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BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

Data Quality Management in the RAVE-Project

Introducing Machine Learning to the Process

RAVE Workshop 2021
28. Januar 2021, Hamburg

BSH, DNVGL, UL International

Agenda

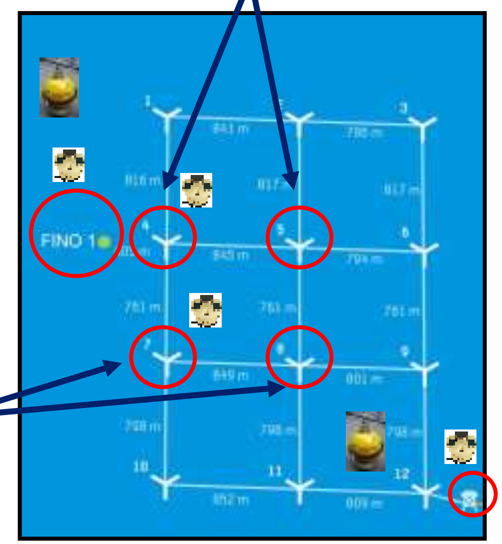
- Introduction
- Limitations/Challenges of ADQC
- Can this be solved with ML model?
- Feature Selection & Data Compression
- Case Study – First results
- Accuracy and Performance of the model
- Other applications
- Future works

Introduction

- 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 Energy (BMWi) 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 BMWi so far amounted to more than 50 million euros

Wind Farm Outlook

- Commission Date: 2009
- 45 Km North of Borkum
- 30 m water depth
- 12 Wind turbines
  - 6 AREVA WIND M5000
  - 6 Senvion 5M



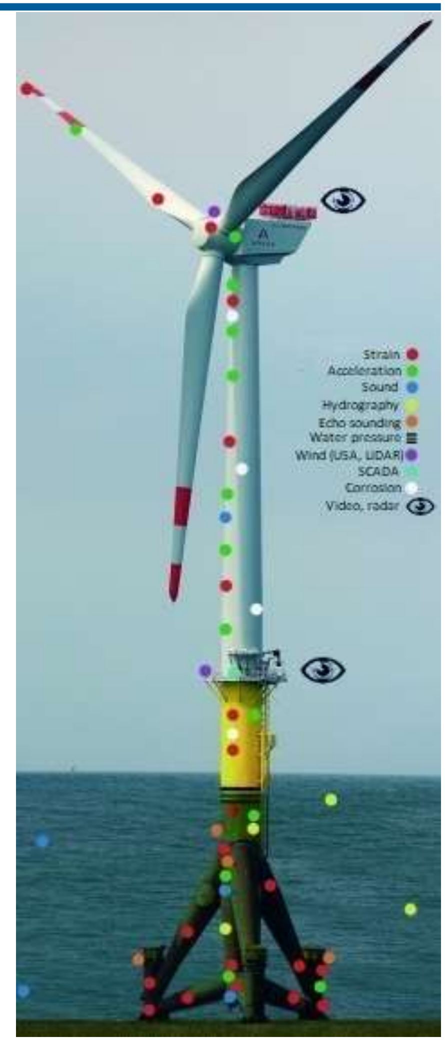
Introduction

<u>Available Measurements</u>

- Controller signals
- Accelerometers and multiple strain gauges at tower, blades and support structure
- Environmental measurements (Atmosphere, Wind and Sea State)
- Other critical structural measurements
- Other electrical signals

<u>**Continuous time series data since 2010**</u>

- The data are stored and published via RAVE-Database
- The RAVE-Database is developed, hosted and administrated by BSH,
  - **Most importantly open to the public**
    → <u>*serviceportal.bsh.de*</u>



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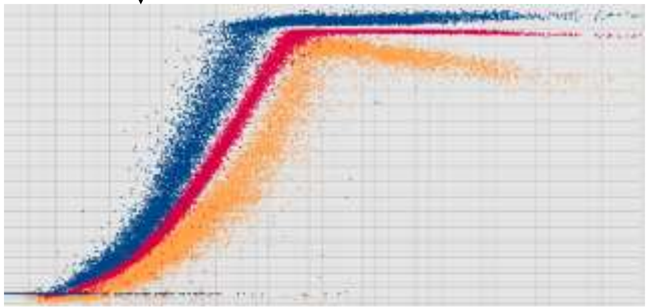
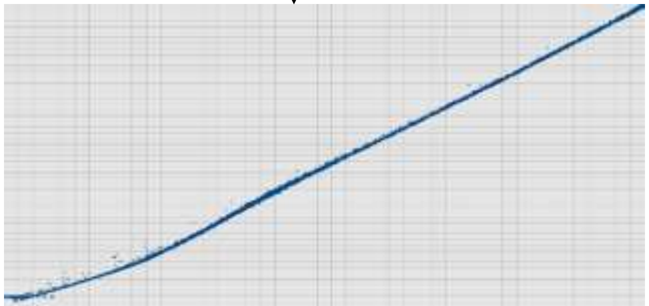
Introduction - Recap

