WP5 -Task 5.2

Impulse current and short circuit current measurements

Le progrès, une passion à partager

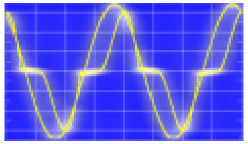
Context

✓ **High-impulse currents occur in high voltage power systems:**

- **Lightning strikes**
- **Switching operations of circuit breakers**
- **Switching manoeuvres in gas-insulated switchgear**
- **Electromagnetic pulses**

➔ **The understanding of higher current events is important for the management of power quality.**

Transmission & Distribution Efficiency



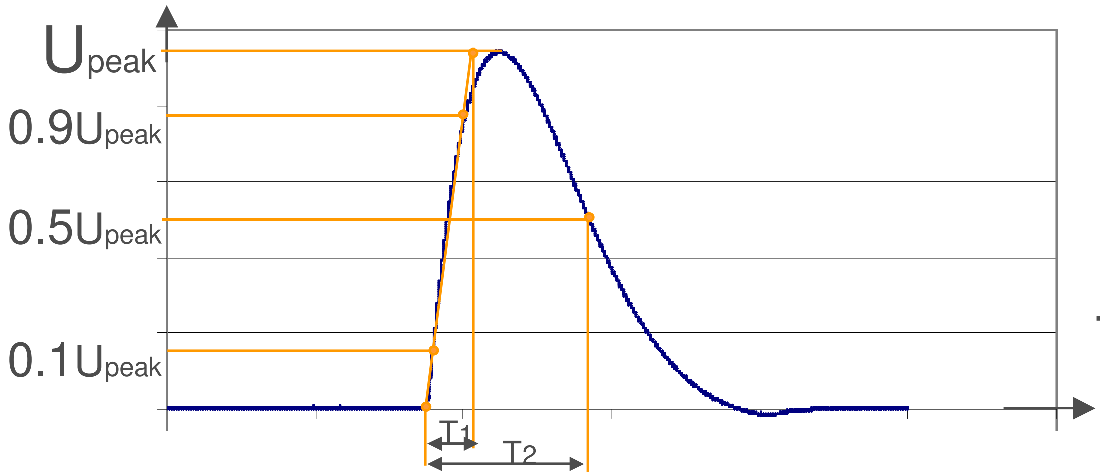
Power Quality Compliance

Task 5.2 Impulse current and short circuit current measurements

Objectives

- ✓ Identify suitable sensors for impulse and fast transient currents up to 60 kA
- ✓ Characterization of the complete measurement system with a target uncertainty of 0,1 %

Parameters of 8/20 µs signals



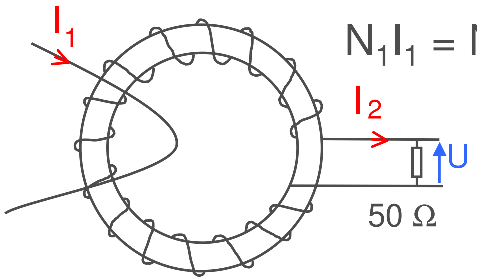
Peak value, U_{Peak} < 60kA

Front time, T_1 : 8 µs

Time to half value, T_2: 20µs

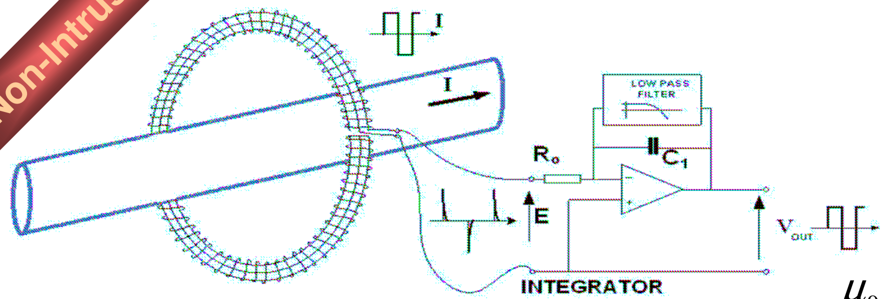
Specification of existing transducers and first selection

Pearson coil



Rogowski coil

Non-Intrusive



$$V_{out} = \frac{\mu_0 NA}{C_1 R_0} \cdot I$$

$$E = \mu_0 NA \cdot \frac{dI}{dt}$$

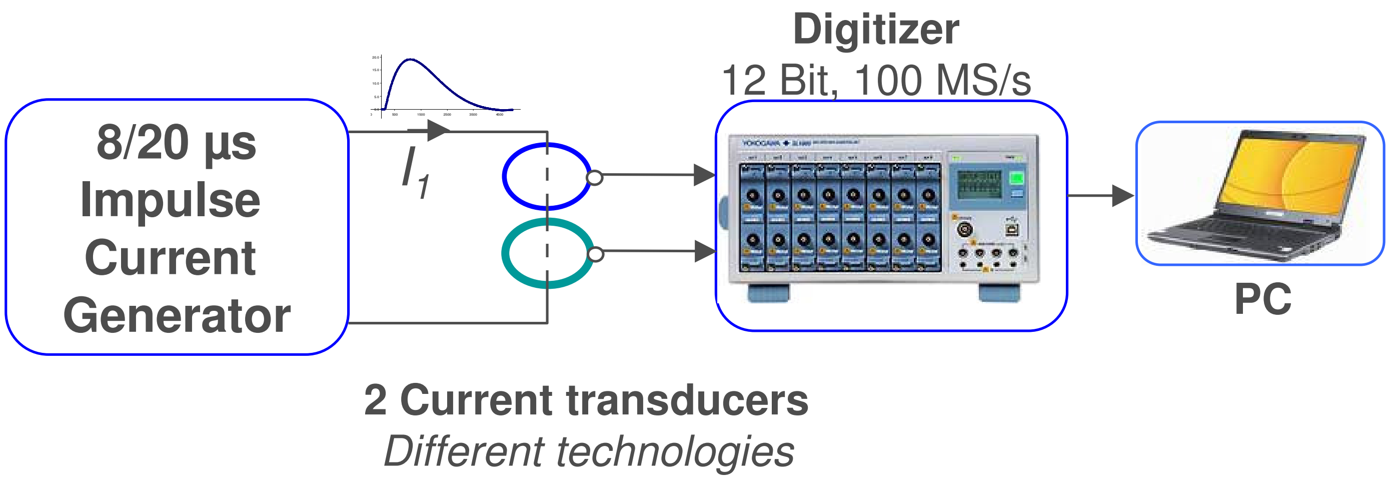
Selection of transducers

- ✓ **Rated current range**
- ✓ **Large bandwidth**
- ✓ **Dynamic performances to accurately capture the short-lived events**
- ✓ **Linearity**
- ✓ **On-site measurements**

