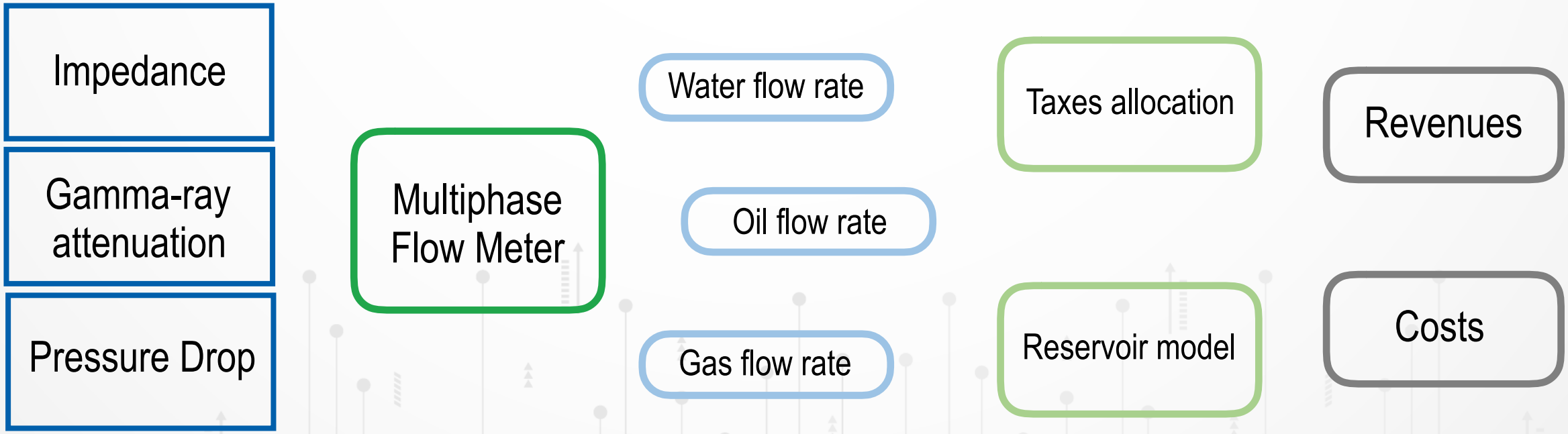
Time series forecasting to detect anomalous behaviours in Multiphase Flow Meters

T. Barbariol
D. Masiero
E. Feltresi
G.A. Susto

Content

Multiphase Flow Meter (MPFM) and Fault Detection (FD)



Faults on input sensors have a great impact on the system

Two possible approaches

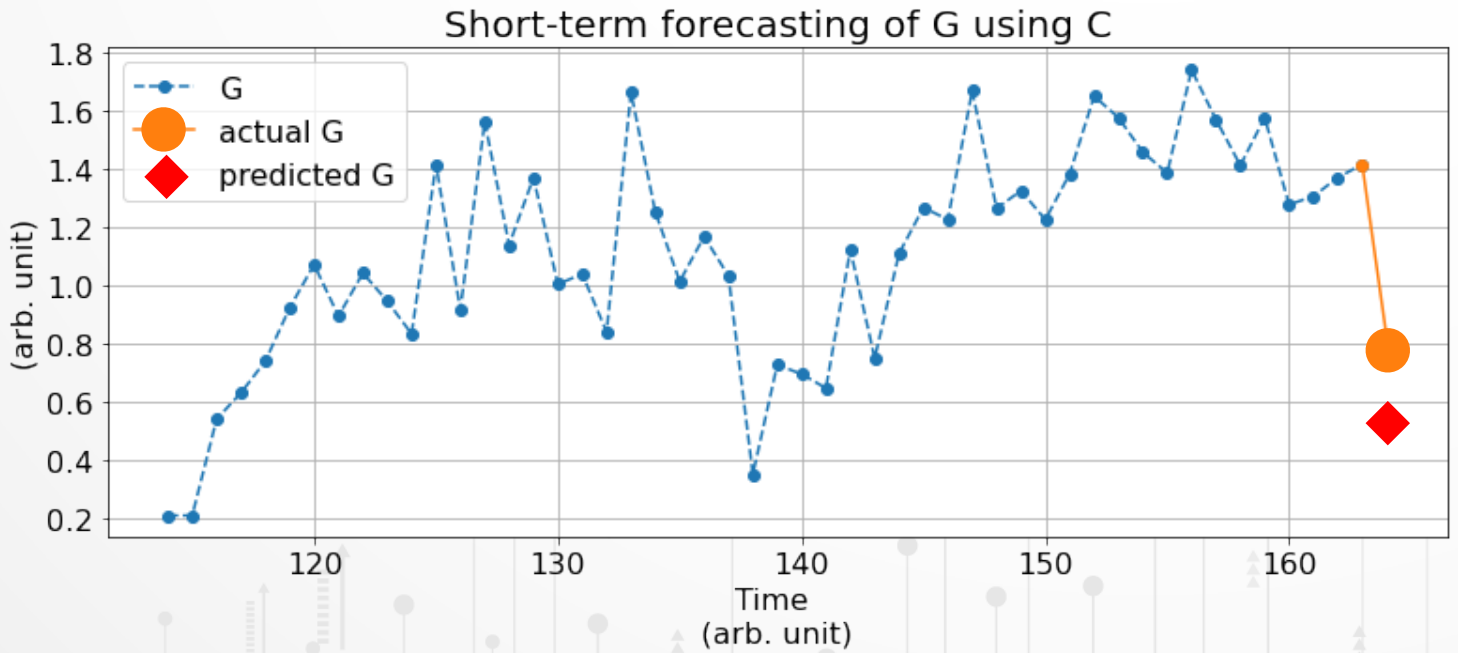
Model-driven approach

- Based on physics
- Robust
- Slow to develop

Data-driven approach

- Based on **experience** encoded in **data**
- **Flexible**
- **Fast** to develop

Fault Detection for Time Series Data



3 steps:

- Forecast
- Residual analysis
- Fault alarm

Forecast (1)

Selected Sensors

- G : gamma-ray densitometer
- C : electrical probe

not aligned in time.

Short-term forecast

preferred over the long-term forecast.