Standard data quality control of measurement data

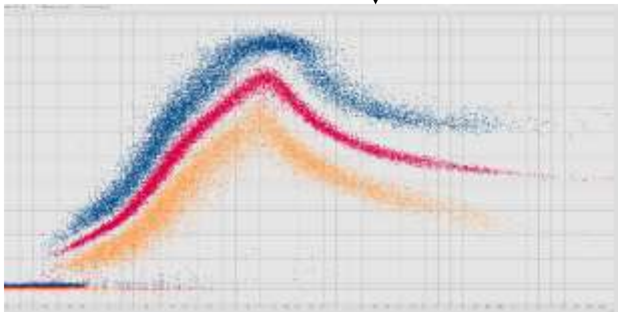
High frequency Raw data signals → Calibrated data signals → Descriptive statistics → Manual/visual check of statistical data → Flagging abnormal data signals



Wind Speed vs Electrical Power

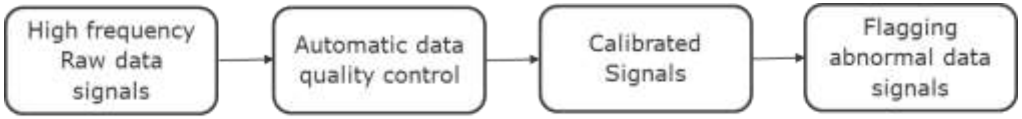


Main shaft torsion vs Electrical Power



Tower tilt moment vs Electrical Power

Introduction – Automatic Data Quality Control



Detailed Flag

Flags : 001000/1 ← Master Flag

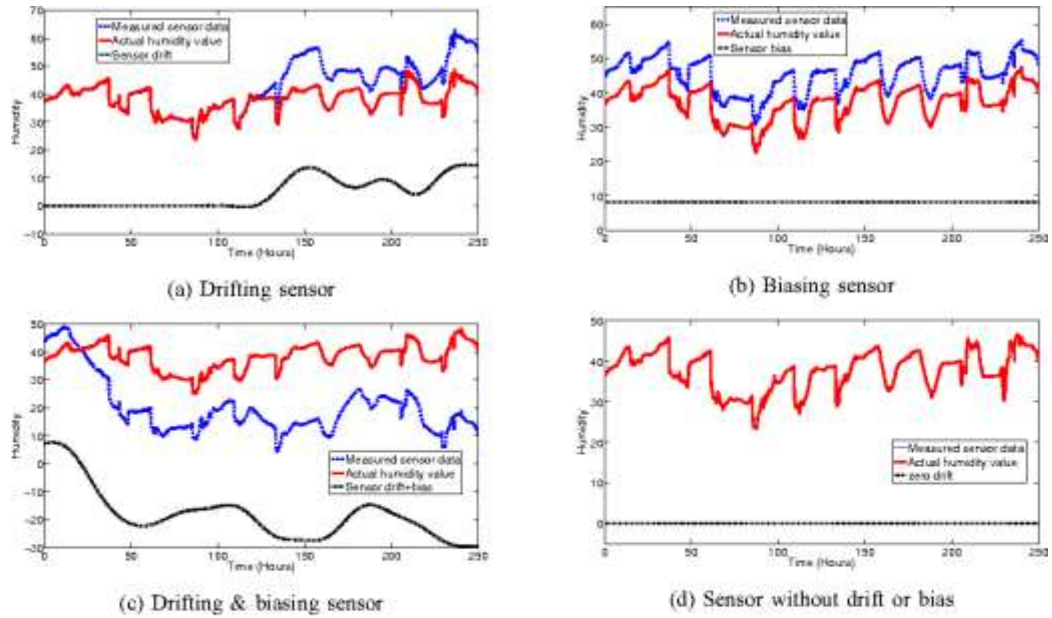
Objective

- 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.

Limitations/Challenges of ADQC

- Detects only 70% of the commonly occurring events
- Time & environmental sensitive events are not detected
- Not using the historically available cleaned data
- 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

Can this be solved using Machine Learning?