Pearson	**Rogowski**
50 000 A	50 000 A
0,25 Hz to 4 MHz	0,6 Hz to 1 MHz
10 mV/A	0,1 mV/A

Task 5.2 Impulse current and short circuit current measurements

- **Measurement chain**: comparison method



➔Pass over the generator fluctuations and other common factors

➔Share the advantage of two different technologies

➔Rigid bar circuit with modular geometry designed

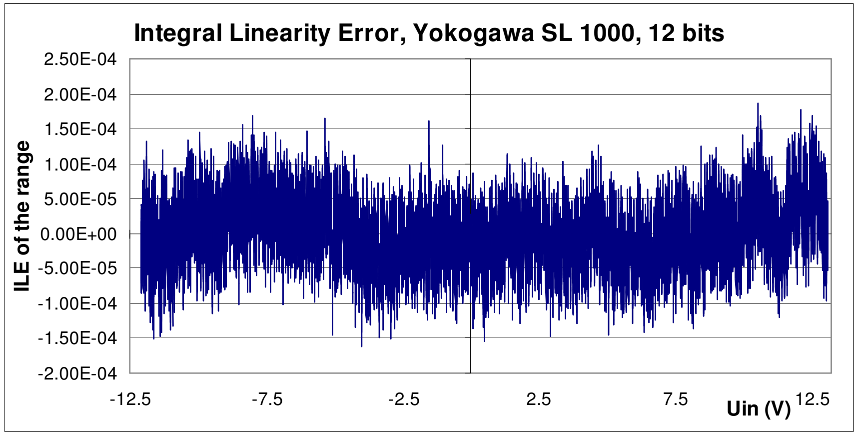
Digitizer characterization according to EN 61083-1: 2001

High-speed data acquisition unit
12-Bit, 100 MS/s

✓ Internal noise level (quantization noise): $8 \cdot 10^{-4}$ of FSR

Limits: $40 \cdot 10^{-4}$ of FSR

✓ INL - Integral Non-Linearity



$$\varepsilon_{NLIS}^{\min} = -1.62 \cdot 10^{-4}$$

$$\varepsilon_{NLIS}^{\max} = +1.85 \cdot 10^{-4}$$

of FS

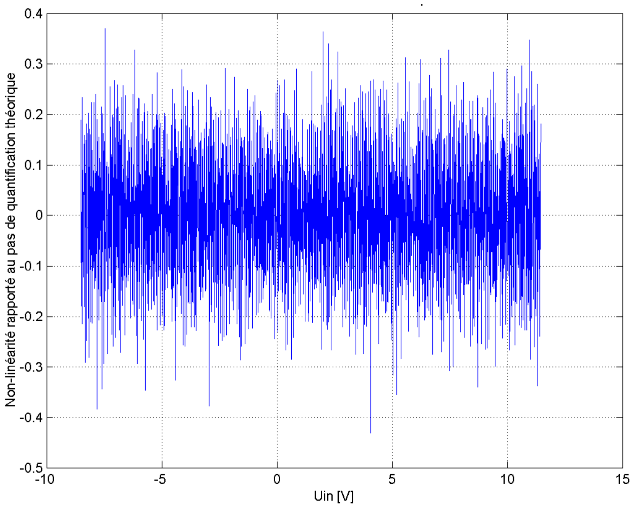
Limits:

$$\varepsilon_{NLIS} = \pm 50 \cdot 10^{-4} \; of \;\; FS$$

Digitizer characterization according to EN 61083-1: 2001

✓ DNL – Differential Non-Linearity

Static

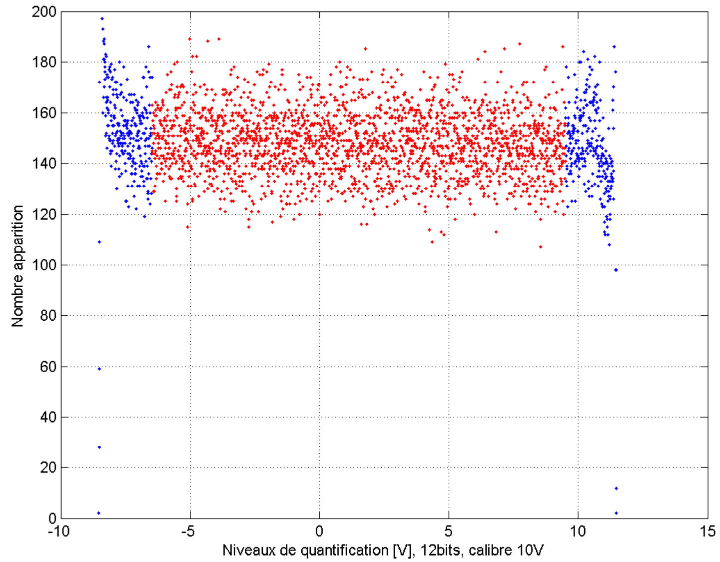


$$\varepsilon_{NLDS}^{min} = -0.43\ LSB$$

$$\varepsilon_{NLDS}^{max} = +0.37\ LSB$$

Limits: $\varepsilon_{NLDS} = \pm 0.8\ LSB$

Dynamic



$$\varepsilon_{NLDD}^{min} = -0.27\ LSB$$

$$\varepsilon_{NLDS}^{max} = +0.27\ LSB$$

Limits: $\varepsilon_{NLDS} = \pm 0.8\ LSB$

Digitizer characterization according to EN 61083-1: 2001

Uncertainty Budget

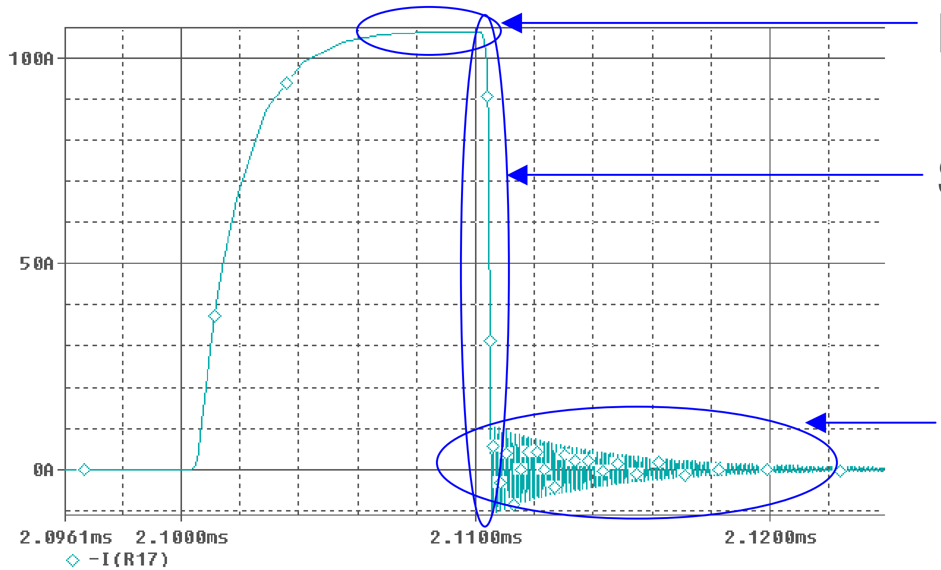
Quantity X_i	Estimated value x_i	Probability distribution	Standard uncertainty $u(x_i)$	Sensitivity coefficient c_i	Uncertainty contribution $u_i(y) = c_i \cdot u(x_i)$	Type
Quantization error, ε_q	0.4	Rectangular	$\frac{0.4}{\sqrt{3}}$	$\frac{1}{2850}$	$0.8 \cdot 10^{-4}$	A
Integral linearity error (ILE), ε_{ILE}	1	Rectangular	$\frac{0.6}{\sqrt{3}}$	$\frac{1}{2850}$	$1.2 \cdot 10^{-4}$	A
Offset error, ε_{off}	0	Normal	$\frac{0.75}{3}$	$\frac{1}{2850}$	$0.4 \cdot 10^{-4}$	B
Gain error, ε_{gain}	0	Normal	$\frac{0.375}{3}$	$\frac{1}{2850}$	$0.4 \cdot 10^{-4}$	B
Sampling error, ε_s	0	Rectangular	Neglected Since sampling time(10ns)<<Time(µs) when measured value is constant	$\frac{1}{2850}$	0	B
Step voltage relative error, $\frac{u(U_0)}{U_0}$	-	-	-	1	$1 \cdot 10^{-4}$	B
Combined standard uncertainty (k=1)					$3.2 \cdot 10^{-4}$	

$$U\big|_{digitizer} = 3.2 \cdot 10^{-4} \; (k = 1)$$

Value allowing to maintain the **10**$^{-3}$ targeted uncertainty for the complete measurement system

Current step generator

- Dynamic characterization of the impulse current sensors and measurement chain



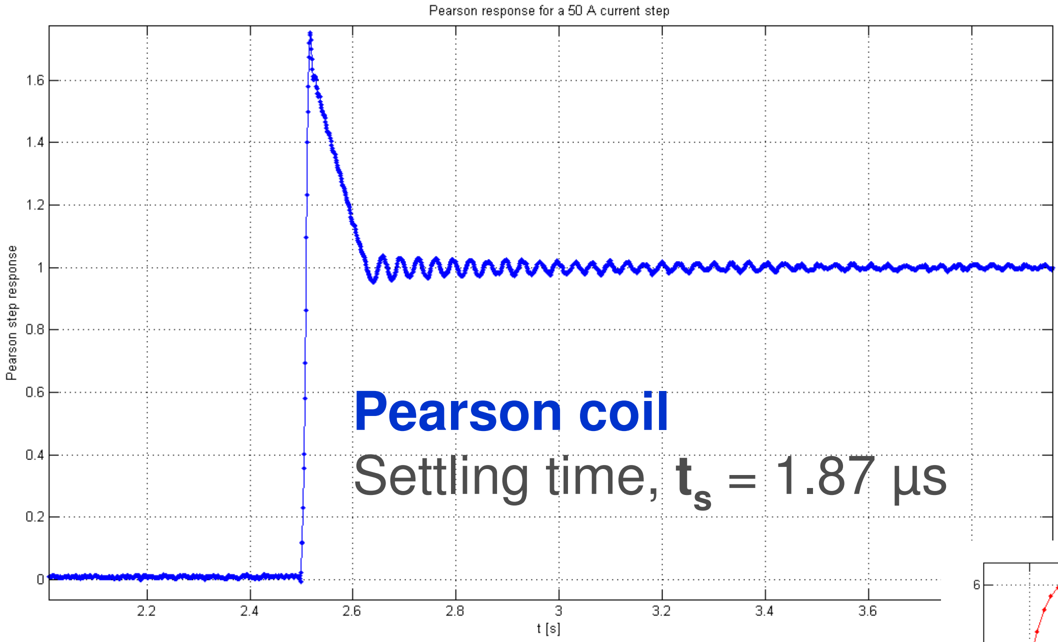
High level of current (~ 100A)

Steep falling slope (tens of ns)

