WHEN TRUST MATTERS

Development and Validation of Automatic Data Quality Control using Probabilistic Bayesian Neural Network

DeepWind 2023

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- Digitalization & Research
- 4 years with DNV

Agenda

- Introduction
- Project Data – Research at Alpha Ventus (RAVE)
- General Background
- Automatic Data Quality Control using BNN
- Case Study – First Results
- Future Works

Introduction – Standard data quality control of measurement data

High frequency Raw data signals → Calibrated data signals → Descriptive statistics → Manual/visual check of statistical data → Flagging abnormal data signals

Disadvantages

- Time consuming process
- High measurement operational cost
- Impossible to check the high frequency measurements
- Immediate detection of measurement errors are not possible
- Extended measurement campaign
- Added uncertainty

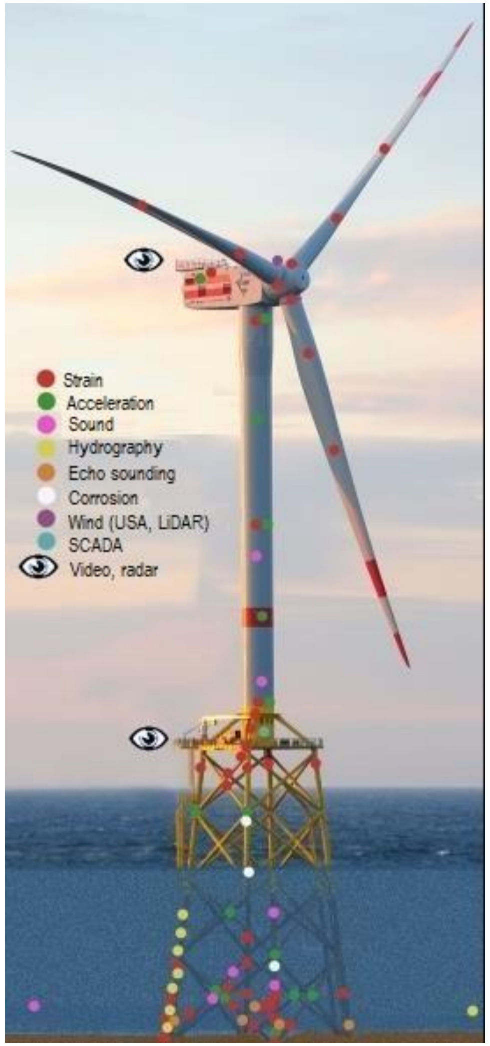
Project Data – Research at Alpha Ventus (RAVE)

- ➢ The research Initiative RAVE carries out research and development work on the offshore test field alpha Ventus.
- ➢ RAVE is funded by the Federal Ministry for Economic Affairs and Climatic Actions (BMWK) and coordinated by the Fraunhofer Institute for Wind Energy Systems (IWES).
- ➢ In more than 30 research projects, more than 60 partners from science and industry have been working on a wide range of research questions since 2008.
- ➢ The financial support from the BMWK so far amounted to more than 50 million euros.

Wind Farm Outlook

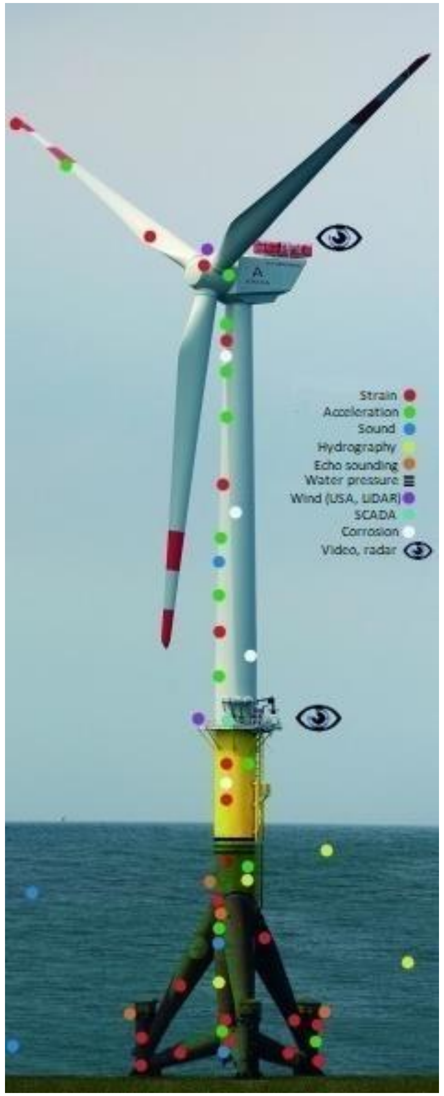
- ➢ 45 Km North von Borkum
- ➢ 30 m water depth
- ➢ 12 Wind turbines
  - 6 AREVA WIND M5000
  - 6 Senvion 5M
- ➢ CAPEX : 250 Million Euros
- ➢ More than 10 years of measurement data