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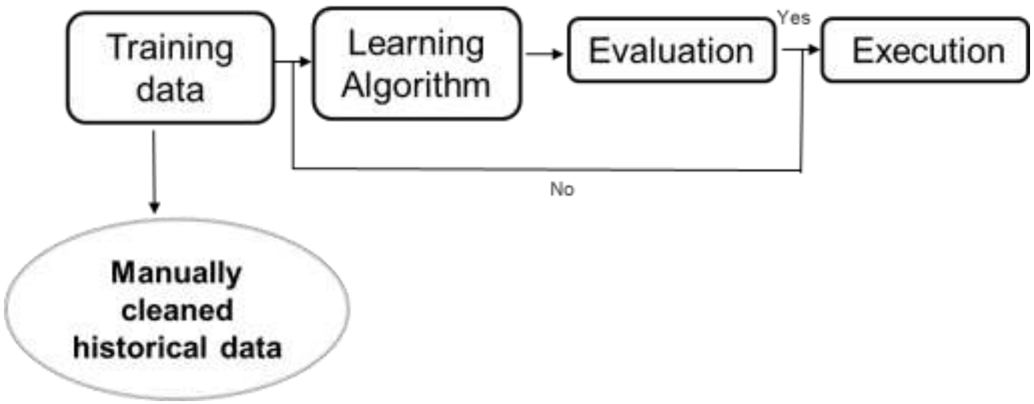
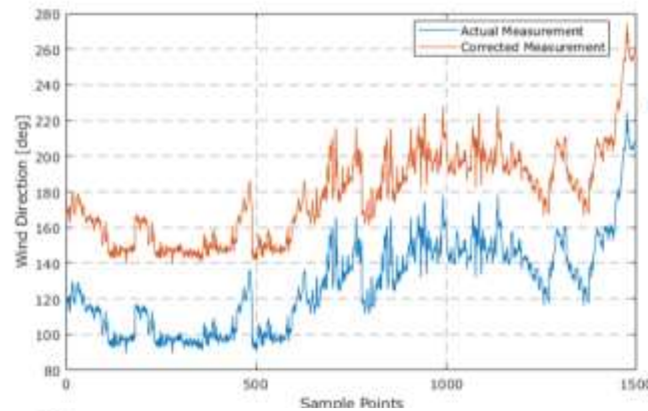
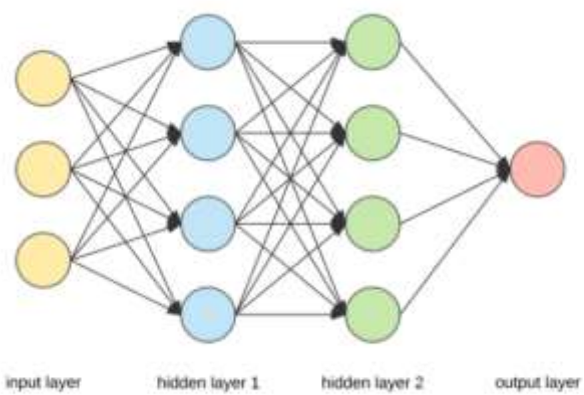