Low parasitic inductance and capacitance

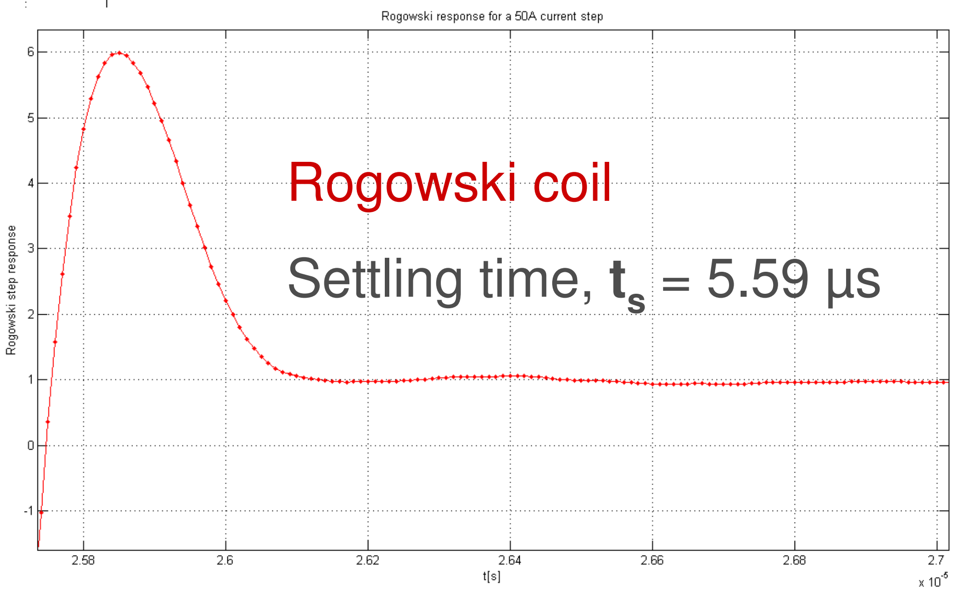
Measurement chain step response

- **Response parameters for a 50A current step**



Pearson coil

Settling time, $\mathbf{t_s}$ = 1.87 µs

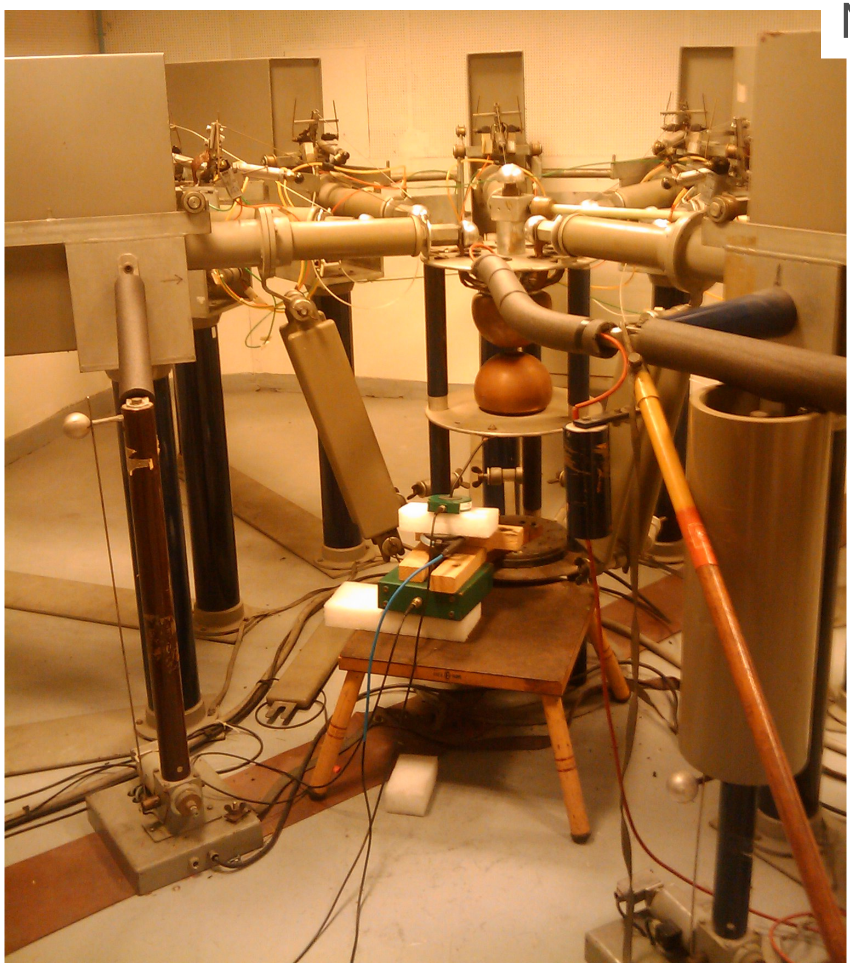


Rogowski coil

Settling time, $\mathbf{t_s}$ = 5.59 µs

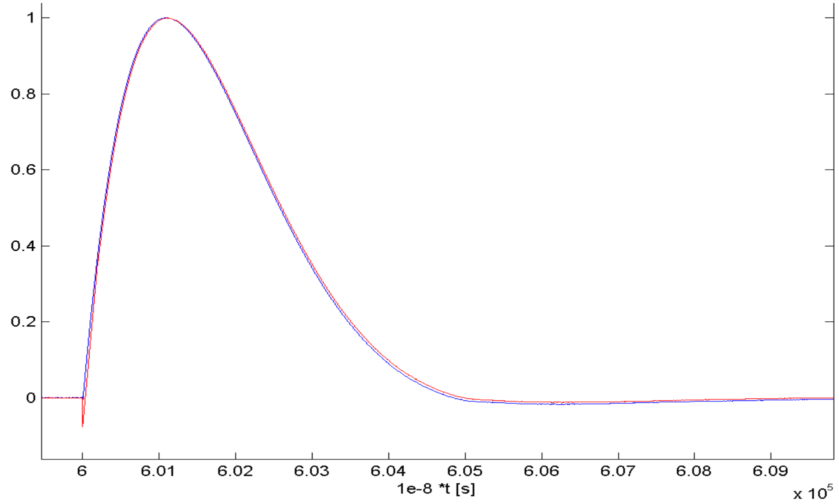
The attenuation of the step responses in few µs indicates no influence on the measure of 8/20 µs impulse currents.