Project Data – Research at Alpha Ventus (RAVE)



Available Measurements

- Controller Signals
- Acceleration sensors on the tower and blades
- Multiple strain guages on the tower and blades
- Wind measurements
- Atmospheric measurements
- Sea-State Measurements
- Other critical structural measurements
- Other electrical signals



General Background – Automatic Data Quality Control

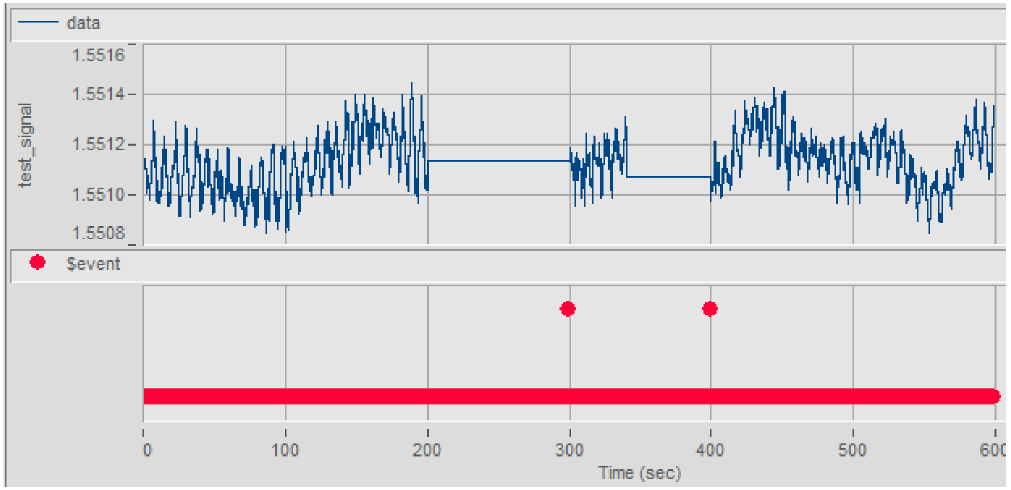
High frequency Raw data signals → Automatic data quality control → Calibrated Signals → Flagging abnormal data signals

Objective

- Control the data collected from RAVE wind farm
- Plausibility check on raw signals (0.2 to 50 HZ signals)
- Automating the control and flagging process
- Independent to sensor and measurement system
- Minimal input parameters (Robust model)
- Save time and operational cost
- High quality data for future applications

Position	Test Type	Meaning	Thresholds	Description
1	Length	Reduced data length	N_{crit}%	Data of length of some value N_{crit} deviating from N 100%
2	Flat Line	Constant Signal	N/A	All values the same (e.g. bad if sensor is strain gauge, Ok/Check if machine data)
3	Flat Line	Partially Constant	t_{crit}	Constant values for a period of > t_{crit} seconds (e.g. signal dropouts)
4	Pre-defined Limits	Measurement Range	$\sum (x_i > x_{crit}) > 0$	At least one value outside the measurement range (e.g. ±10 V)
5	Spike	Spike events exceeded	n_{crit}	Number of spikes found in signal exceeds critical value.
6	Spike	Low Correlation	r_{crit}	Despiked signal poorly correlated with uncorrected signal.
7	Visual/ Qualitative	Qualitative assessment	N/A	Data assessed manually (e.g. poor correlation with wind speed).
8–16	-	*- Spare -*	-	Further tests included here.

