HOCHSCHULE FURTWANGEN UNIVERSITY | HFU

UNIVERSITÉ HAUTE-ALSACE

# CANDO 2020
# Investigation of Rogowski Current Sensors for Appliances Classification in NILM

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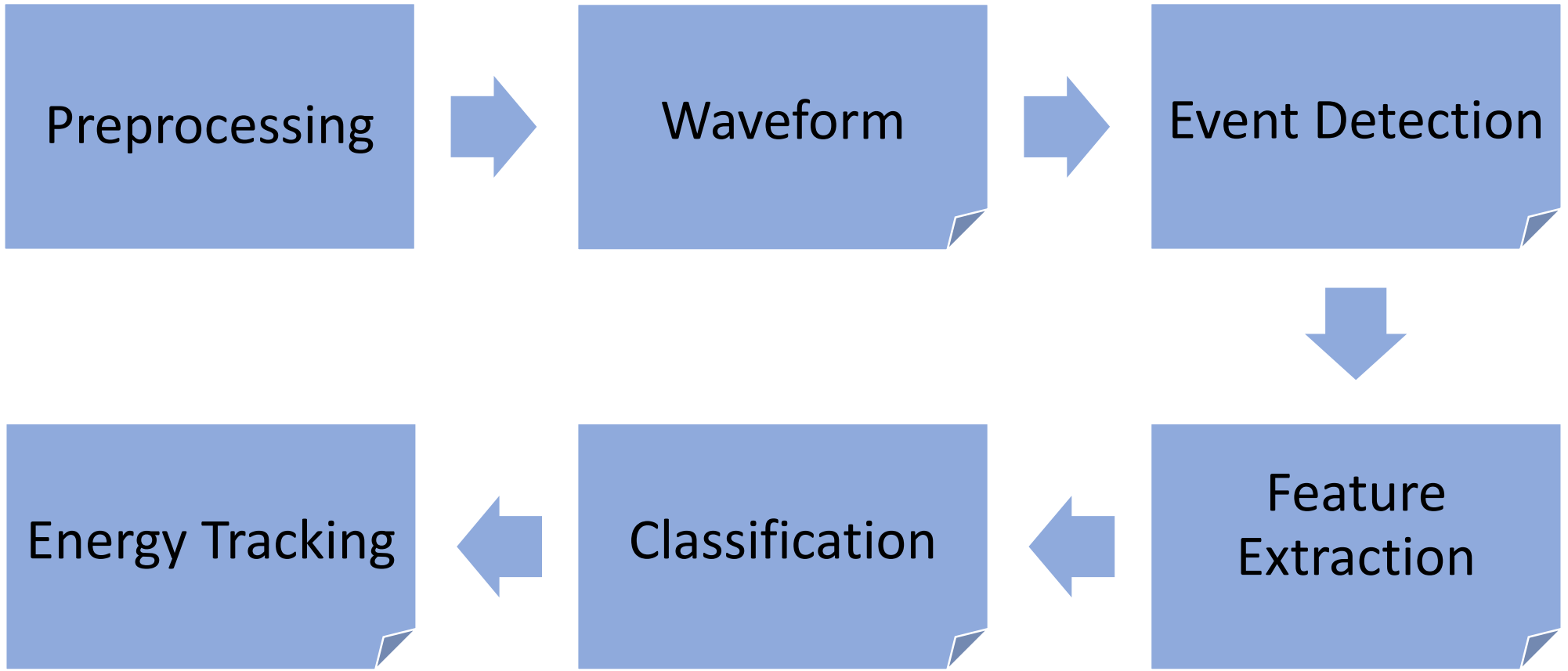
# Agenda

1. Introduction to NILM
2. Measurement System
3. Feature Extraction and Classification
4. Results
5. Conclusion

# The idea of NILM

# Structure of NILM



# Measurement System

- Comparison of current sensors
  - AC Current Transformer: TT 50-SD
    - Primary nominal current rms: 50 A
    - Split core type
    - Diameter for wire: 8mm
    - Bandwidth (± 1dB) 50/60 Hz
  - Rogowski coil: Metrawatt Metraflex 3003
    - Primary nominal current rms: 30/**300**/3000 A
    - flexible current sensors
    - Diameter for wire: ≈200 mm
    - Bandwidth 10 Hz ... 20 kHz