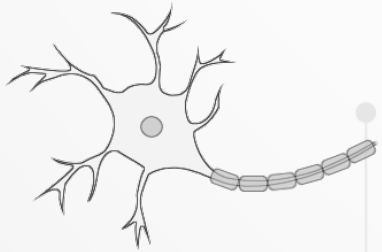
Models

- Naive Forecast
- Hard Subtraction
- Temporal Convolutional Network (TCN)

Temporal Convolutional Network

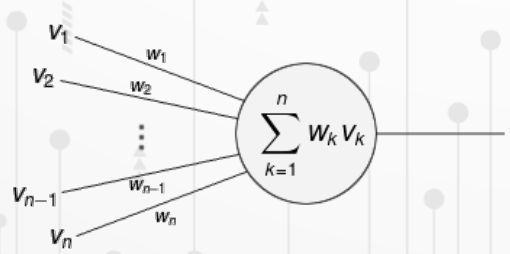
Special type of **Neural Network** (NN) developed for **time-series forecasting**.

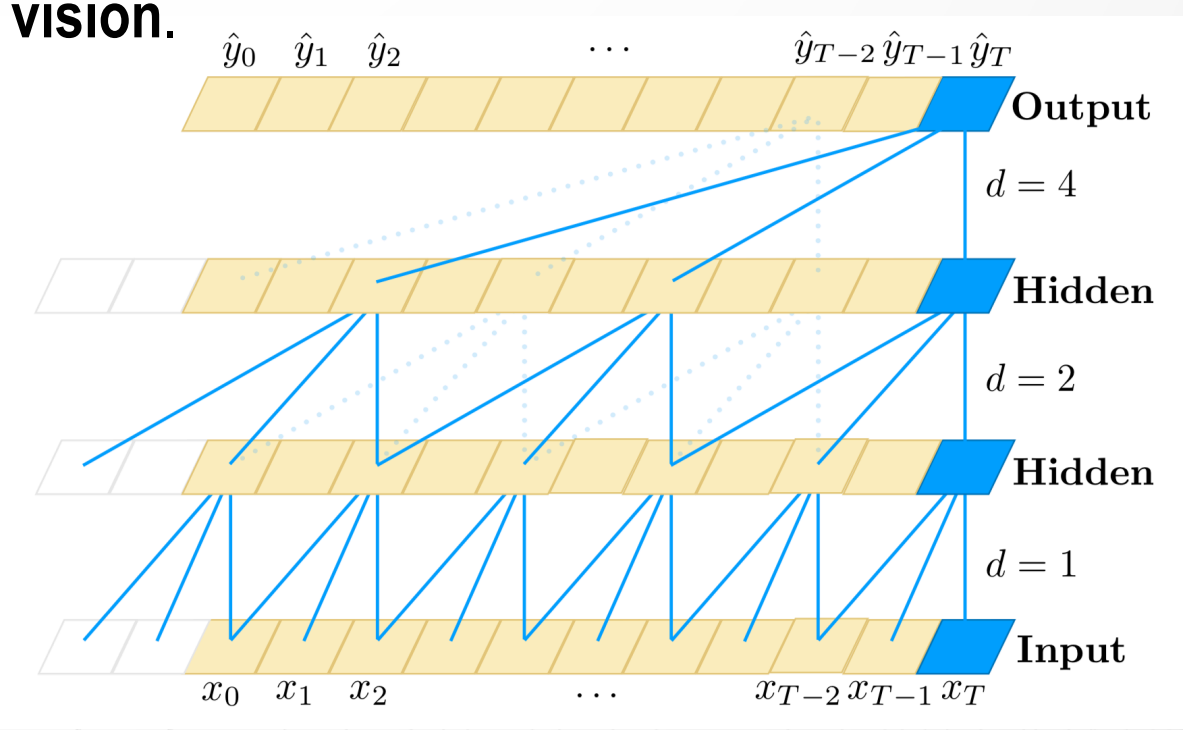
Based on Convolutional NN, popular in **computer vision**.



