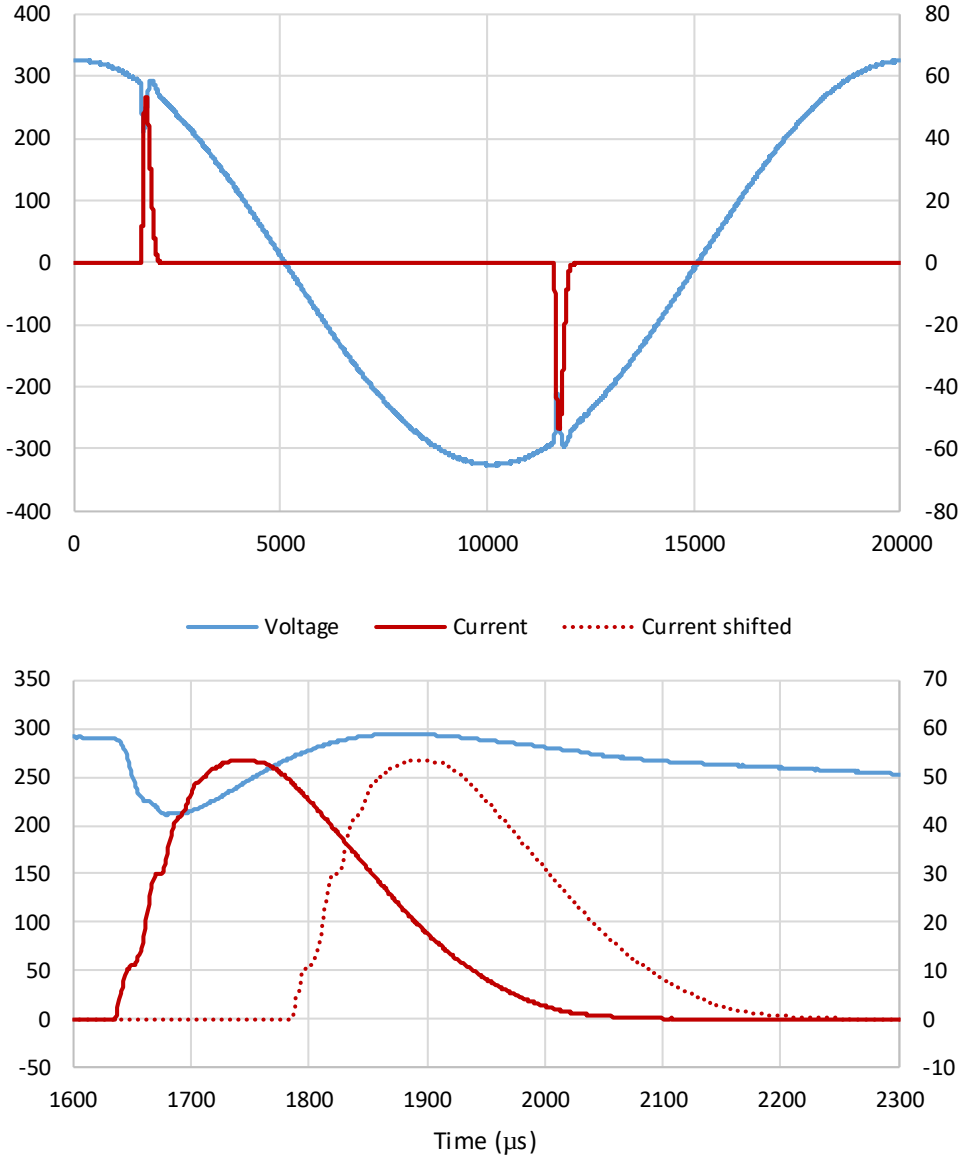
Energy measurement

- Determination of energy *E(T):*

$$E(T) = \int_0^T V(t) \cdot I(t)\, dt$$

- Different **input stages** for *V* and *I*:
  - High-ohmic voltage dividers for *V*
  - Rogowski coils for *I*

- **Conventional** compensation method:
  - Time shifting
  - Does **not** work for high-frequency components