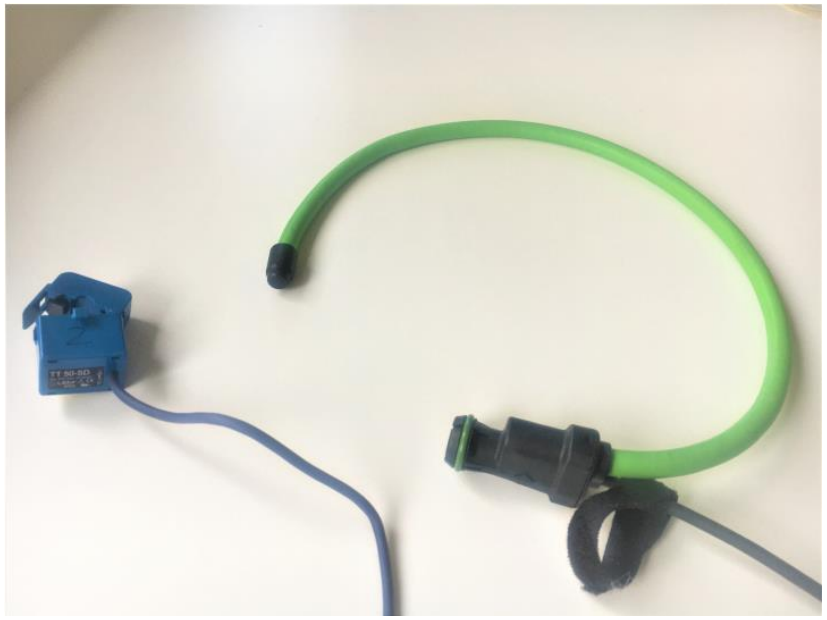
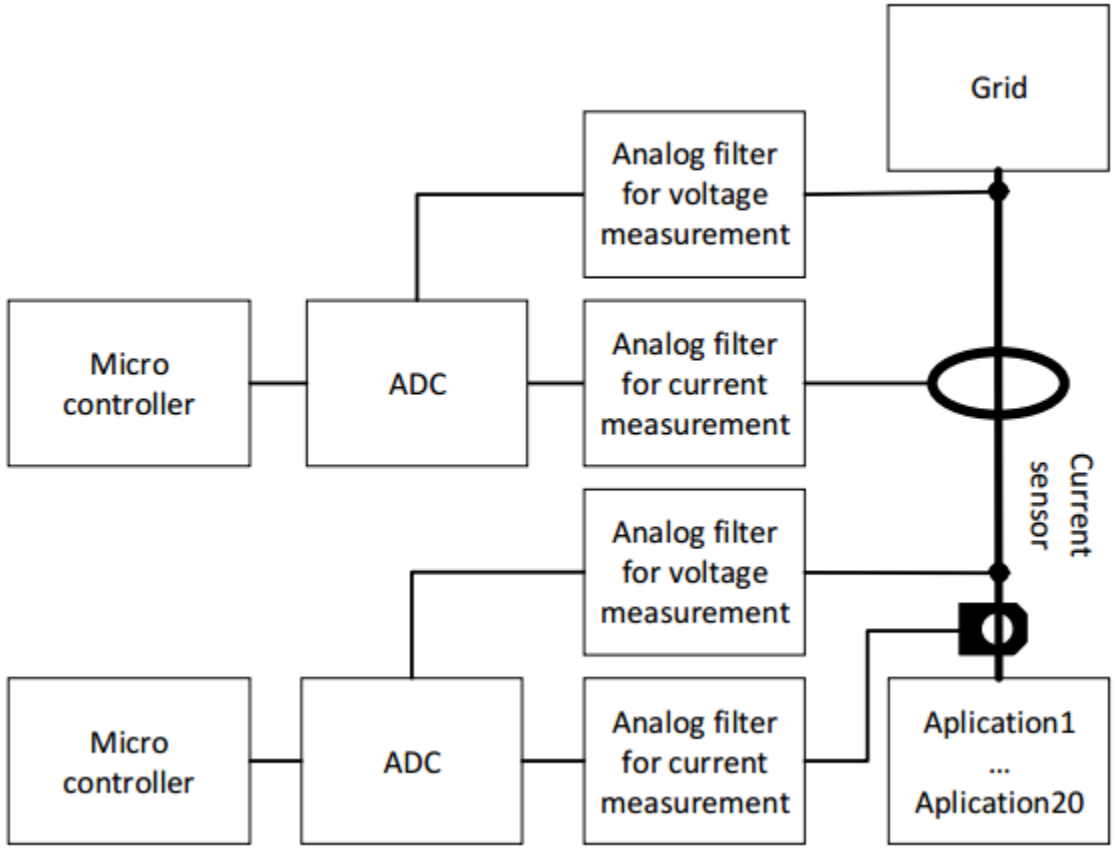


Illustration of the current-sensors to be evaluated. The conventional current transformers: LEM TT50SD (left) and the Rogowski coil Metraflex 3003 (right)

# Measurement System

- Two measuring systems were set up in parallel
- Current and voltage were measured
- The current was measured with the Rogowski coil and with the conventional current transformer




Measurement setup of NILM systems with a Rogowski coil and conventional current transformers.

# Measurement

- 20 devices have explicitly been switched on and off
- Current and voltage curves were recorded
- Each device was turned on and off 50 times
- Sampling frequency of 14 kHz
- Resolution of 16 bit (at a maximum current of 64 A)

$$I_{res} = I_{max}/2^{15} = 2.76\,\mathrm{mA}$$

$$I_{max} = 64\,\mathrm{A} \cdot \sqrt{2} = 90.5\,\mathrm{A}$$

TABLE I
DEVICE LIST

| Dev. No. | Name | P(W) |
|---|---|---|
| 1 | Hairdryer (setting 2) | 1155 |
| 2 | Radio | 6.2 |
| 3 | Hair Straightener | 56 |
| 4 | Heat Gun (setting 1) | 820 |
| 5 | Router | 9.2 |
| 6 | Desk Lamp | 20 |
| 7 | Kettle | 2100 |
| 8 | Hairdryer (setting 1) | 500 |
| 9 | Heat Gun (setting 2) | 1603 |
| 10 | Fan | 22 |
| 11 | Multifunction Tool (Dremel ®) | 30 |
| 12 | LED lamp | 1 |
| 13 | Vaccum cleaner (Kobolt) | 210 |
| 14 | W-Lan Range extender TP-link TL-W850RE | 1.4 |
| 15 | Fan | 22 |
| 16 | Fan | 22 |
| 17 | Gray Desk Lamp | 23 |
| 18 | Laptop | 60 |
| 19 | Flex Bosch GWS 18 230 | 1800 |
| 20 | Flex Hitachi | 840 |