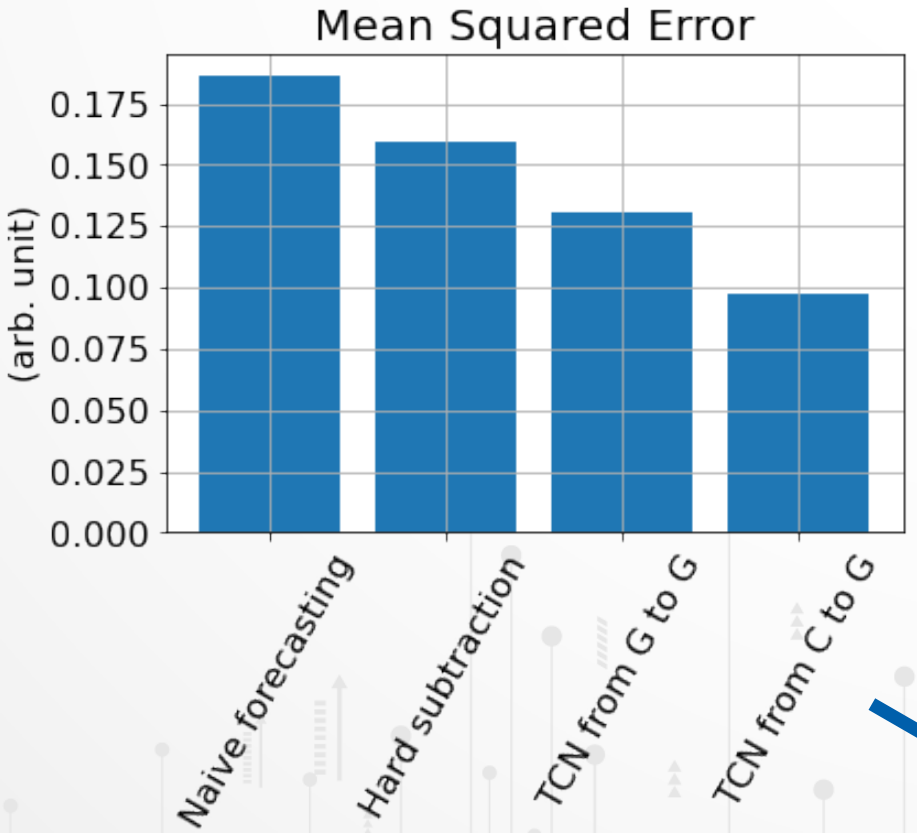
Biological neuron

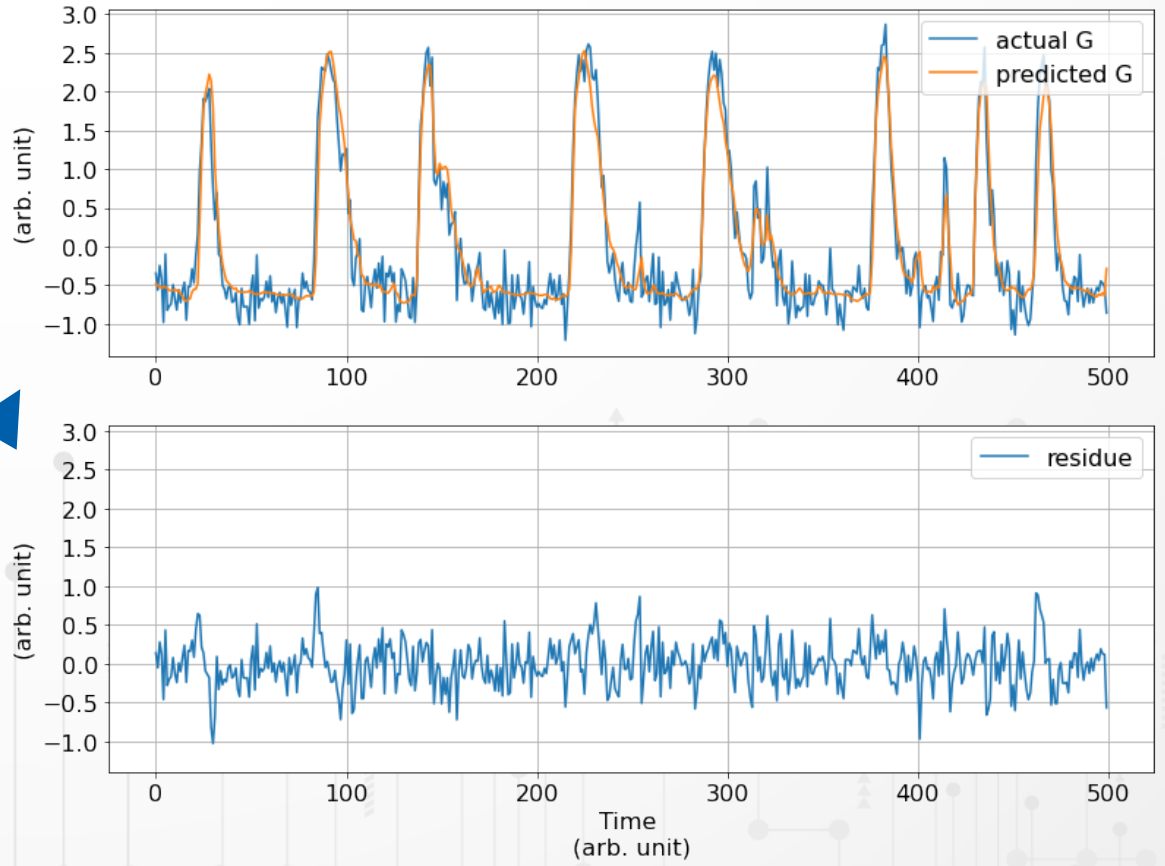
Artificial neuron



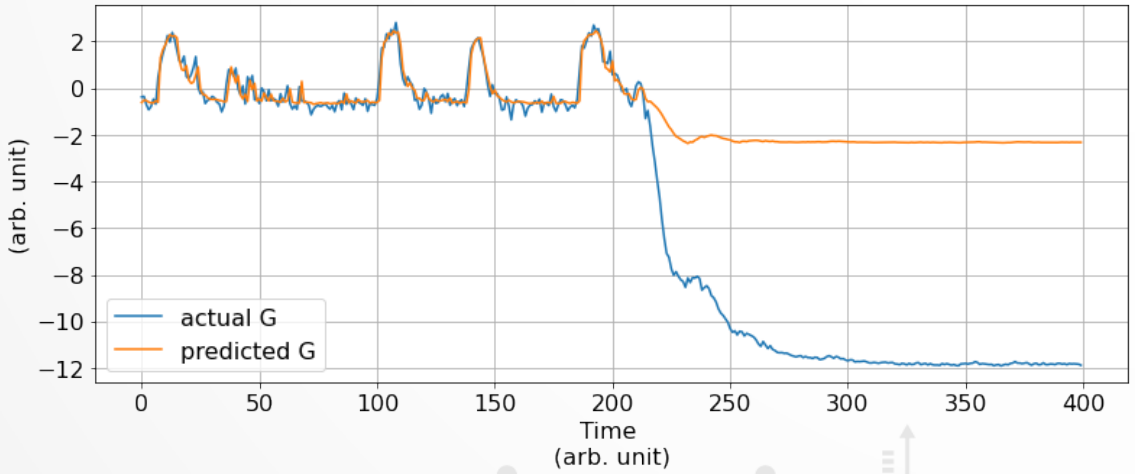


Forecast (2)


Mean Squared Error
(arb. unit)
0.175
0.150
0.125
0.100
0.075
0.050
0.025
0.000
Naive forecasting
Hard subtraction
TCN from G to G
TCN from C to G


actual G
predicted G
(arb. unit)
residue
Time
(arb. unit)