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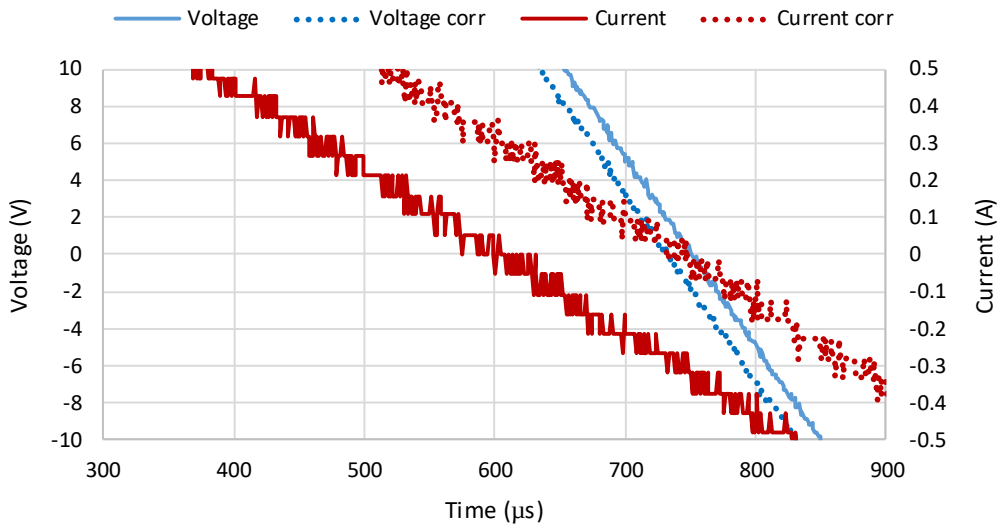
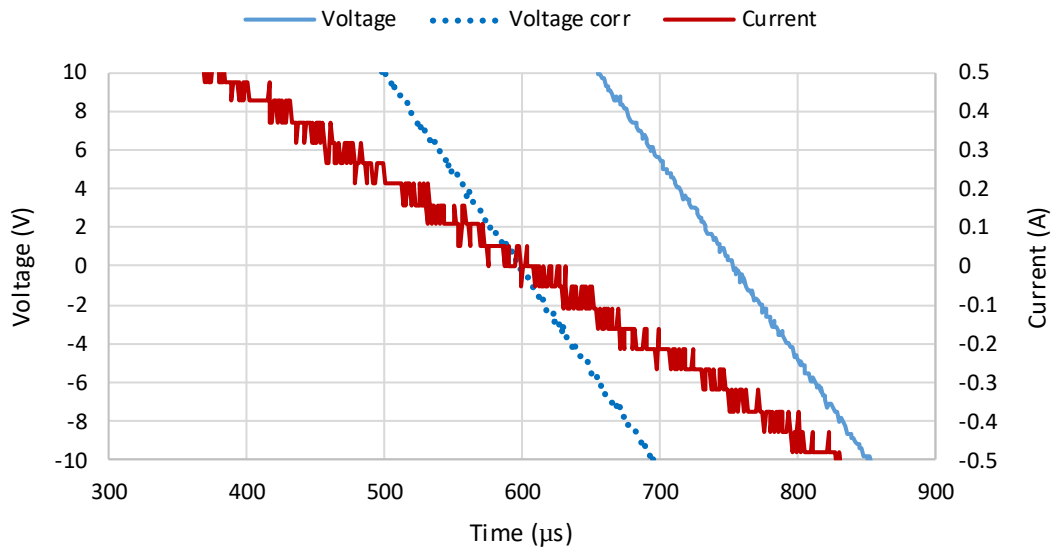
Improved filter compensation methods

- Determination of energy *E(T):*

$$E(T) = \int_0^T V(t) \cdot I(t)\, dt$$



- Different improved compensation techniques:
  - **Inverse-Filtering Method** based on *V* and *I* input characteristics
  - **Equivalent-Filtering Method** ensures V and I experience similar filter characteristics



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VSL waveform recorder and benchmark meter

- **Validation** of improved waveform recorder **energy calculations**:
  - No filter / time shift / inverse-filtering / equivalent-filtering
  - Sine wave (30˚ phase shift or PF=0.866)
  - Various dimmed household appliances
  - Compared pulse output using arbitrary-waveform testbed
  - Improved meter determines energy **well within 2 %**

Meter error ε:

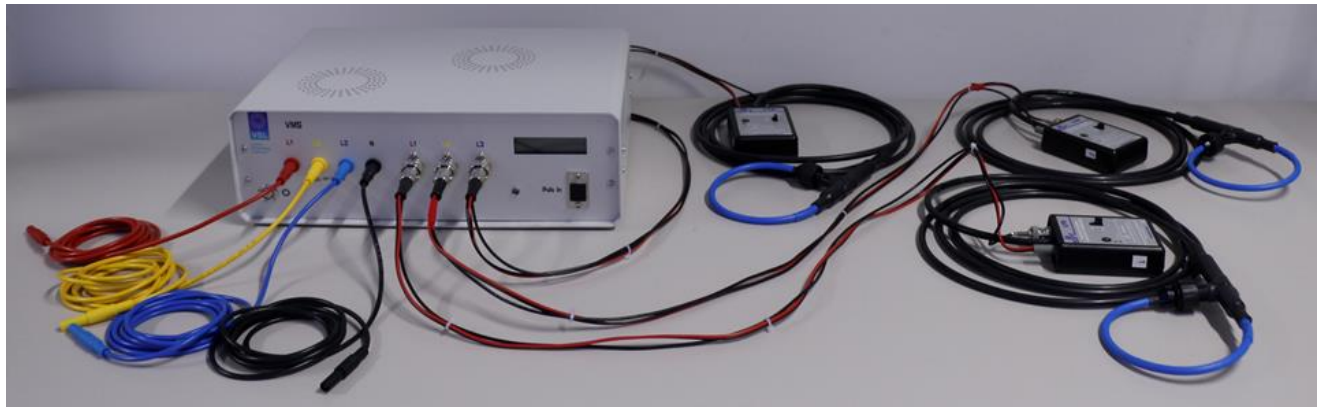
$$\epsilon = \frac{E(T) - E_p}{E(T)}$$

Label	None	Time	Inverse	Equivalent
PF0.866	-2.3 %	0.2 %	0.2 %	0.1 %
R75	7.2 %	-0.6 %	-0.5 %	-0.7 %
CL75	2.4 %	10.6 %	0.0 %	-0.1 %
CL50	0.0 %	7.4 %	0.2 %	0.1 %
WP4	5.2 %	4.0 %	-1.2 %	-0.5 %
WP9	0.5 %	2.2 %	-0.5 %	-0.3 %

Summary and conclusion

- Voltage and current on-site **waveform recorder**
- Energy calculation performance improved by **sophisticated filtering**
- Accuracy much **better than 2 %** for even the most harmful waveforms

⇒ ***Benchmark meter*** *suitable for settling customer complaints*



$$E(T) = \int_0^T V(t) \cdot I(t)\, dt$$

$$\epsilon = \frac{E(T) - E_p}{E(T)}$$

Z. Marais, H.E. van den Brom, G. Kok and M.G.A. van Veghel, "Reduction of Static Electricity Meter Errors by Broadband Compensation of Voltage and Current Channel Differences," *IEEE Trans. Instrum. Meas.* 70, 2021