# Feature Extraction

**FIT-PS Procedure**

a) using the zero crossings voltage to detect one period

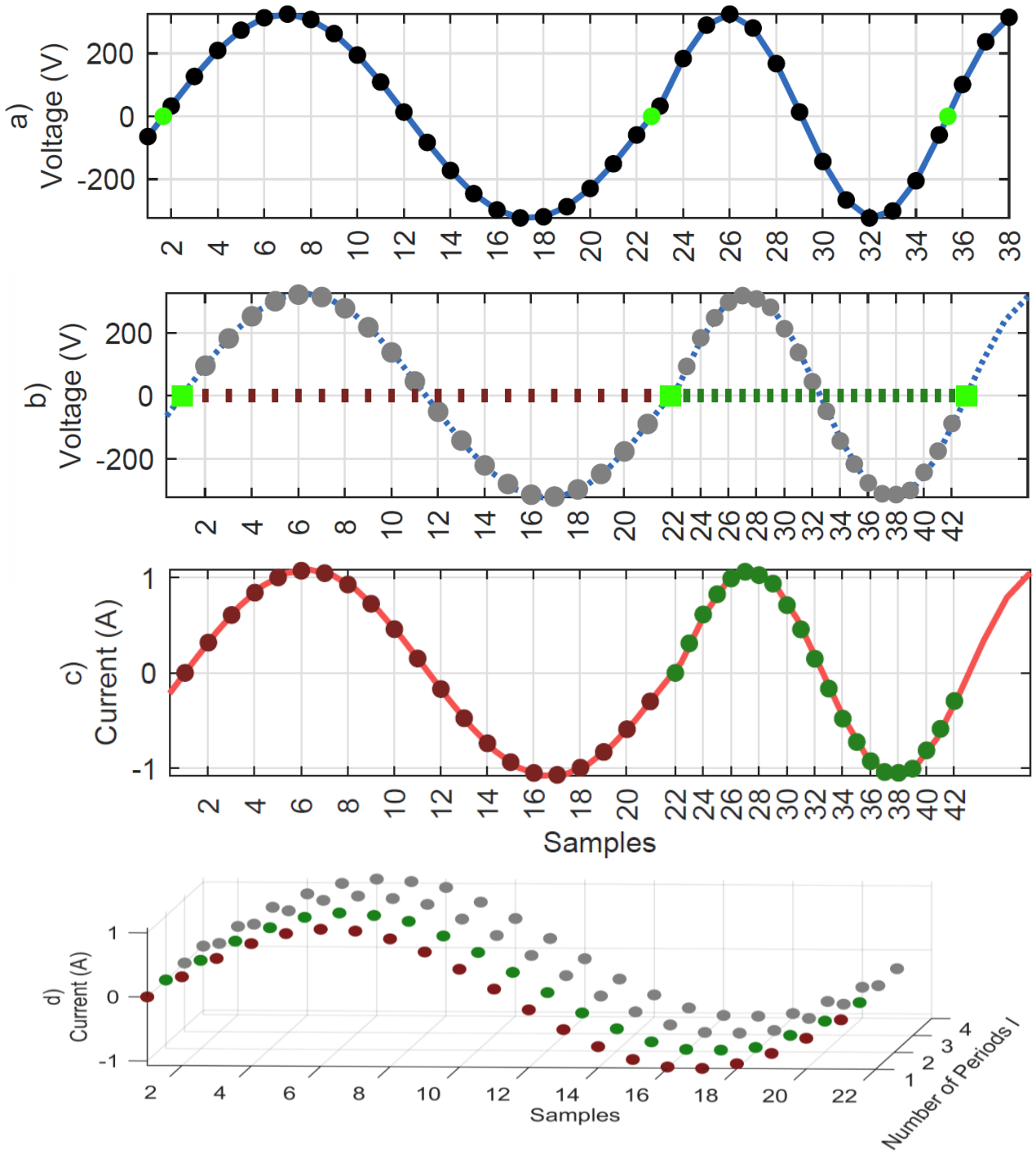
b) define new equidistant sampling positions