Robustness of the forecast

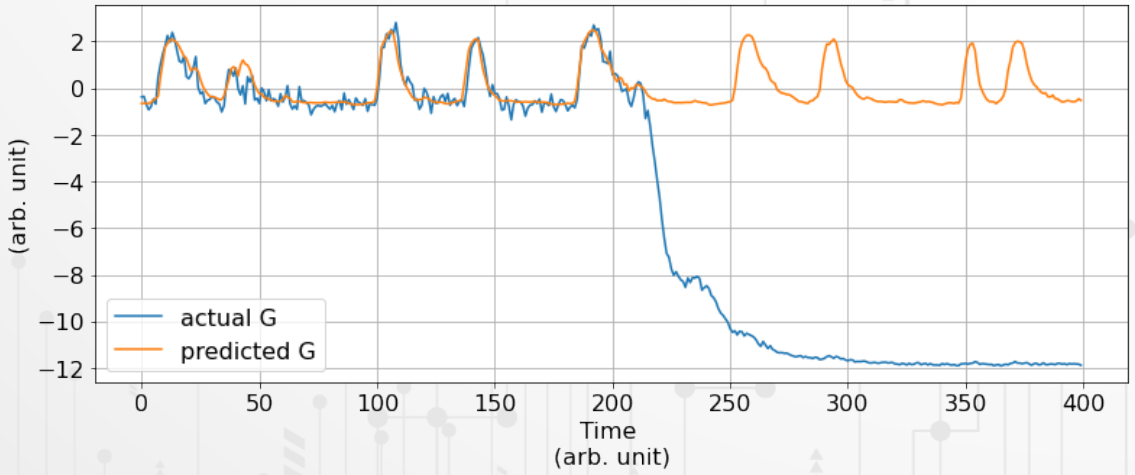


Input: G

Fault on G

Model: TCN

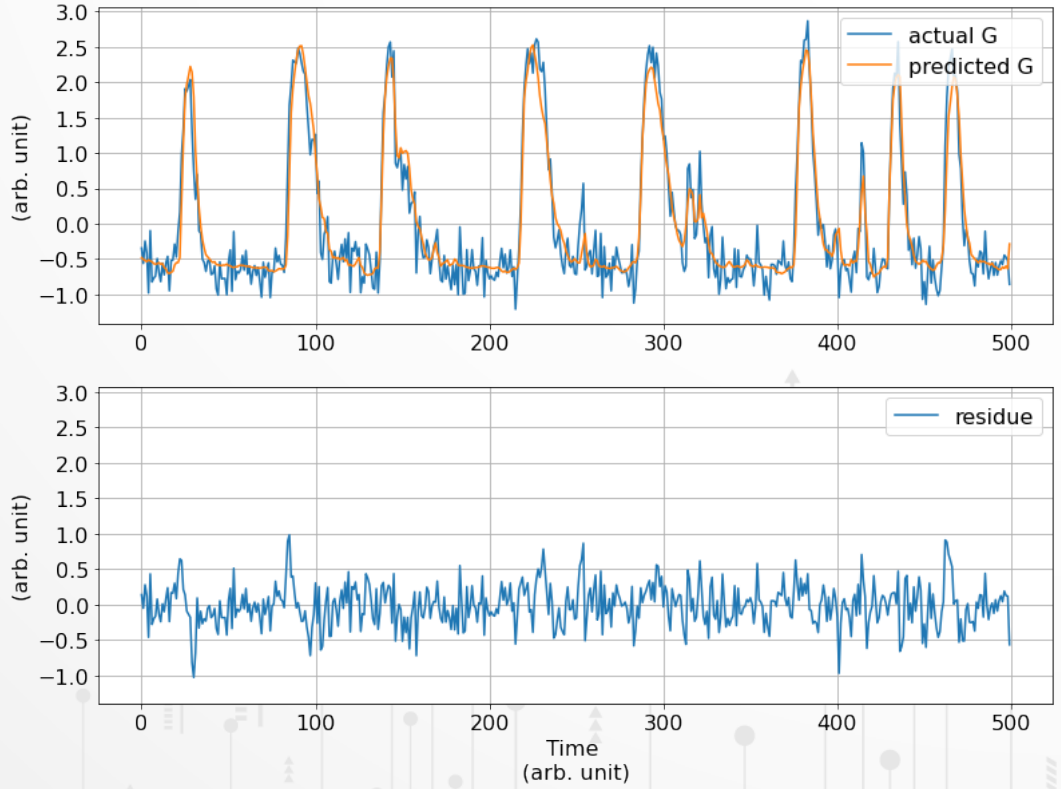
Output: G



Input: C

Predictions based on **exogenous** variable are more **robust**.

Fault Alarm (1)