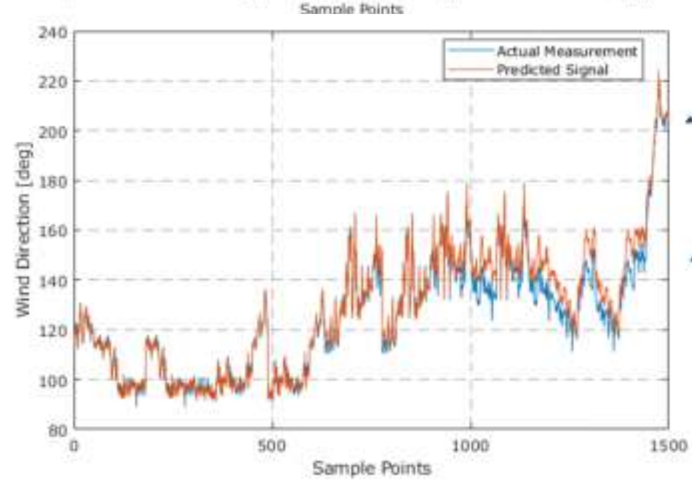


50 degrees offset

ADQC Output
000000 – No events found

Deep Neural Networks





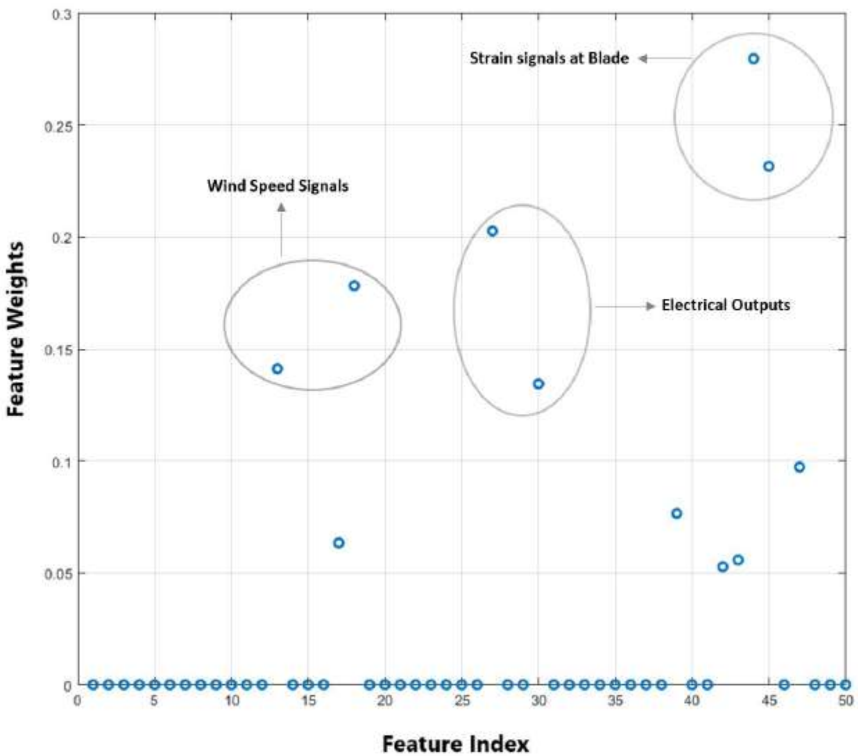
ADQC Output
000000 – No events found

RAVE-ML
0 - Pass

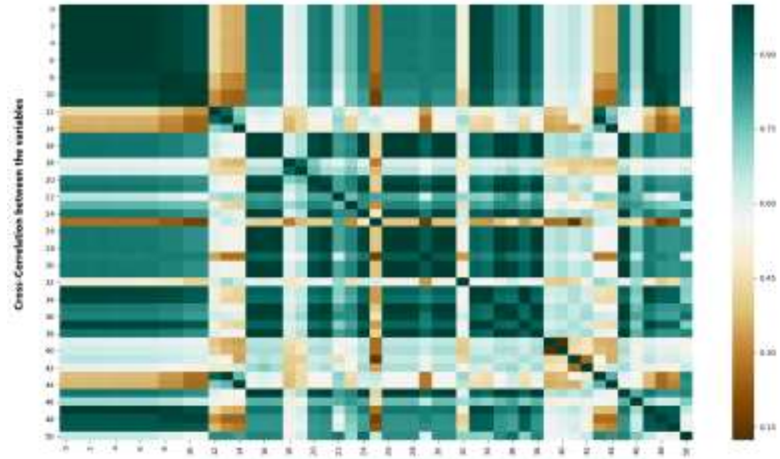
35

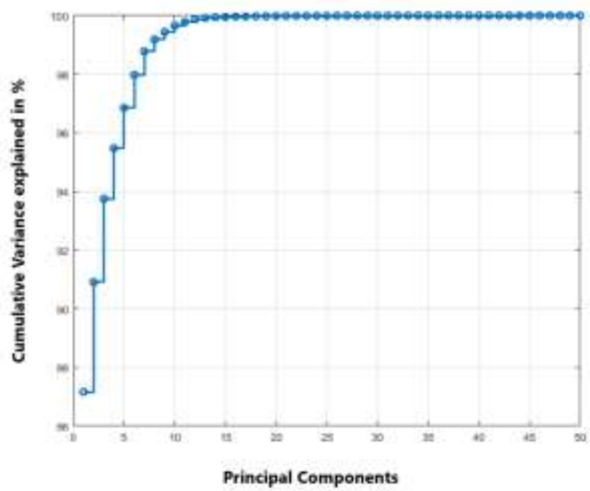
Feature Engineering/Data Compression

Neighbourhood Component Analysis



Cross Correlation





Principal Component Analysis

Feature Selection

Feature engineering

Taking the most valuable features into account

Dimensionality reduction

by principal component analysis (PCA)

→

Avoidance of collinearity

Principal components (compressed data)

In consideration of the model's robustness the features have been reduced to SCADA data and accelerometers:

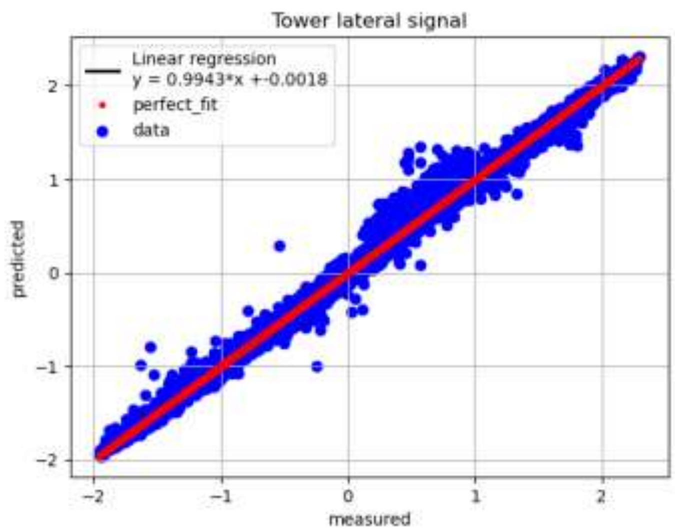
- Pitch angle
- Generator speed
- Yaw angle
- Wind speed
- Electrical power

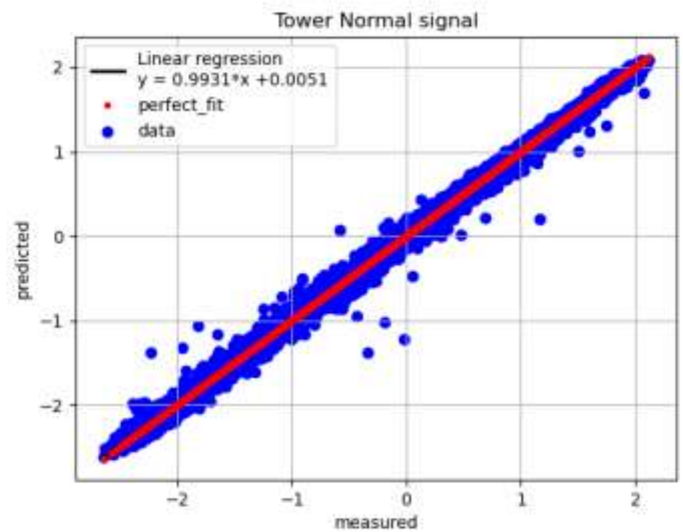
- Accelerometer
  - Support structure
  - Upper tower
- Temperature
- Humidity