Impulse current measurements up to 60 kA (peak value)

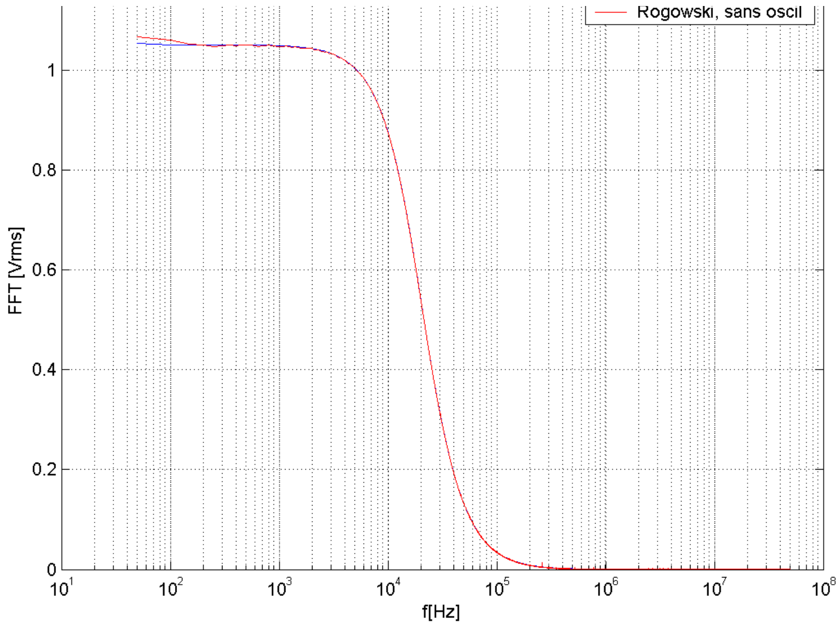


Site measurements

Normalised impulse waves, Pearson, Rogowski



Frequency spectra



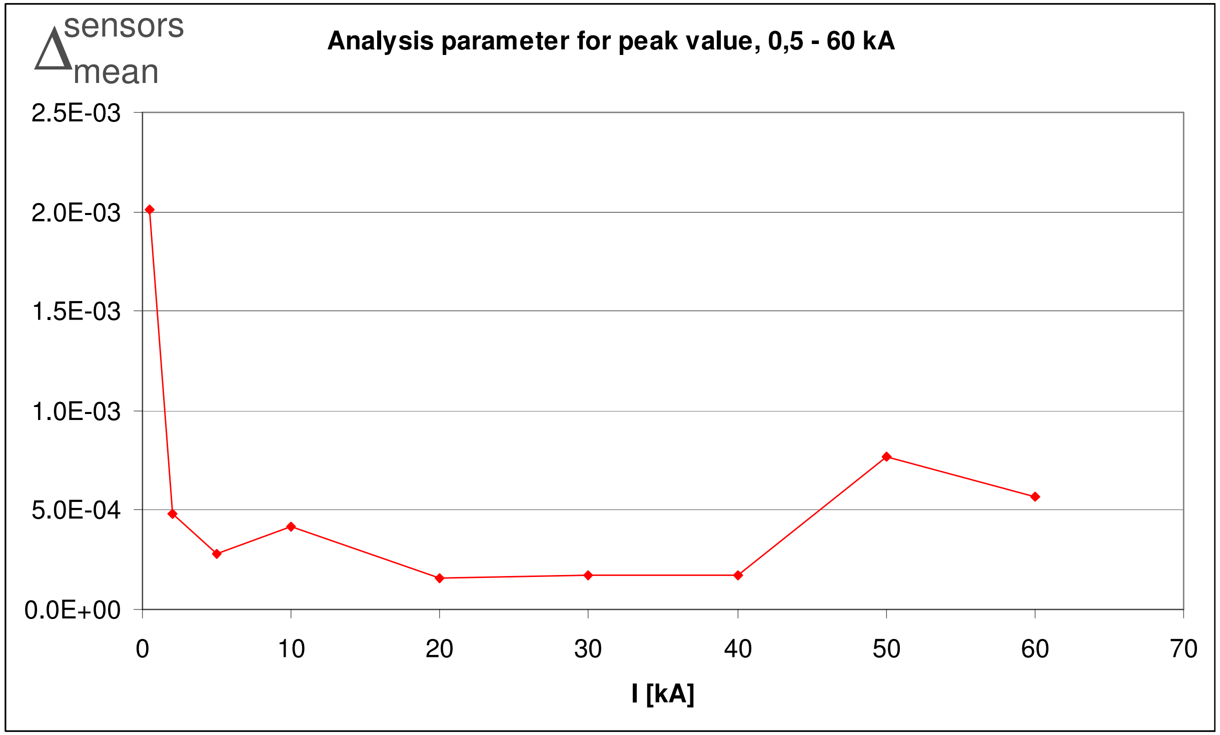
Results for the impulse currents up to 60 kA

Analysis parameter: the mean value of the difference (absolute value) between the 2 transducers for a set of 10 measurements

✓Peak Value $2 \cdot 10^{-4}$

✓Front Time $2 \cdot 10^{-2}$

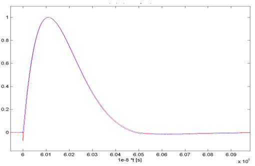
✓Time to Half Value $5 \cdot 10^{-3}$



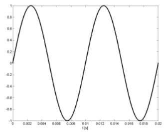
➔ *Reduced dispersion between Pearson and Rogowski coils for the measurement range*

➔ *Comparison method validation*

Link between measurements of current pulses and calibrations at 50 Hz



Gain $^{8/20\ \mu s}$ = Gain ^{50Hz} ?