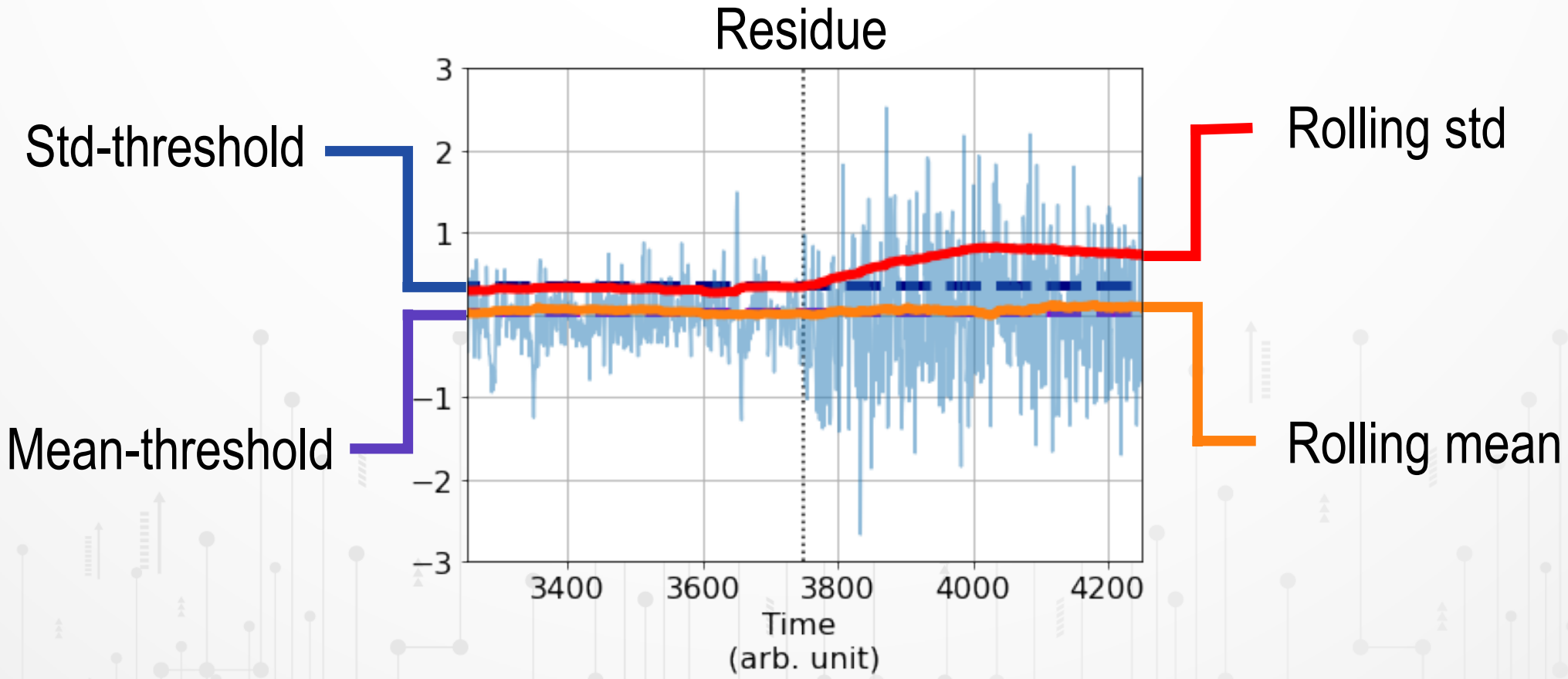
Noisy residue

Window smoothing

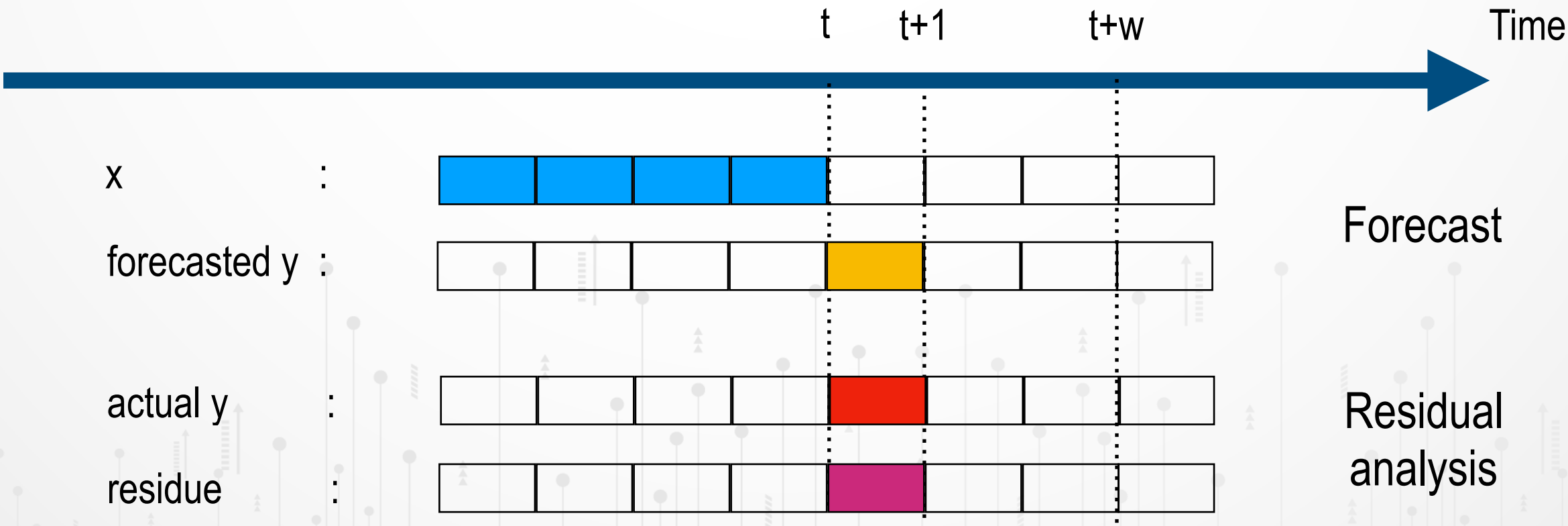
Rolling mean

Rolling standard deviation

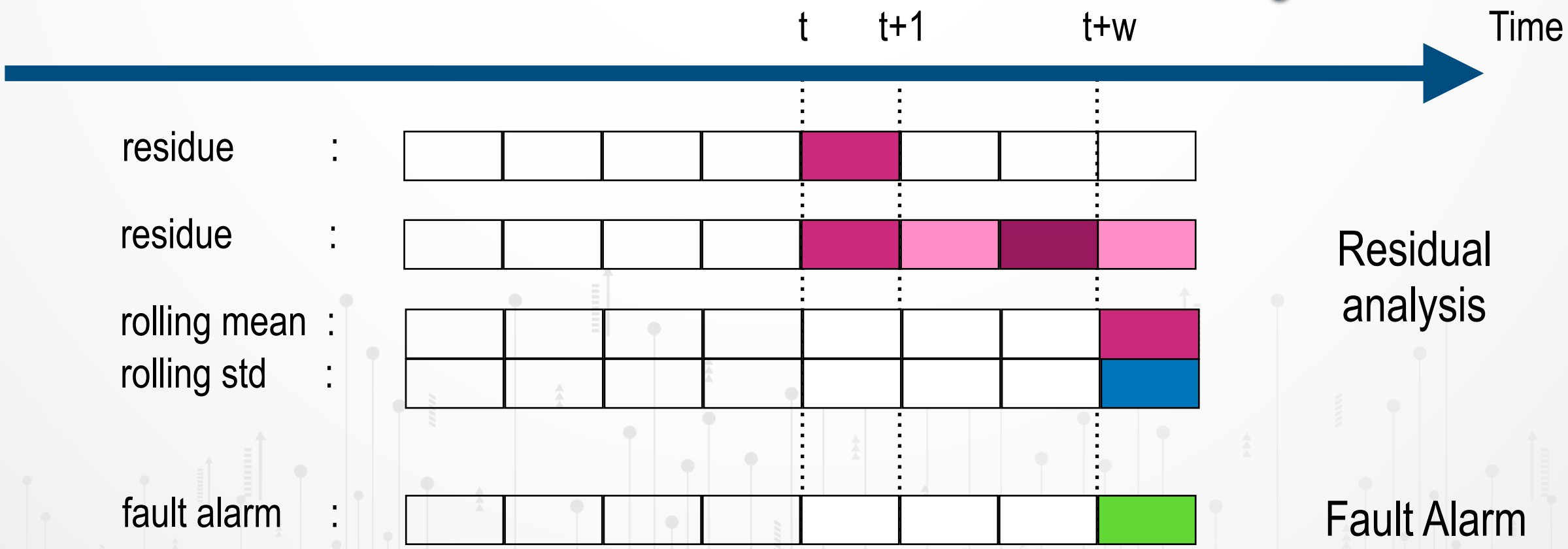
Fault alarm (2)