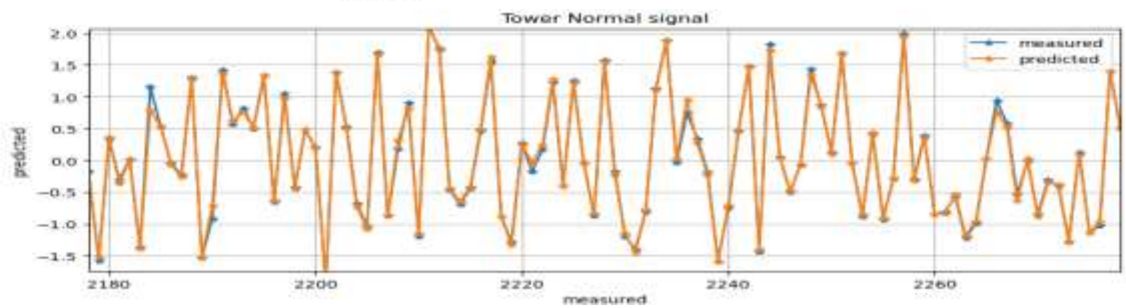
Case Study – First Results

Able to estimate all signals (Structural, acceleration, controller , etc..)

Example 1 : Tower signals







Case Study – First Results

Able to estimate all signals (Structural, acceleration, controller , etc..)

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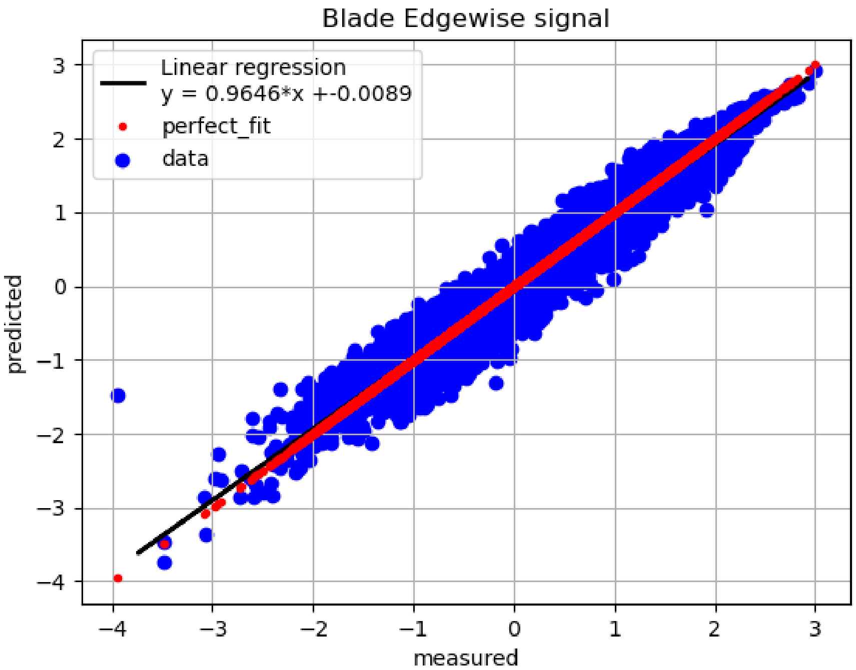