General Background – Automatic Data Quality Control



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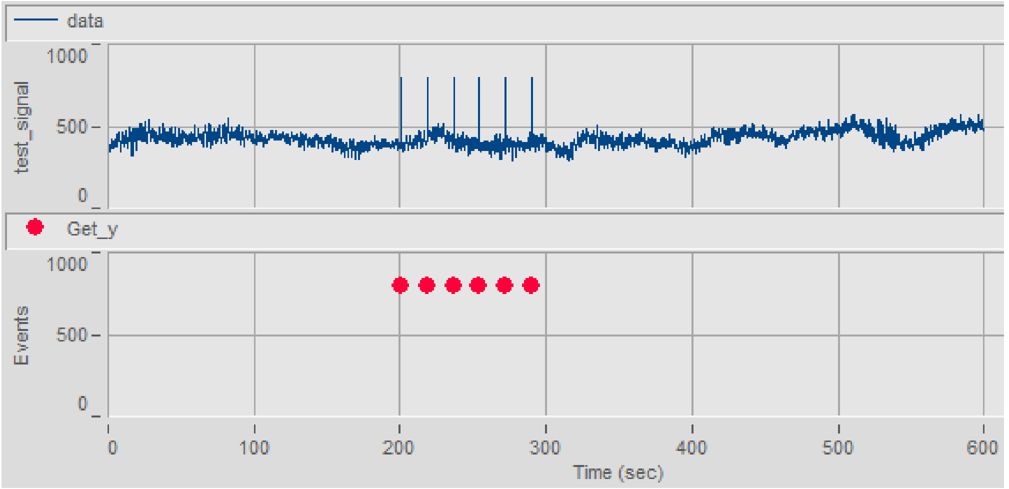
Master Flag



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Master Flag

General Background – Automatic Data Quality Control

DQ	DR
Trot_hss_Nm	Master_check
000111	Fail
000111	Fail
000111	Fail
000111	Fail
000111	Fail
000111	Fail
000111	Fail
000111	Fail
000111	Fail
000111	Fail
000111	Fail
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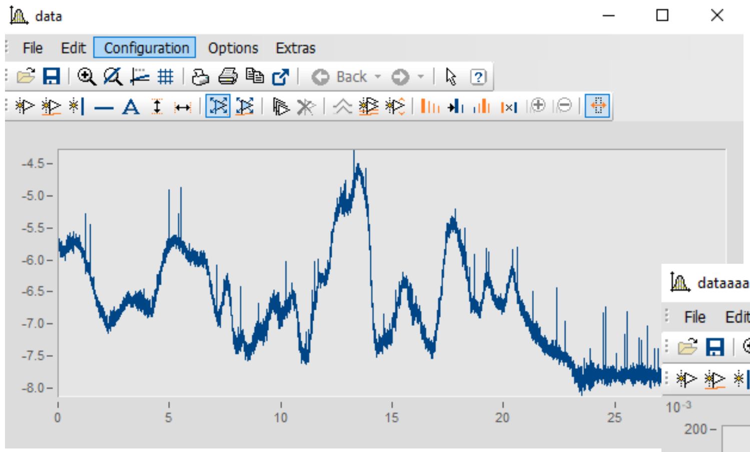
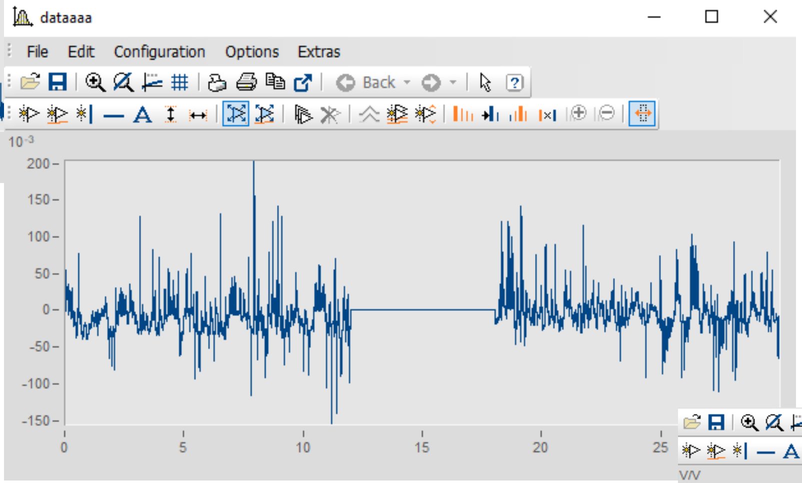
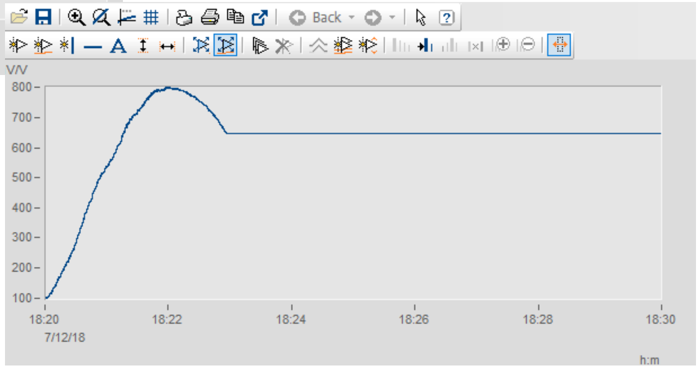