Scheme (1)


t
t+1
t+w
Time
x :
forecasted y :
actual y :
residue :
Forecast
Residual analysis

Scheme (2)


t
t+1
t+w
Time
residue :
residue :
rolling mean :
rolling std :
fault alarm :
Residual analysis
Fault Alarm

Tests on Real and Synthetic Faults

Synthetic: Complete Failure

Both the rolling mean and the rolling std exceed the threshold.

Actual signal

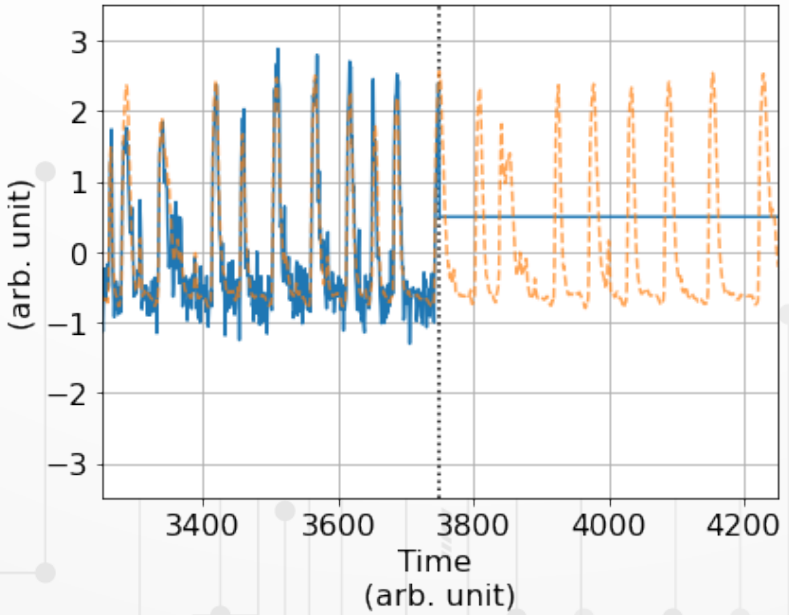
Forecasted signal

Rolling mean

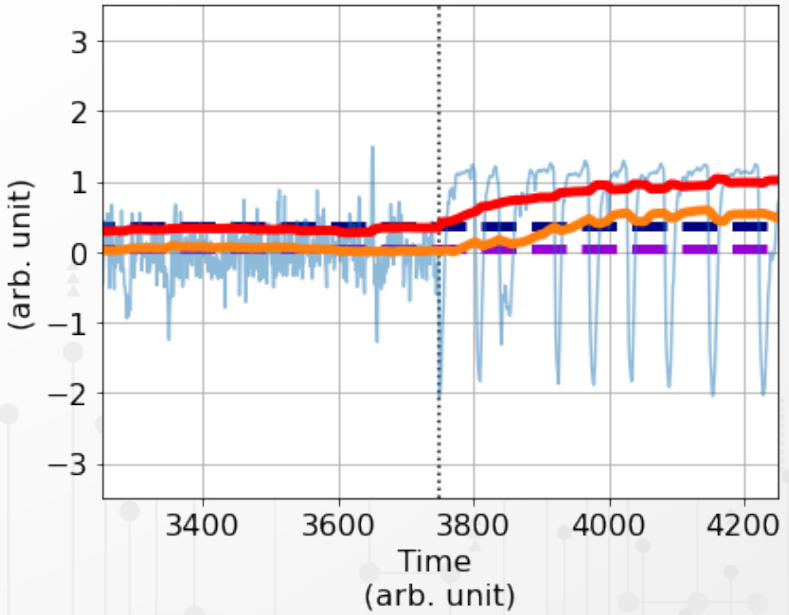
Rolling std