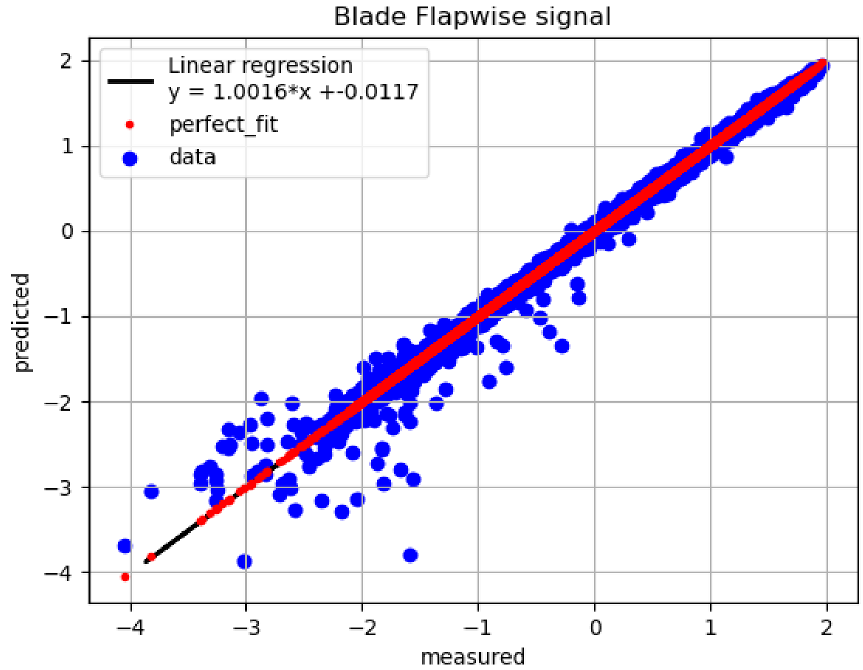

Case Study – First Results

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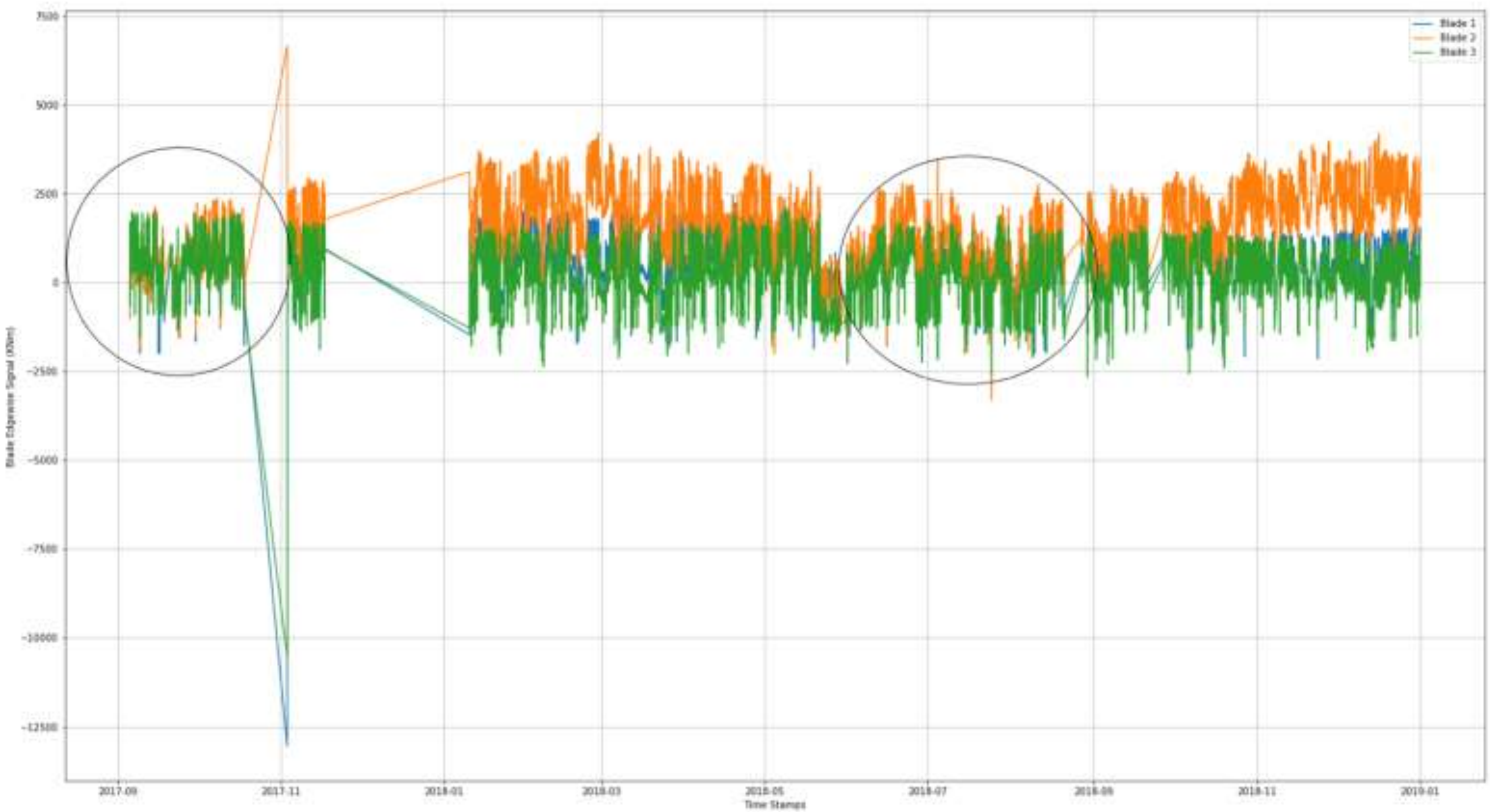
Detection of sensor drift in the blade signals due to temperature change