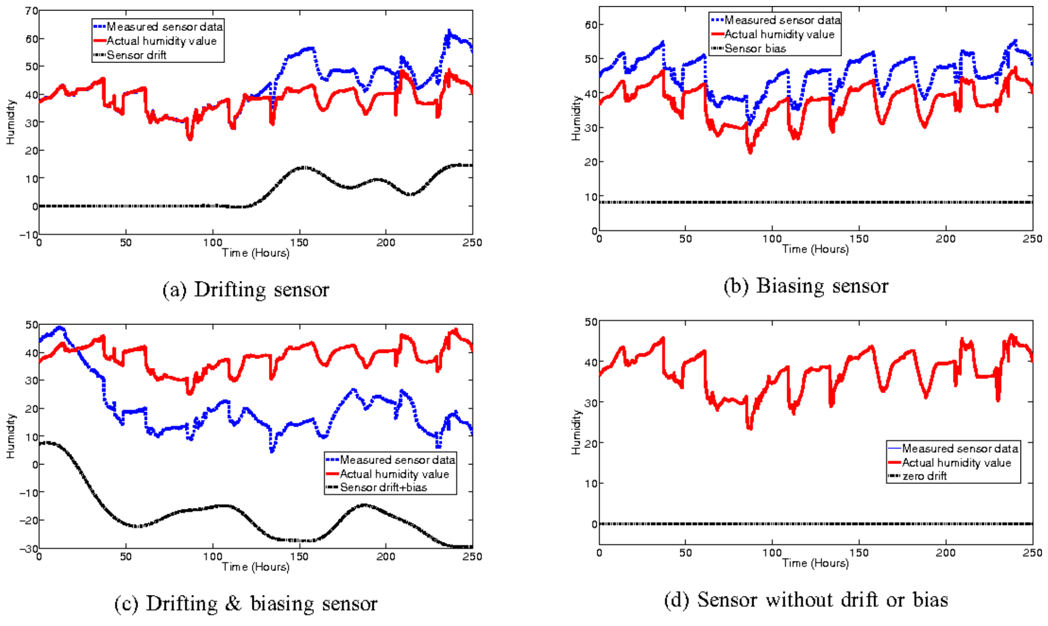




General Background – Automatic Data Quality Control

Limitations

- ➢ Detects only 70% of the commonly occurring events
- ➢ Time & environmental sensitive events are not detected
- ➢ Not using the historically available cleaned database
- ➢ No data filling/replacement method available
- ➢ No additional advantages