Thresholds

Signal



Residue



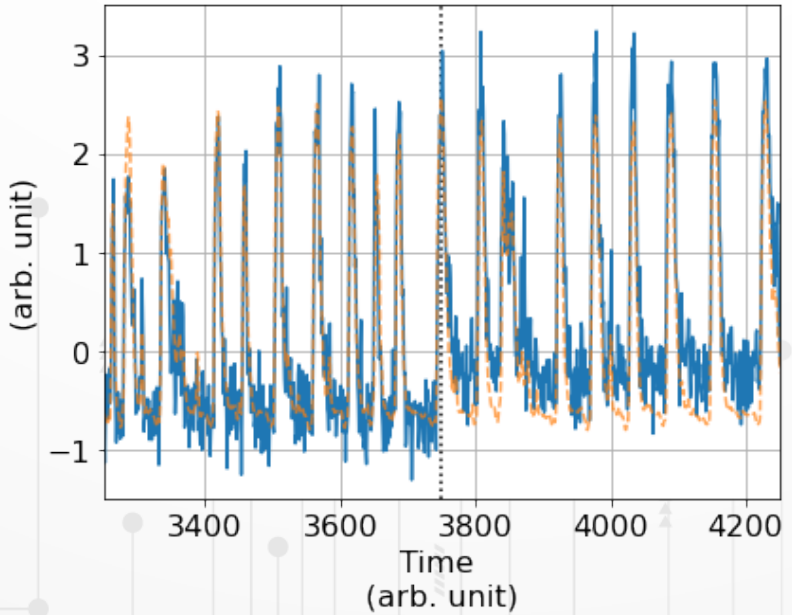
Tests on Real and Synthetic Faults

Synthetic: Bias

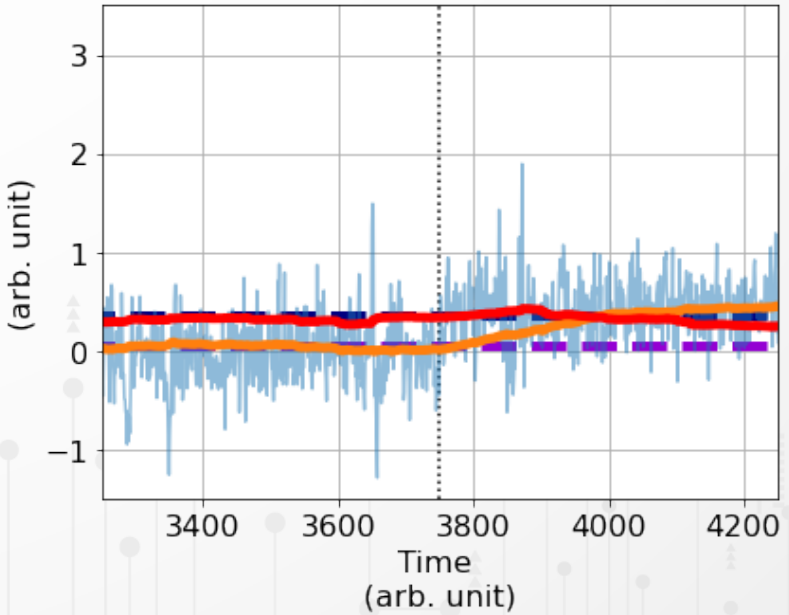
The rolling mean exceeds the threshold.

Actual signal
Forecasted signal
Rolling mean
Rolling std
Thresholds

Signal



Residue



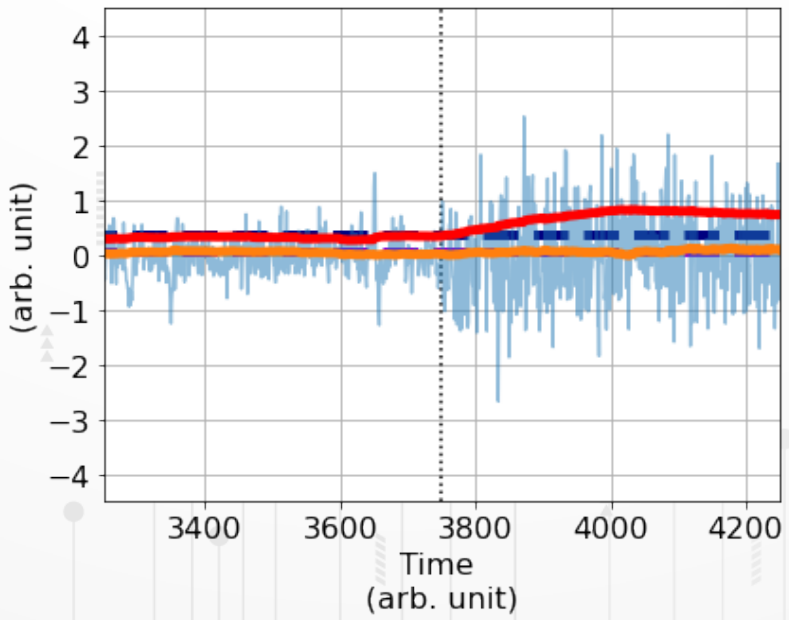
Tests on Real and Synthetic Faults

Synthetic: Precision Degradation

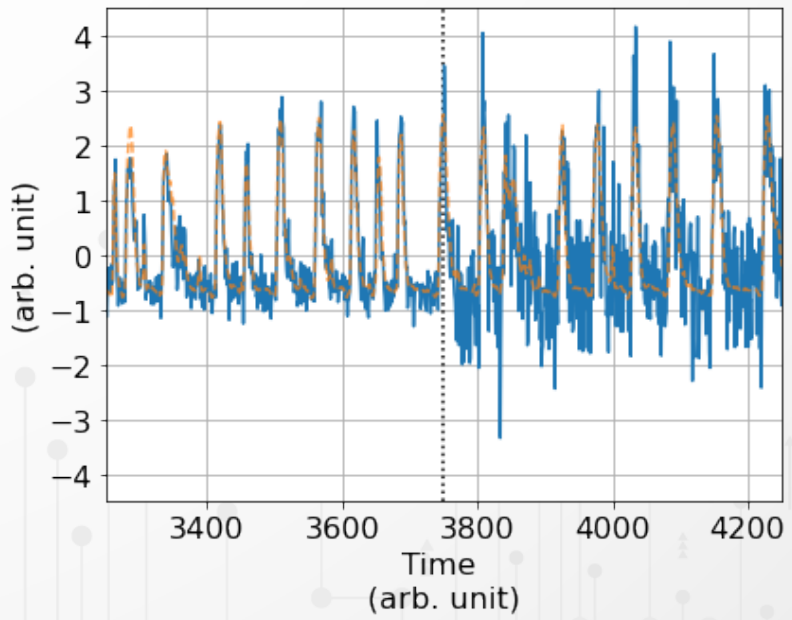
The rolling std exceeds the threshold.