c) interpolation of the current signal

d) reshape the signal

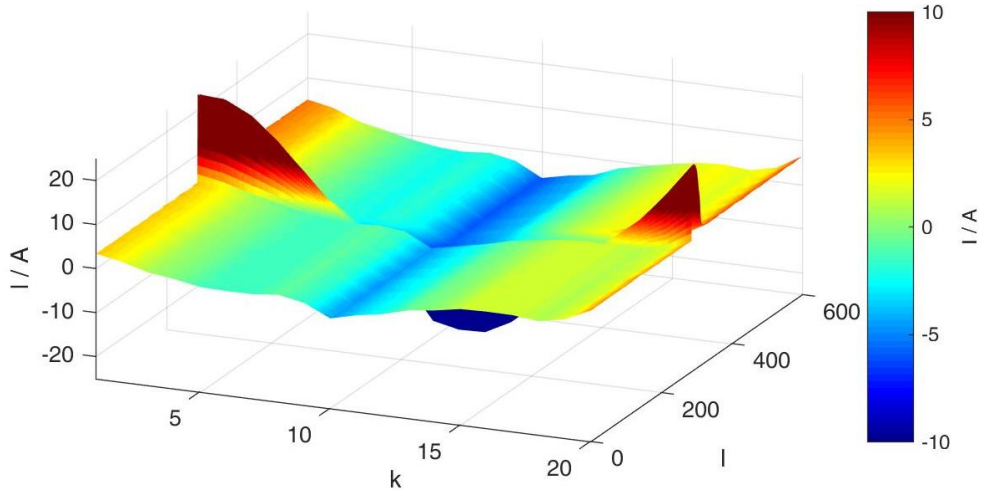
$$\mathbb{N}, \mathbb{N} \to \mathbb{R}$$

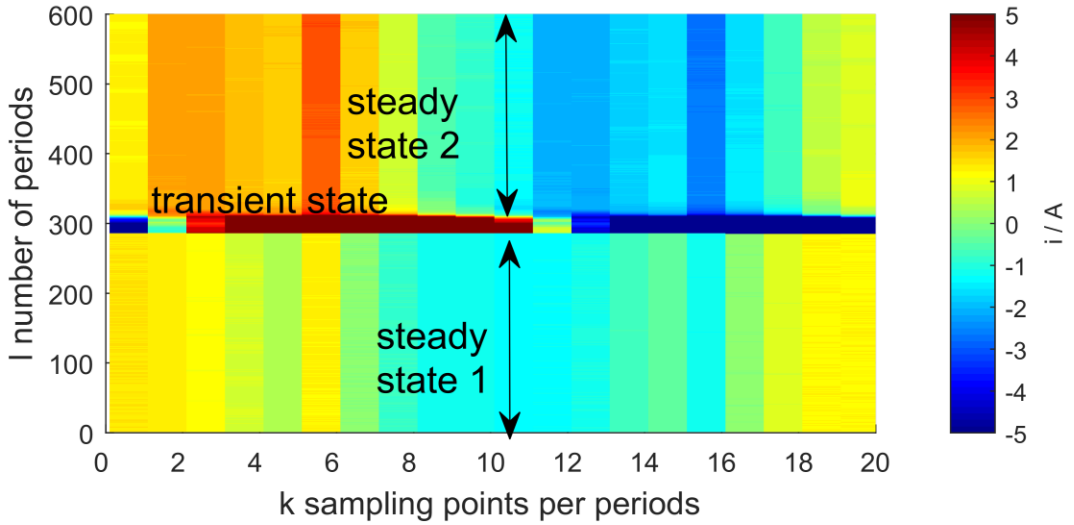
$$l, k \mapsto i(\underbrace{(l-1) \cdot T_g}_{\text{period}} + \underbrace{T_s \cdot k}_{\text{inside one period}})$$