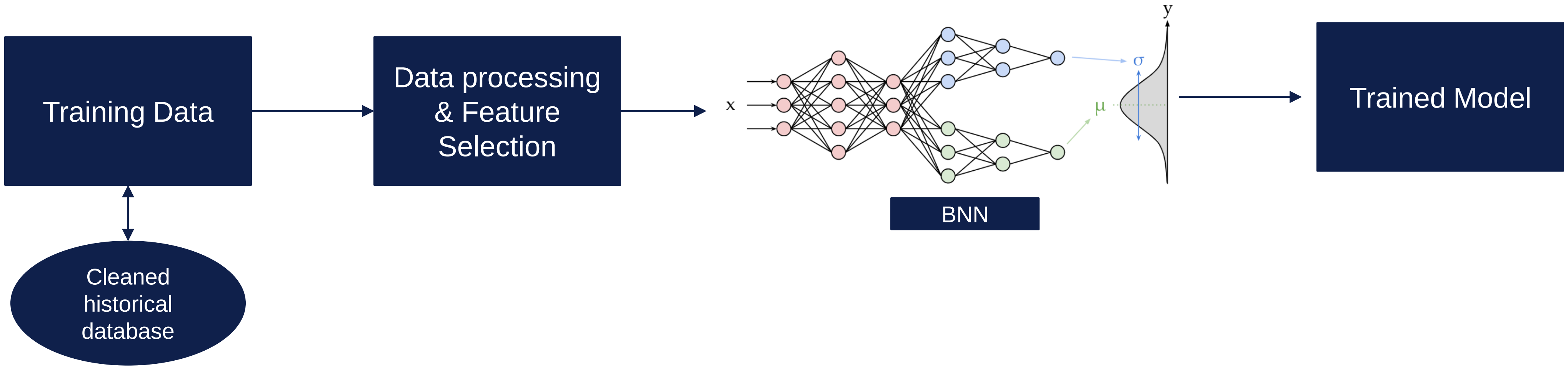


(a) Drifting sensor (b) Biasing sensor (c) Drifting & biasing sensor (d) Sensor without drift or bias

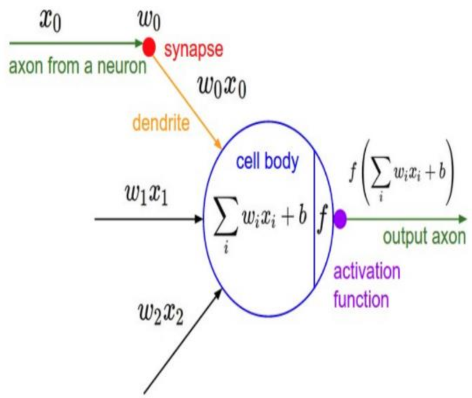
ADQC Output – 000000/0

No Events Found

Automatic Data Quality Control Using Bayesian Neural Network



Neutral network state of Art



Conditional Probability : Bayes Theorem

$$P(A|B) = \frac{P(B|A)\,P(A)}{P(B)}$$

Standard Neural Net / **Bayesian Neural Net**

Standard Neural Net

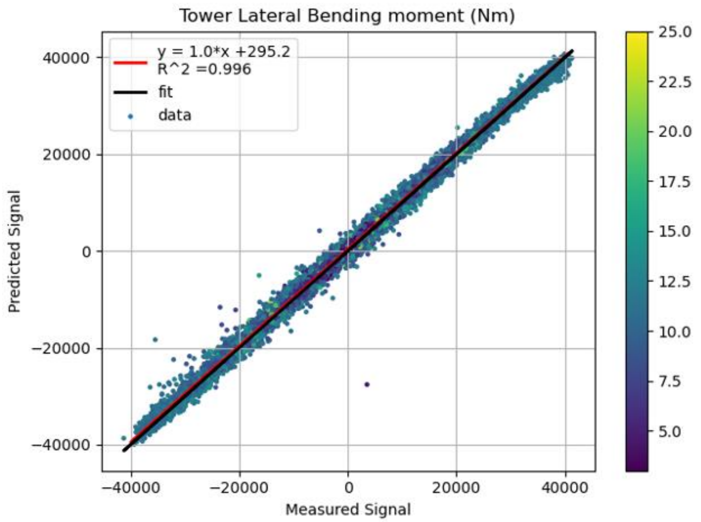
- Parameters represented by *single, fixed values (point estimates)*
- Conventional approaches to training NNs can be interpreted as *approximations* to the full Bayesian method (equivalent to MLE or MAP estimation)