What we know

Pearson sensor – 8/20 µs

- ✓Designed for pulse currents
- ✓Adapted dynamic

Rogowski coil – 50Hz

- ✓ Accept high power frequency currents
- ✓ Low dynamic

What we need to know

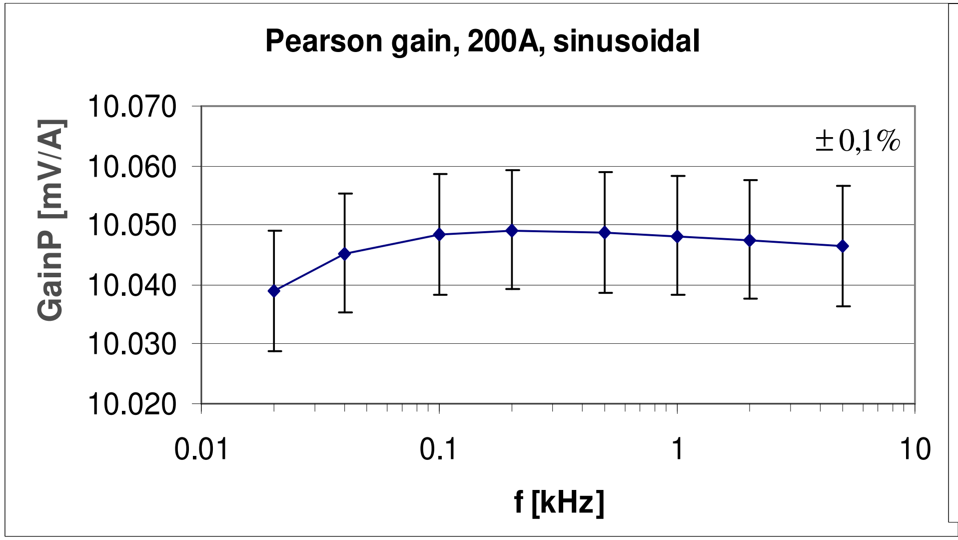
(A) Sensors performances

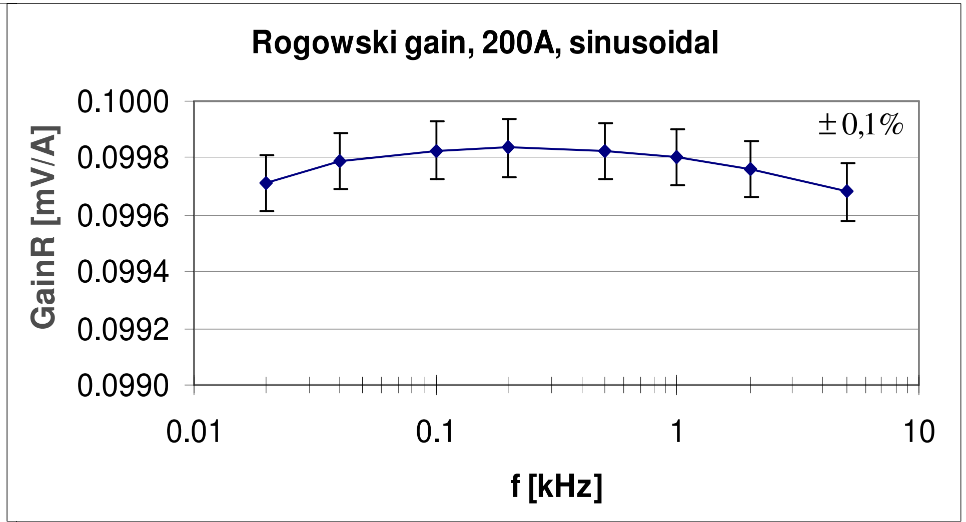
- Linearity up to 60 000 A
- Frequency response from 50 Hz to 100 kHz

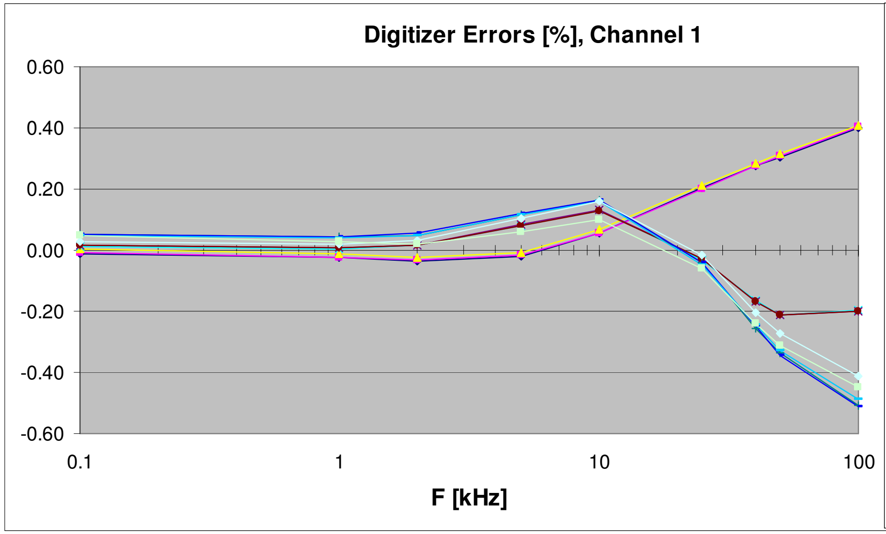
(B) How does the digitizer influence the dynamic gain to be established?

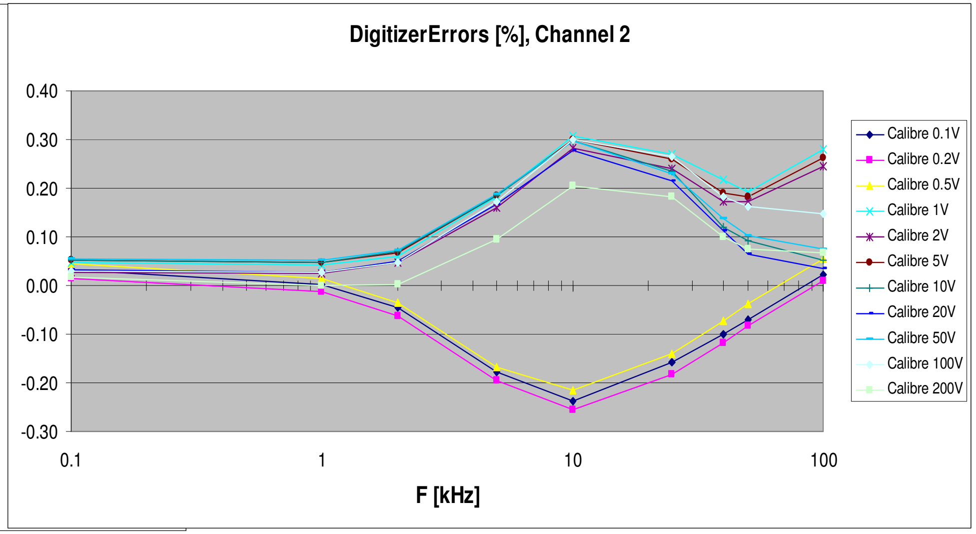
Link between measurements of current pulses and calibrations at 50 Hz