- Actual signal
- Forecasted signal
- Rolling mean
- Rolling std
- Thresholds

Signal



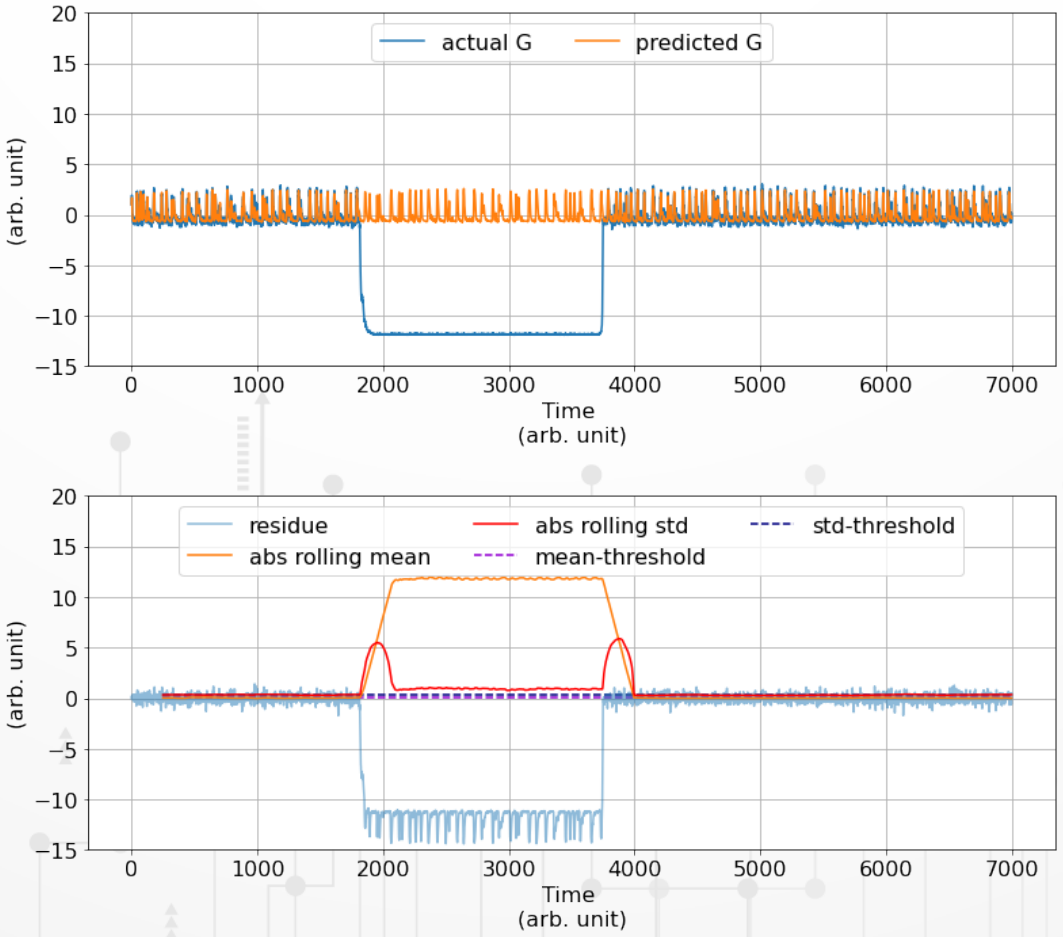
Residue



Tests on Real and Synthetic Faults

Real:

Gamma-ray shutter closed



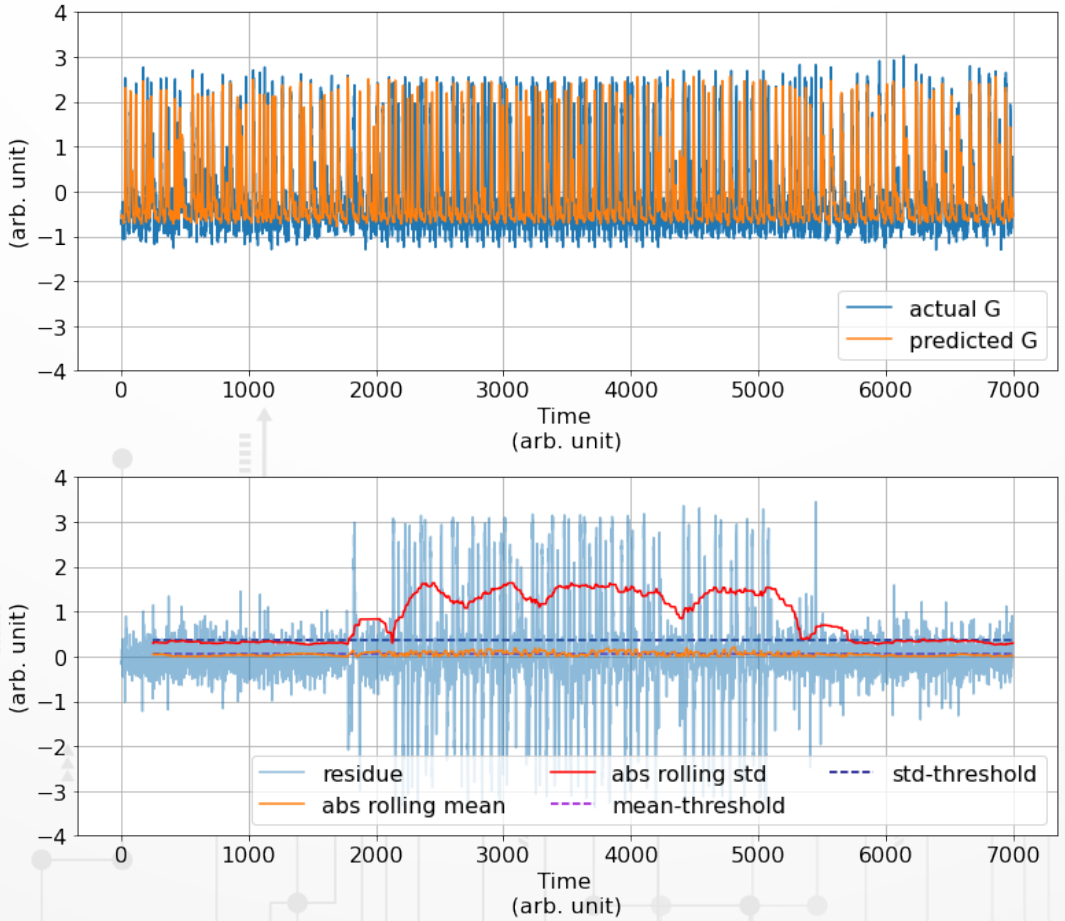
Easier than the synthetic faults.

Tests on Real and Synthetic Faults

Real:

Transmission interrupted

The instrument transmits the same sequence over an over again.



Very difficult to be detected by a human expert.

Very easy to be detected by an automatic system.

Conclusion

Goal achieved:

- Fault Detection system based on sensor streaming data
- Independent from the specific meter

Real tests show that:

- The TCN forecast is accurate
- The residue processing and fault alarm is highly reliable

NORTH SEA FLOW MEASUREMENT WORKSHOP

measuring for the energy transition

Contact Us

Tommaso Barbariol

Università degli Studi di Padova

Via Gradenigo 6/b, 35131

Padova (PD), Italy

tommaso.barbariol@phd.unipd.it

https://www.linkedin.com/in/tommaso-barbariol-004259134/

Pietro Fiorentini