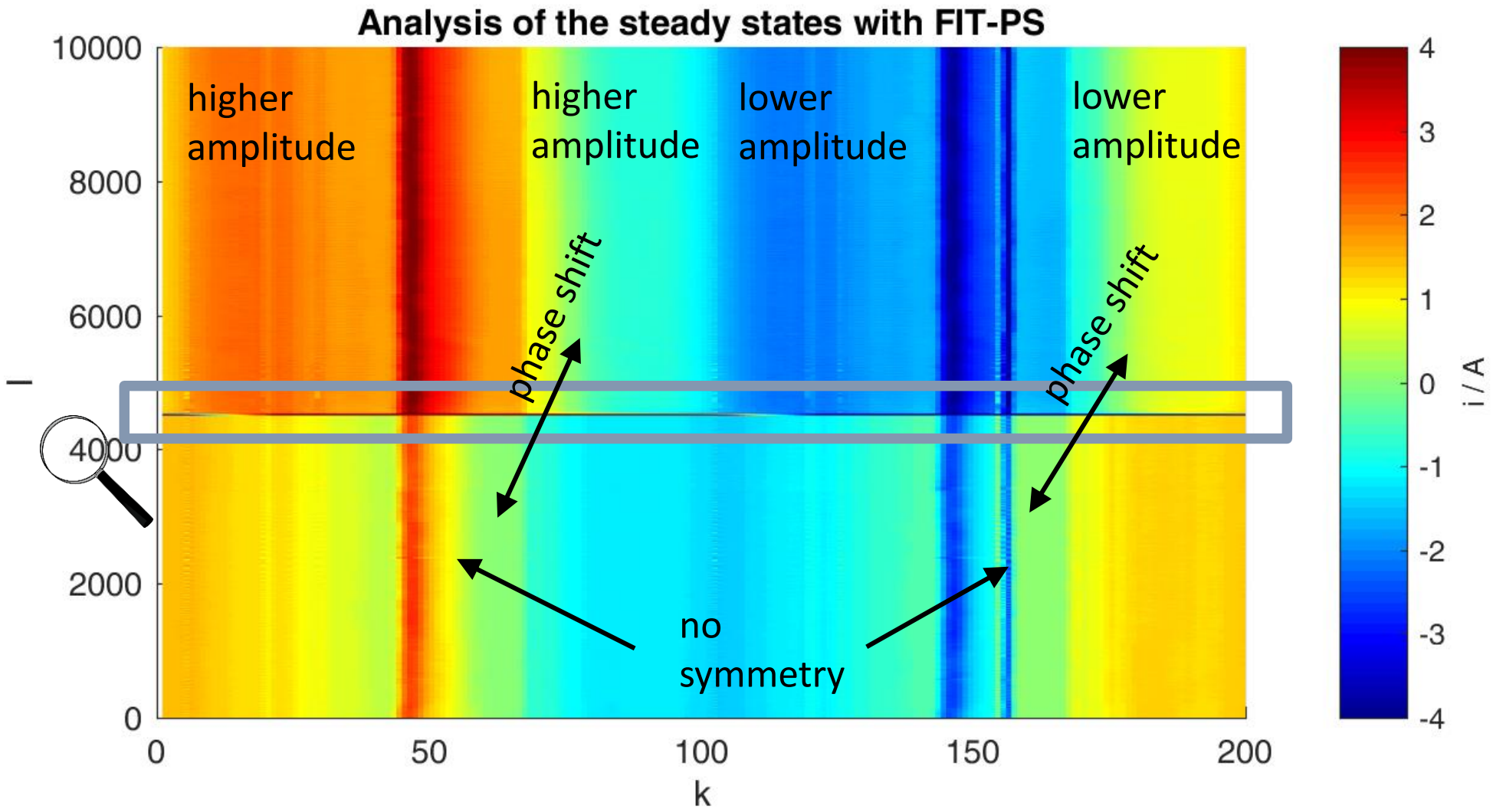
# Signal Analysis using FIT-PS

- Two steady states with a transient state between
- Only small variations along *I* direction in the dimensions *k* during the steady state
- Clear separation between the steady state and the transient state
- FIT-PS shows the difference of both steady states within one period