- Frequency response of sensors and digitizer





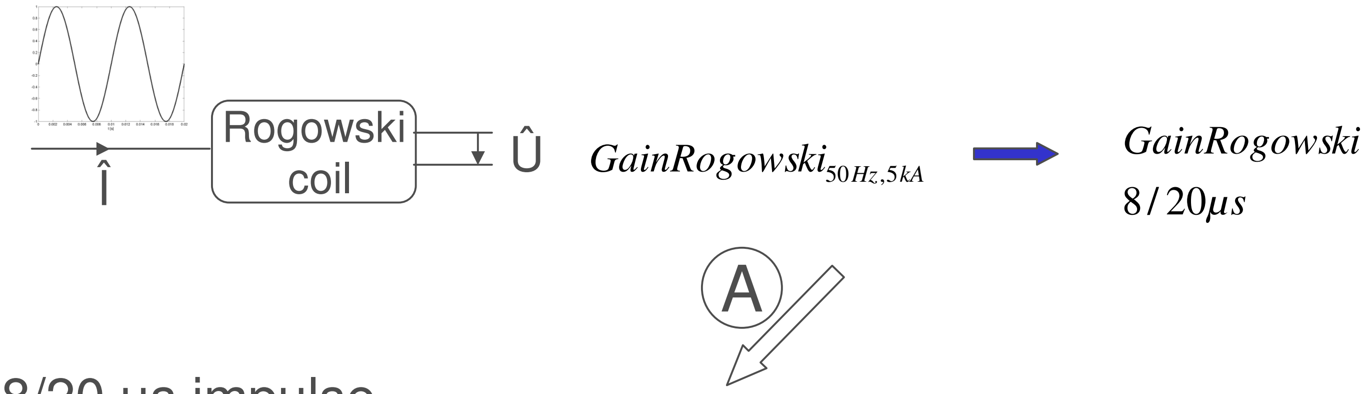




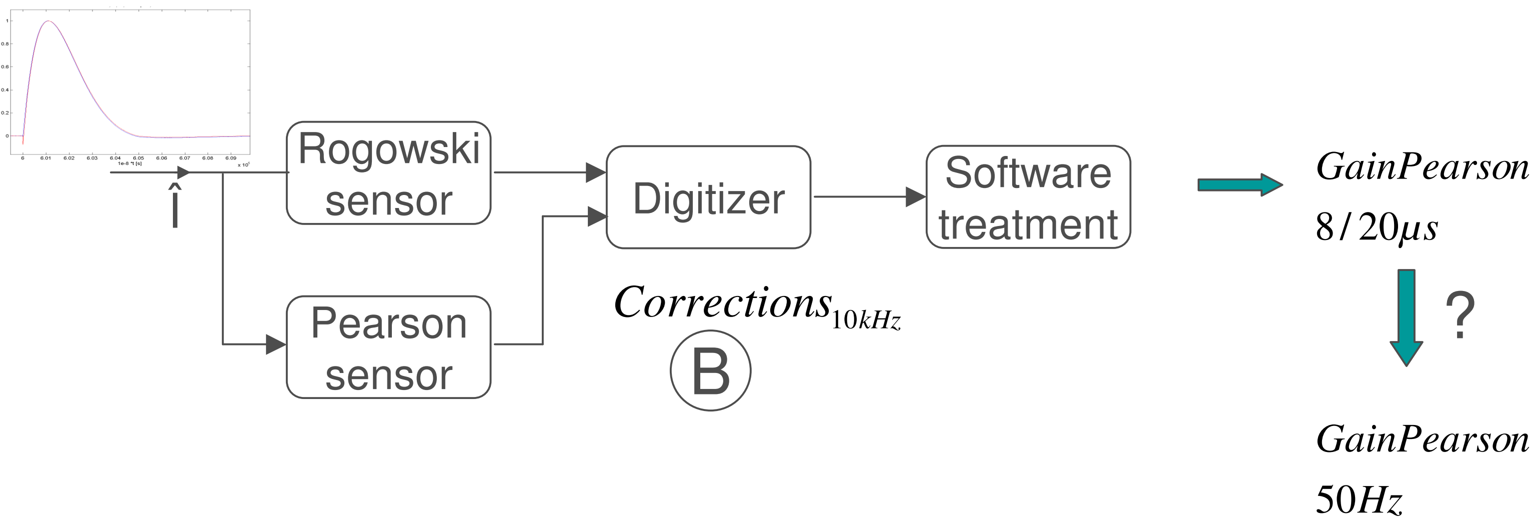
Link between measurements of current pulses and calibrations at 50 Hz