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

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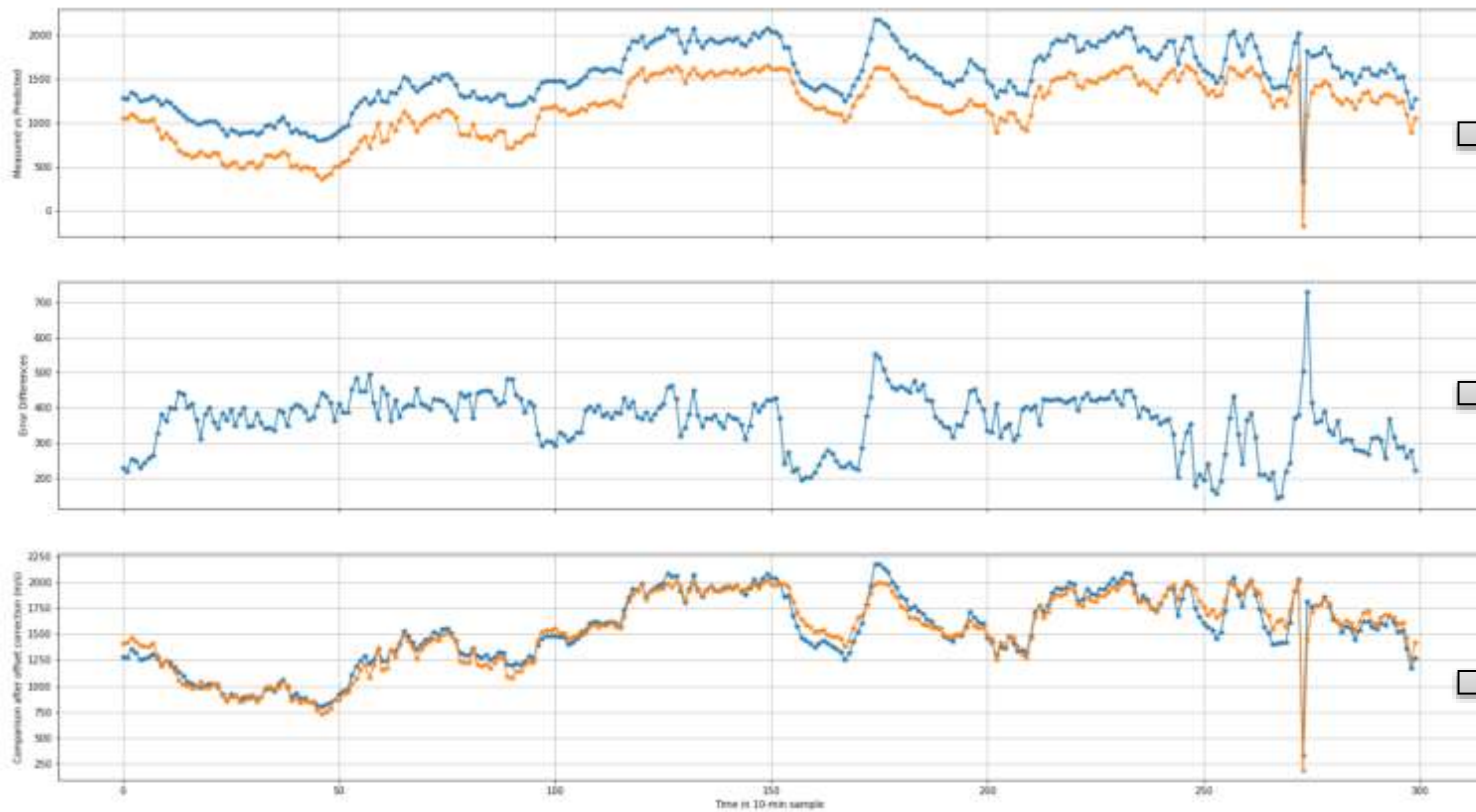
Case Study – First Results

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



Measured vs Estimated

Error difference

Correcting the measured signal based on prediction

Accuracy/Performance of the model

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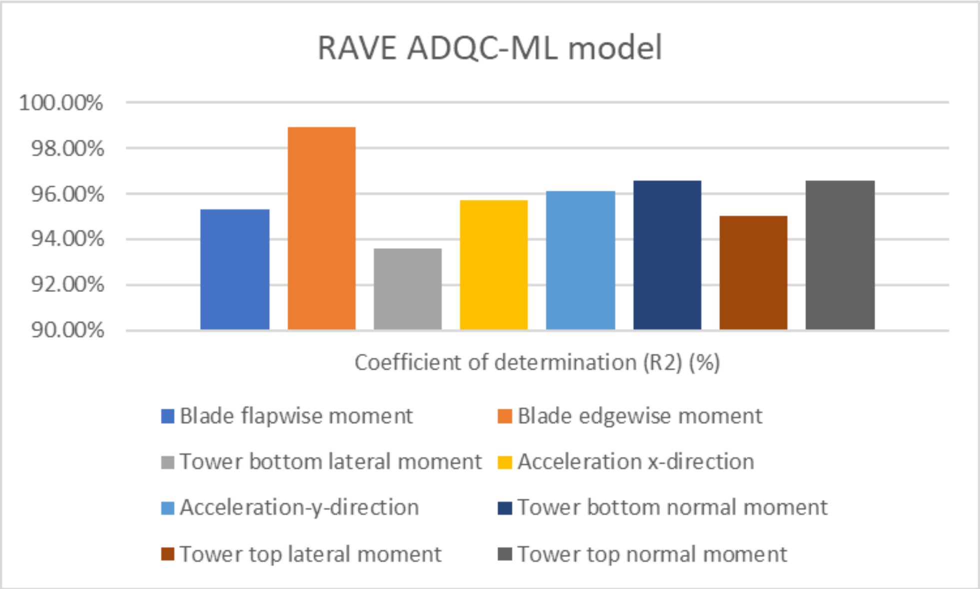