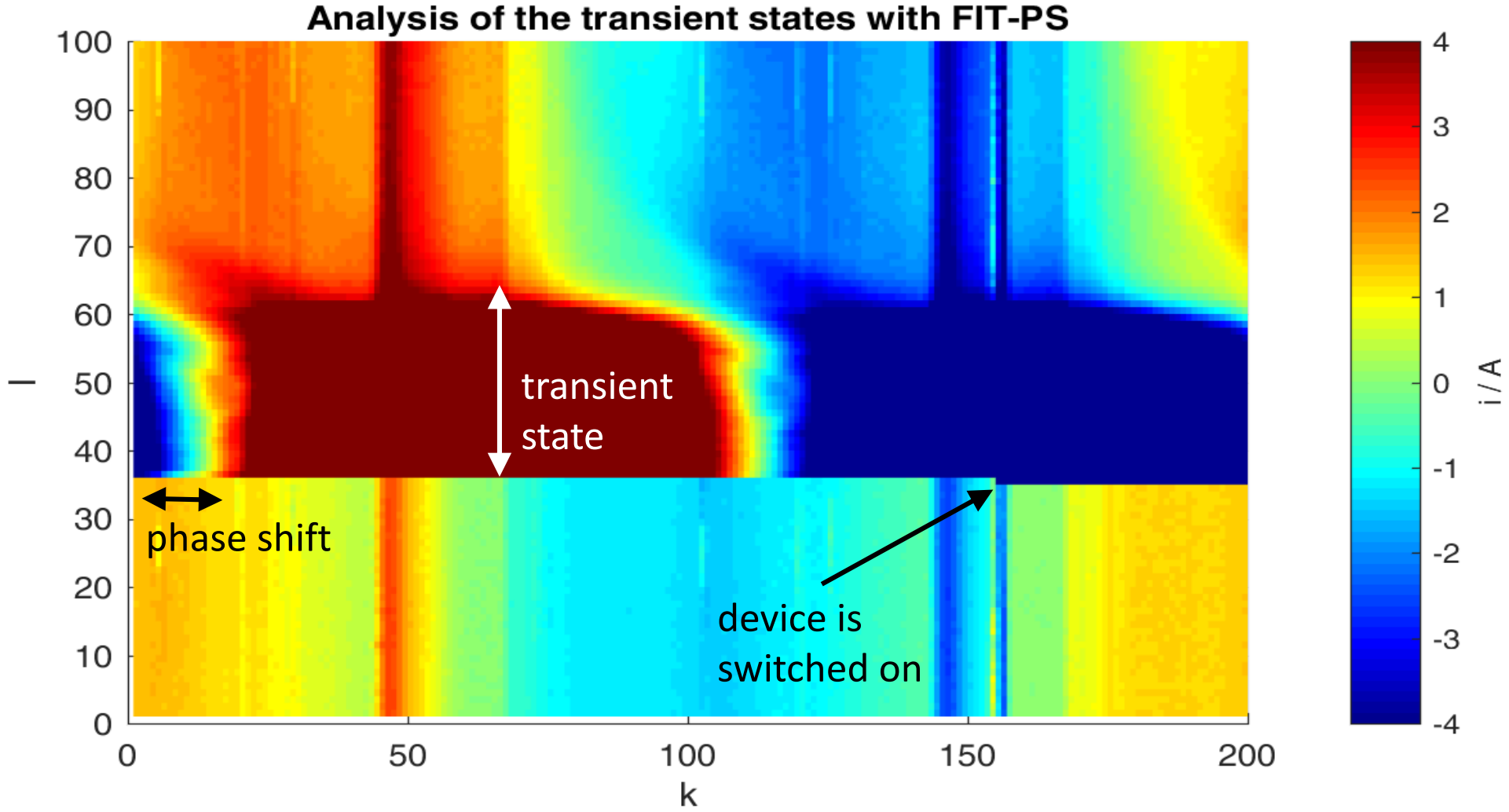


# High Sampled Signals

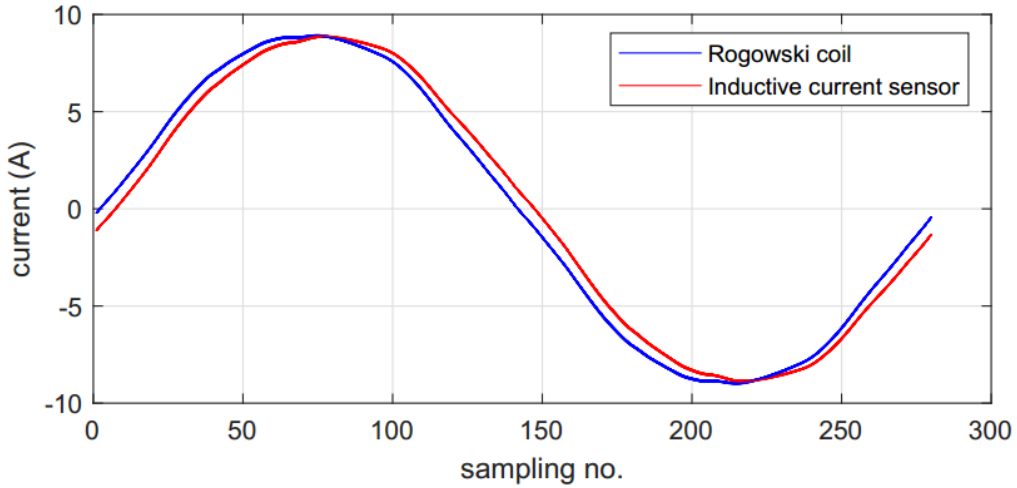


# High Sampled Signals

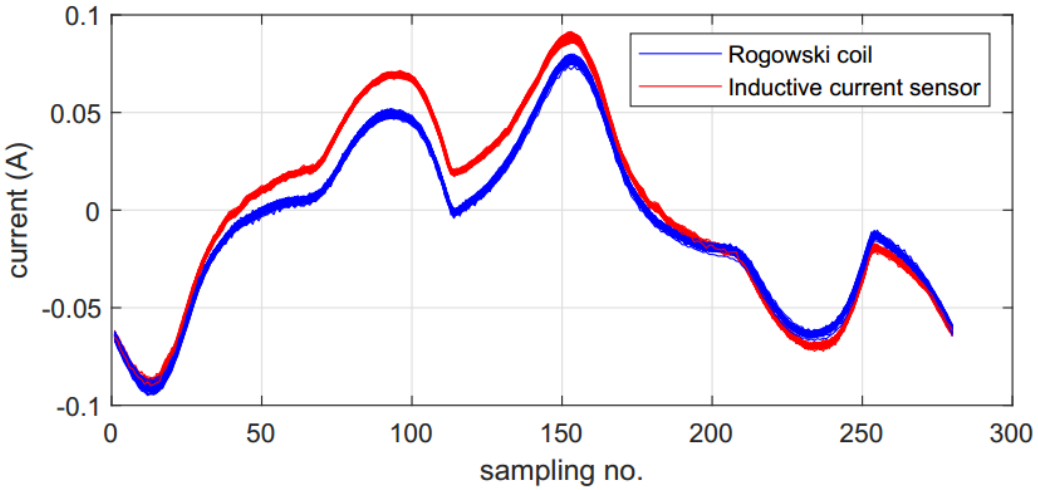


# Example of FIT-PS signal

- Example of FIT-PS signal representation of device No. 7



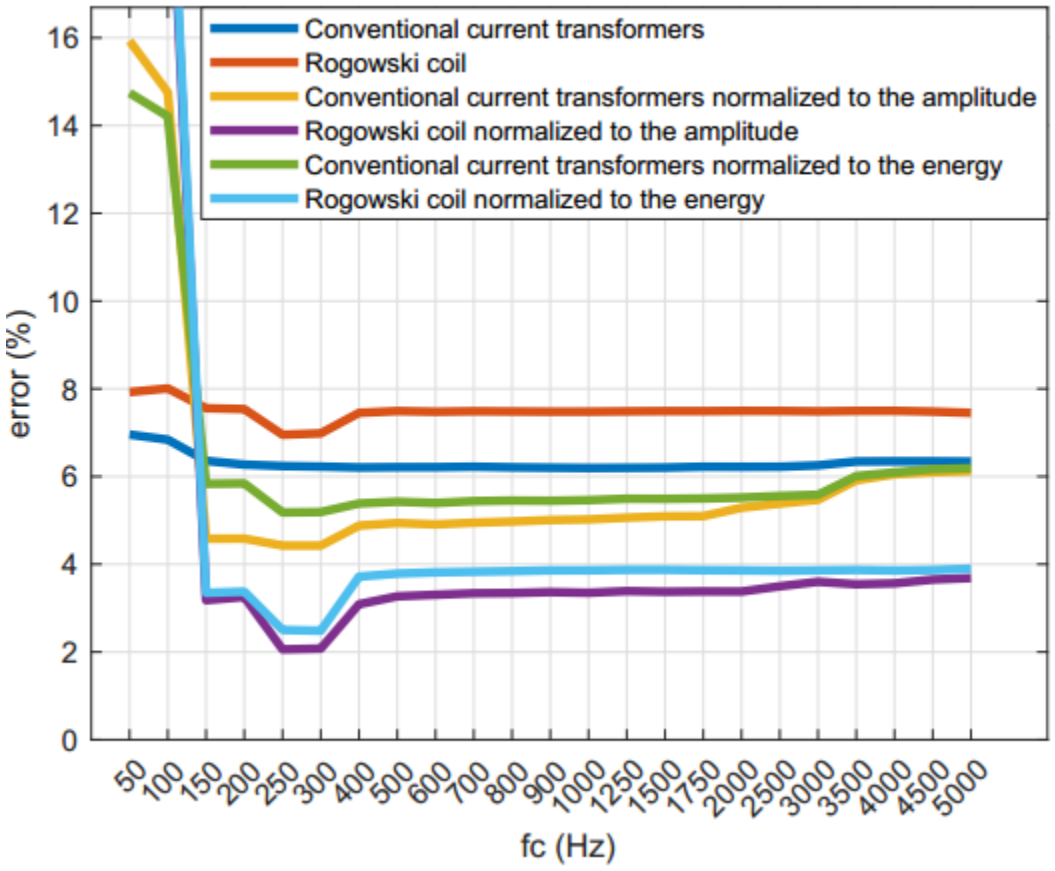

- Example of FIT-PS signal representation of device No. 5




- The figures show the FIT-PS feature with a characteristic current shape of a kettle and a router.