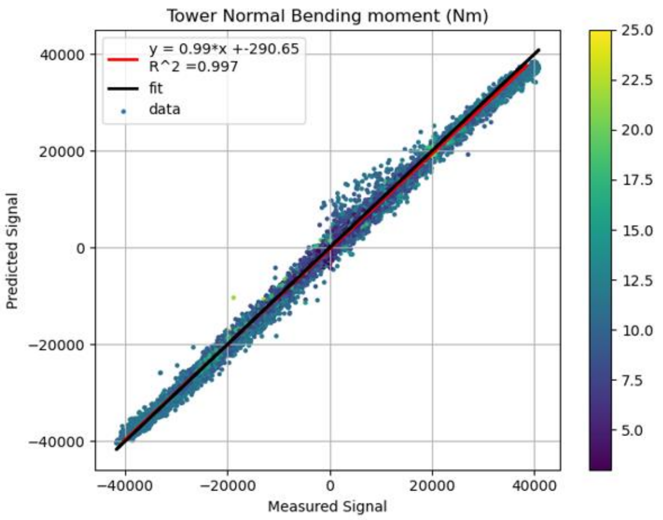
Bayesian Neural Net

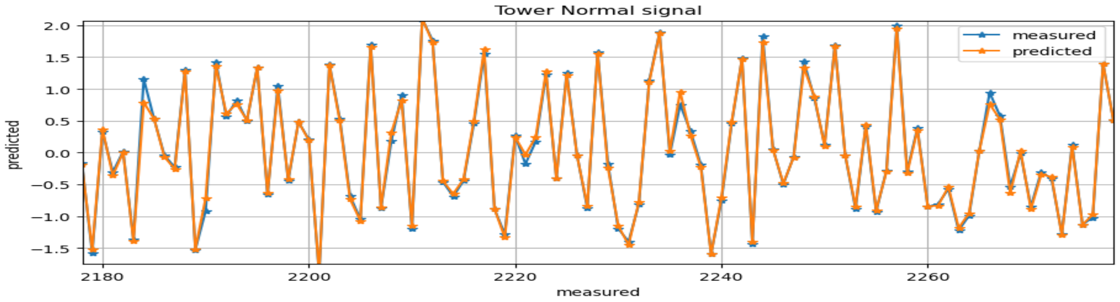
- Parameters represented by *distributions*
- Introduce a prior distribution on the weights $P(\mathbf{w})$ and obtain the posterior $P(\mathbf{w} \mid \mathcal{D})$ through Bayesian learning
- Regularization arises naturally through the prior $P(\mathbf{w})$
- Enables principled model comparison