Approach

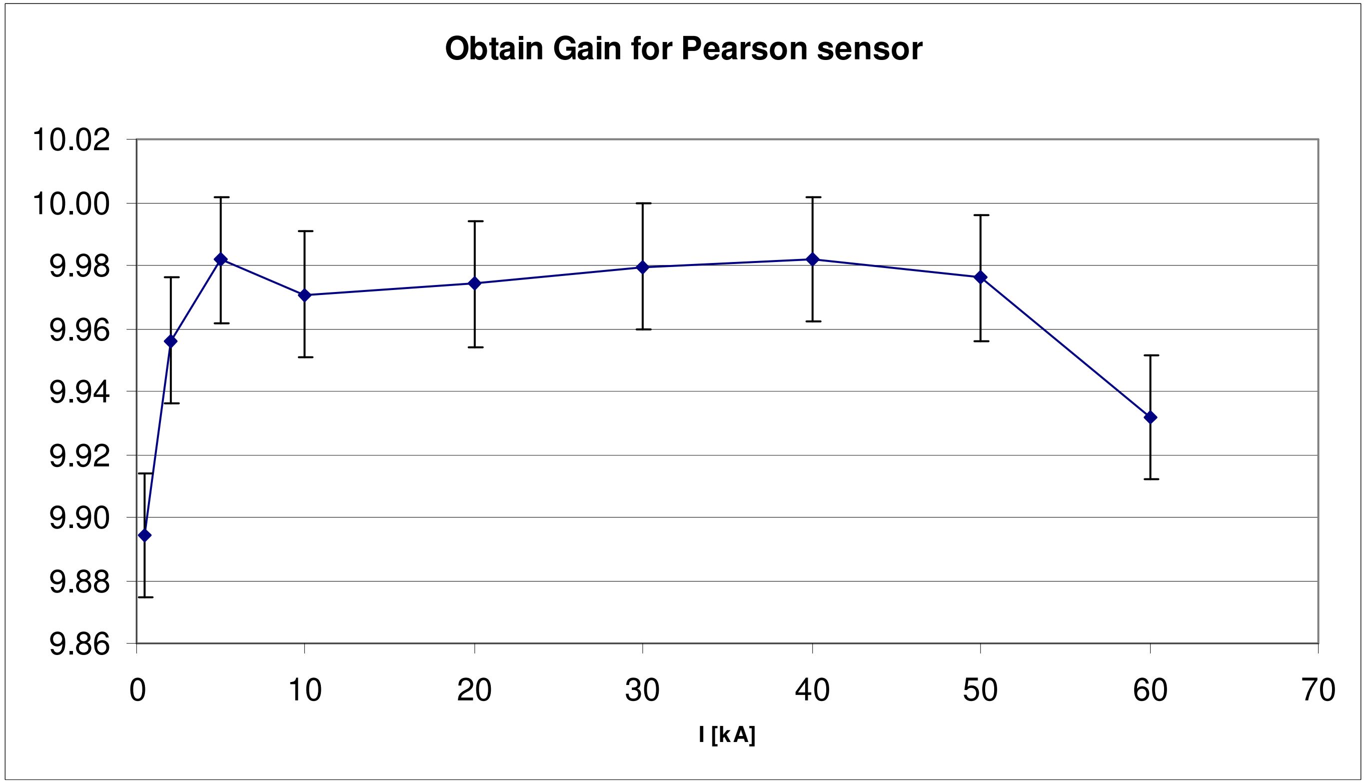
Sinusoidal regime



8/20 µs impulse



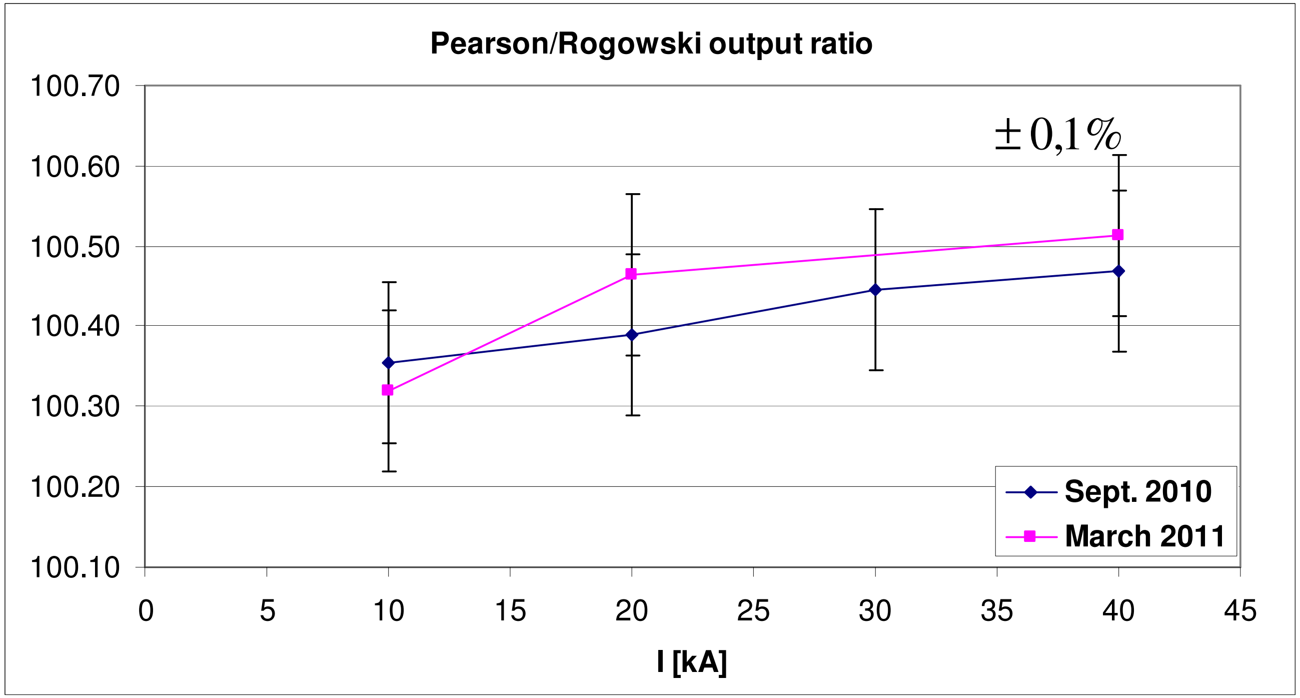
Results



- ✓ [5 kA; 50 kA] the obtained gain for Pearson sensor is constant at $\pm 0{,}1\%$
- ✓ Î < 5 kA SNR impact
- ✓ Î > 50 kA Sensors out of range specifications

Conclusions

- **Commercial sensors might be used for 8/20µs impulse current measurements with an uncertainty of 0,1% (k=1)**
- **On-site measurements indicate a reproducibility of 3.10^{-4}**
- **Quality of the analysed sensors allows to use them as impulse current standards**



Different circuit configurations

Measures at 7 months interval

Same components of the impulse measurement chain

Thank you for your attention.