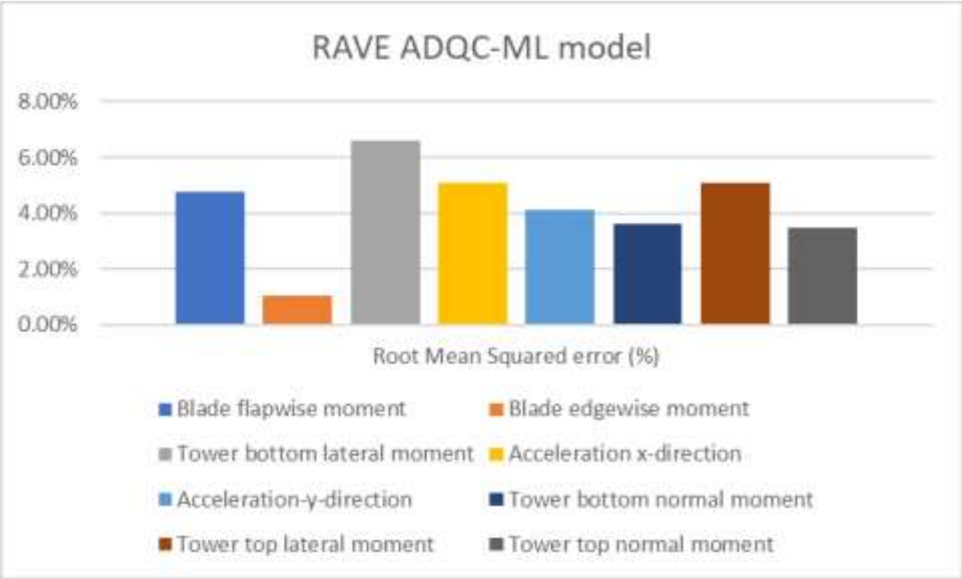

$$R^2 = 1 - \frac{Variance\ (DEL_{Estimated} - DEL_{Real})}{Variance(DEL_{Real})}$$

$$RMSE = \sum(DEL_{Estimated} - DEL_{Real})\text{^}2$$

- Quantification of important signals are shown here
- Accuracy/performance range applicable to most of the signals available in RAVE project

Other applications

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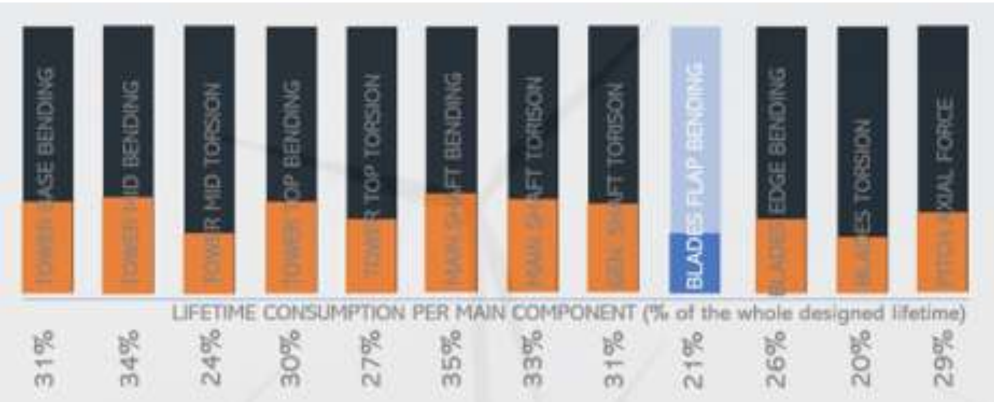
Reliable Lifetime Estimation



Wind farm optimization

Model built based on one turbine

Transferred to other turbines

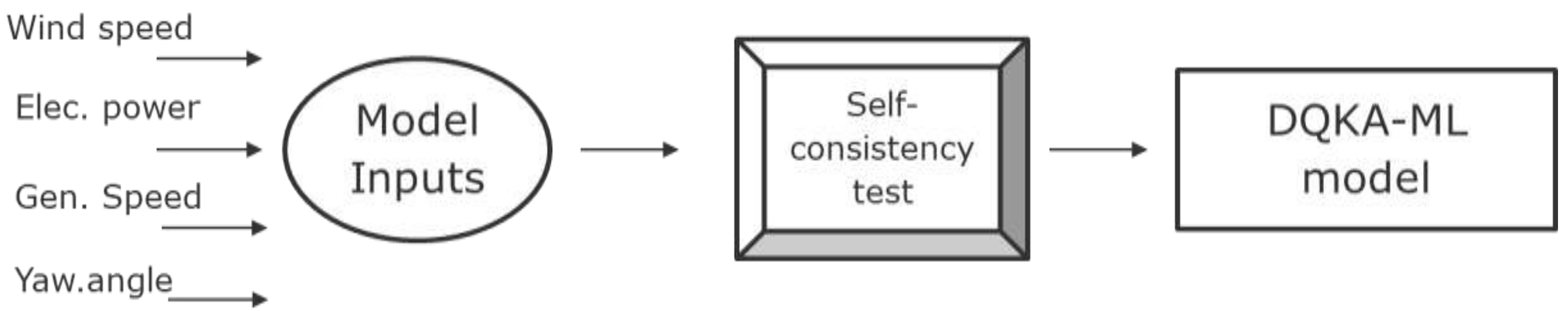
Measurement Data fulfilment/extrapolation

Turbine 1

Turbine 2

Future Work

➢ **Self consistency test for model's input variables**



➢ **Flagging strategies… how can be compare estimated and measured data to flag ?**

➢ **How can we quantify the uncertainties ?**

➢ **Providing calibration factors along with the flags**

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Thank you for your attention !!!!

Questions ??

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Forschungszentrum Jülich

Bundesministerium
für Wirtschaft
und Energie