Automatic Data Quality Control Using Bayesian Neural Network

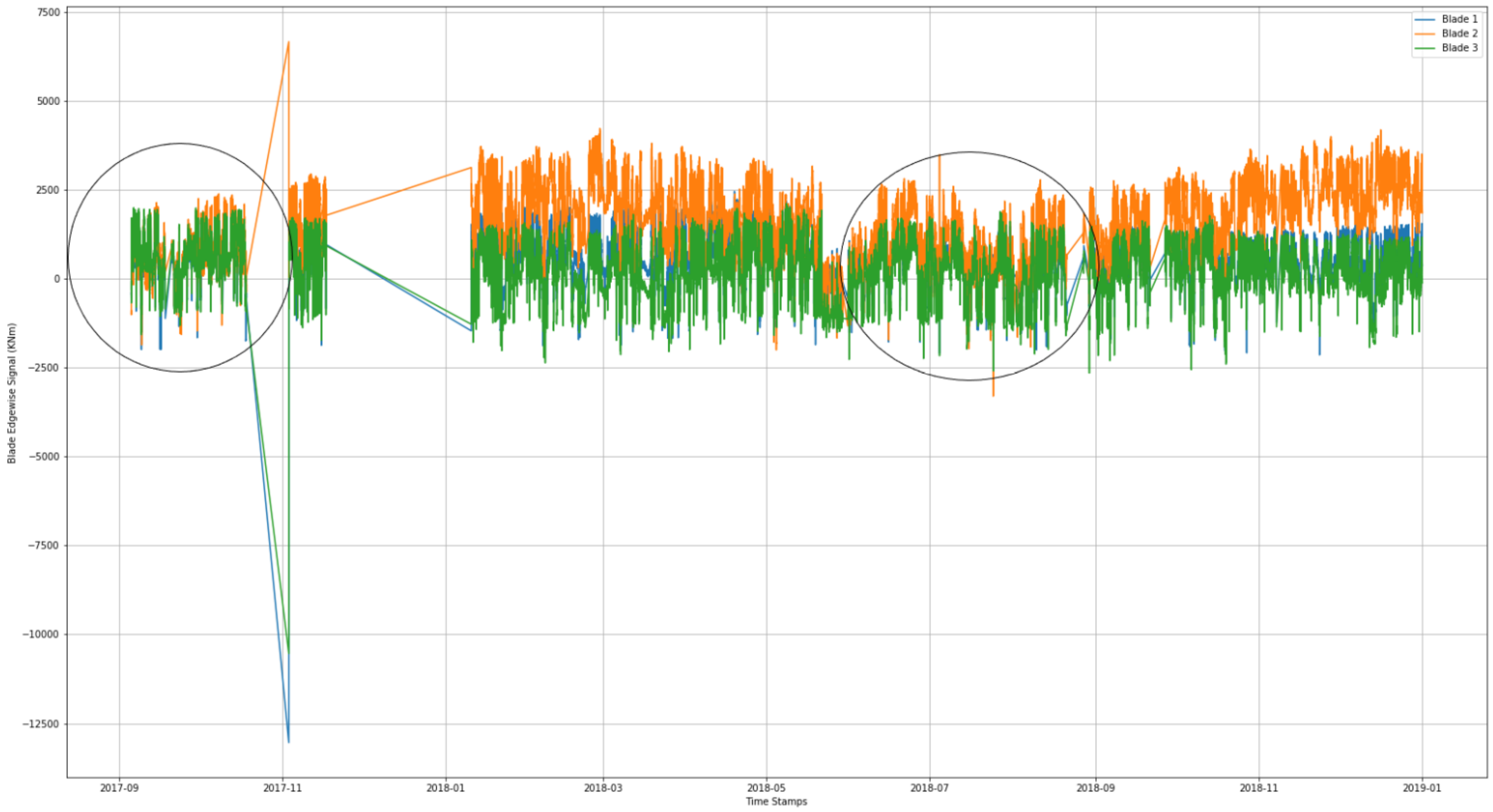
Example : Tower Signals







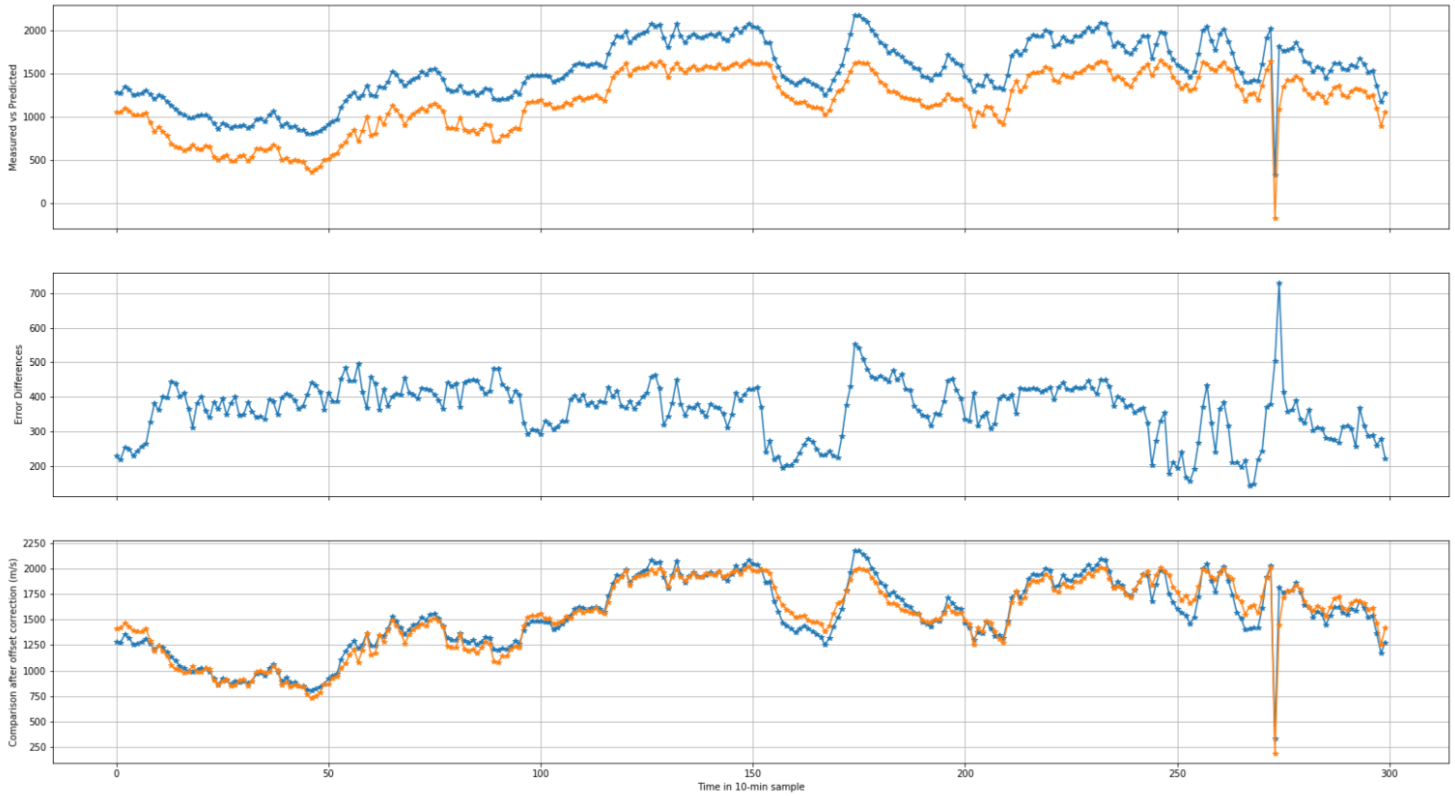
Case Study – First Results



- ➢ **Sensor installed and calibrated in Autumn (Black circles)**
- ➢ **Drifting problem in the other seasons**

Case Study – First Results

Detection of sensor drift in the blade signals due to temperature change



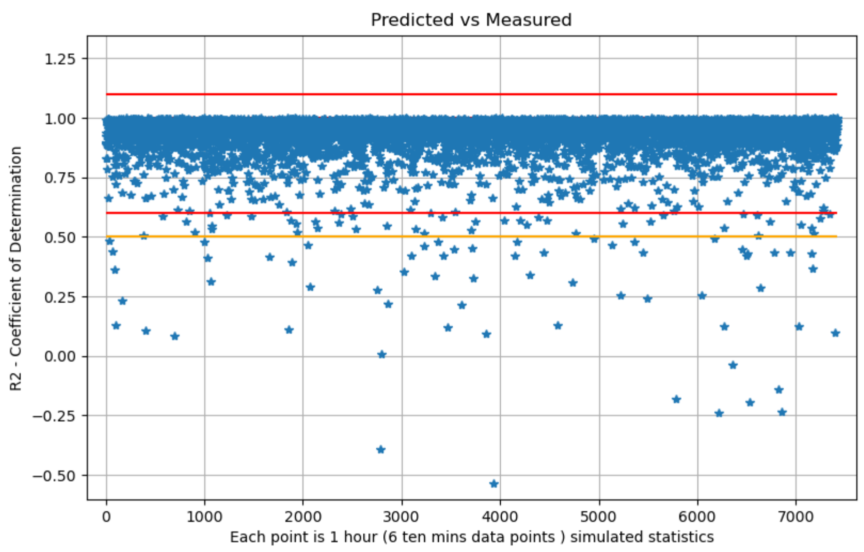
Measured vs Estimated