- Measured simultaneously with a Rogowski coil and a conventional current transformer

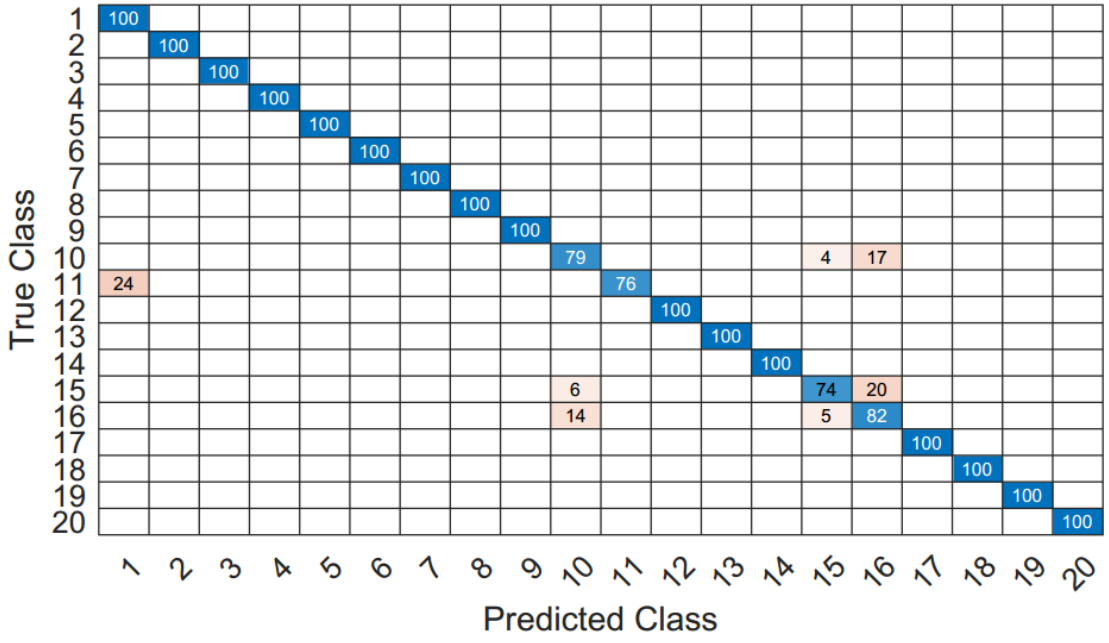
# Results of the classification with all devices

- 100 on/off events
- Low-pass filter (Kaiser window)
- Stop-band attenuation: 80dB
- Pass-band ripple is 0.01 dB
- The pass-band edge frequency is adjusted from 50 Hz to 5 kHz.
- Classification is realized using k-Nearest-Neighbor (k=3)