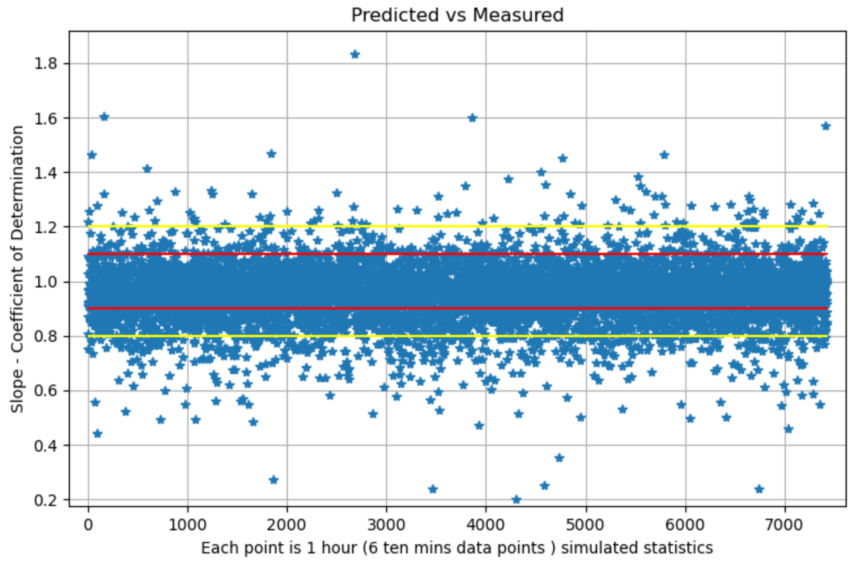
Error difference

Correcting the measured signal
based on prediction

Future Work

- Past performance based data flagging strategy





- Calculating the metrics (Predicted vs Measured) for 1 day window
- Comparing the calculated metrics with the historical performance
- Flagging the data falling outside the threshold range

Thank You

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Bundesministerium für Wirtschaft und Energie