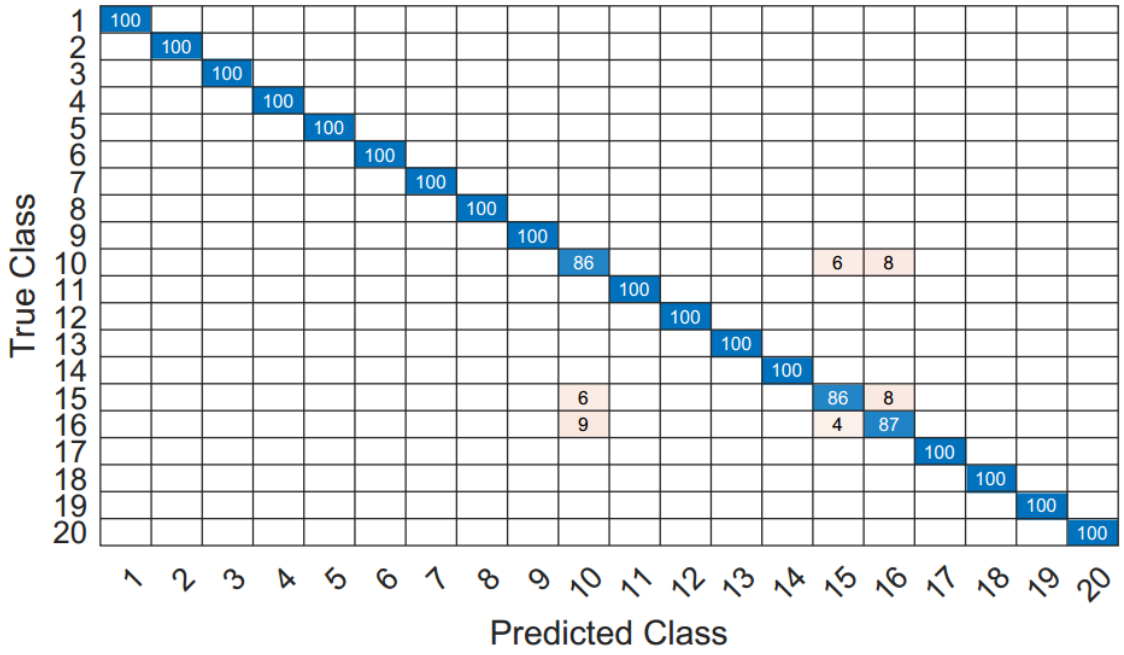


# Results of the classification with all devices

- Confusion matrix of the conventional current transformers at *fc*=300 Hz normalized to the amplitude

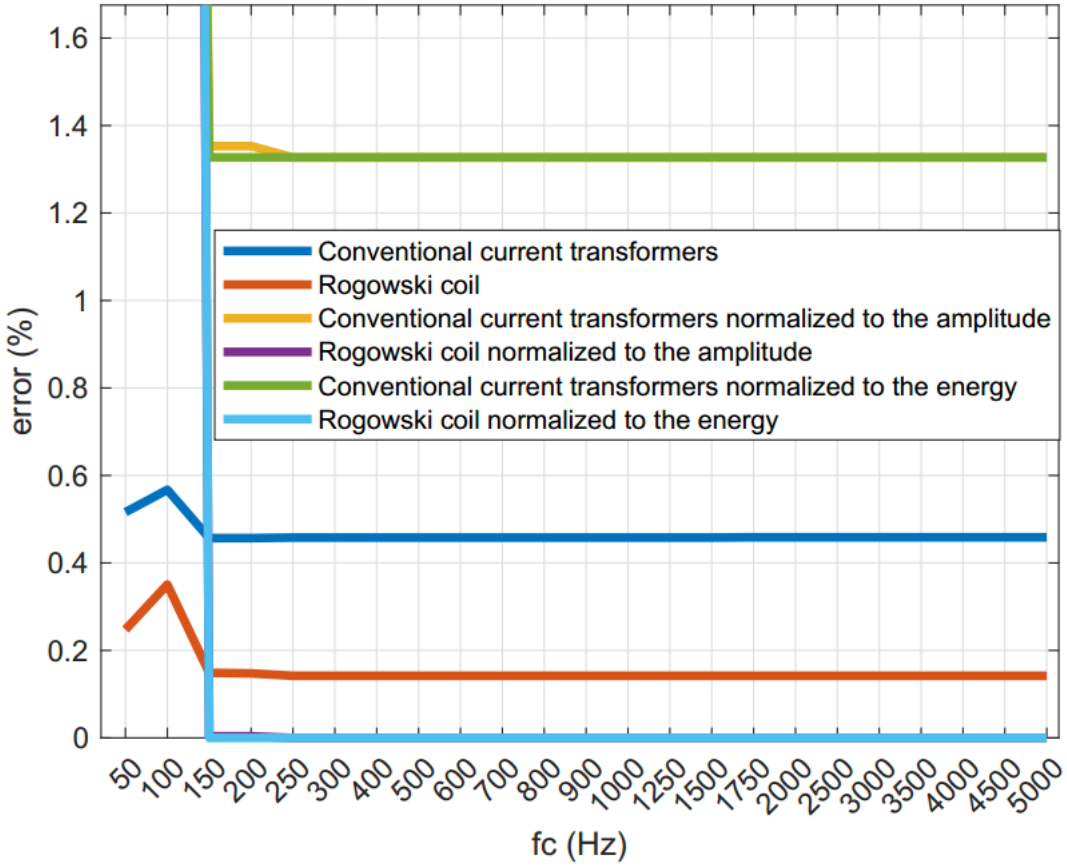



- Confusion matrix of the Rogowski coil at *fc*=300 Hz normalized to the amplitude



# Results of the classification without identical devices

- With the achieved results, the conventional current transformers mainly showed errors with the three identical fans.
- For this reason, only one of the three fans is used. Thus, 18 devices needs to be classified.
- The error with normalized features of the Rogowski coil is zero for frequencies equal or higher 250 Hz. The error of the conventional current transformer is with 1.3 % significantly higher.



# Thank you for your attention

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