Predictive Maintenance of Turbine Main Components

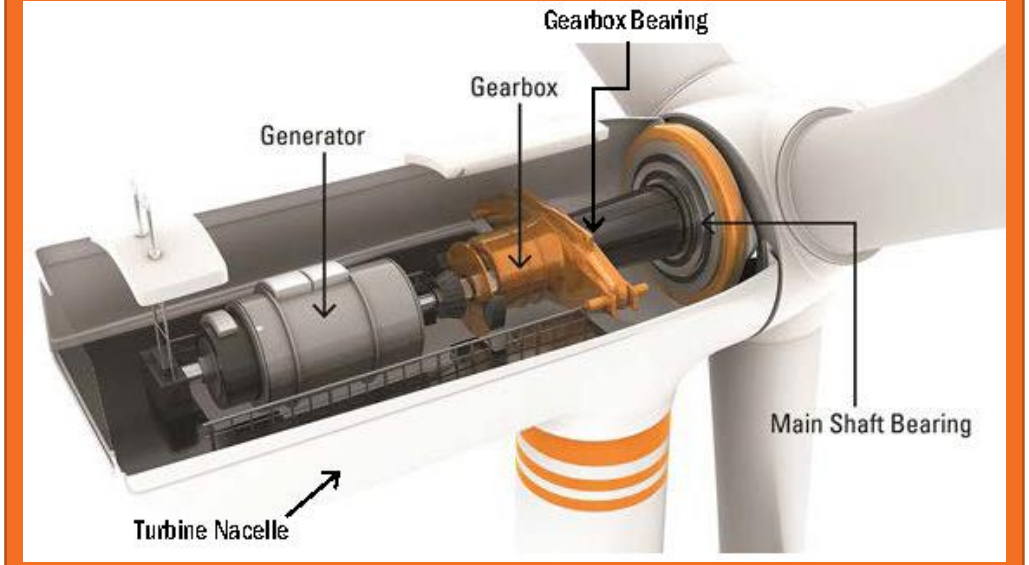
Wind Farm Operators Forum

Gdańsk, 13-14 March 2019

15.03.2019

Motivation

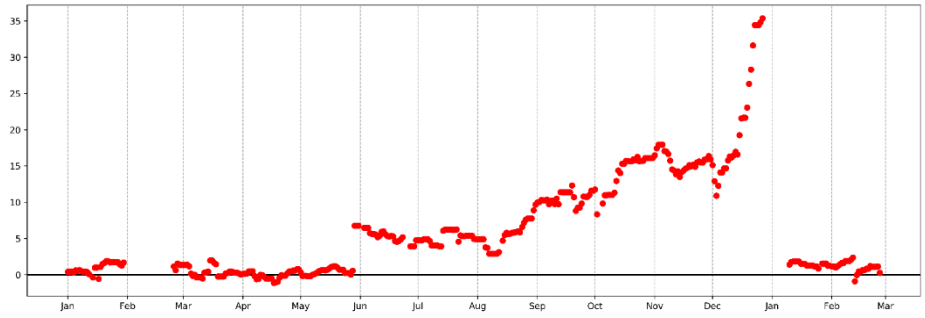
- Reduce downtimes
- Increase Asset Lifetime
- Reduce O&M costs
- Reduce insurance costs



- **How many temperature measurements are available in a modern wind turbine?**
- **Who is using this data? How?**

From full-scope to partial-scope O&M agreements (main components not included)

- Risk management
- Crane logistics
- Spare logistics
- Personnel planning
- Favorable weather windows
- Uptower repairs possible?



Predictive Maintenance of Main Components using SCADA data

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Current Development at Nispera

R&D project with Technical University of Zurich to develop models able to identify component failures before they occur. Main features:

- Automatic identification of faults using SCADA data available on the wind farm
- Advanced machine learning algorithms for fault detection and isolation
- Predict the remaining useful lifetime (RUL)

Requirements:

- High accuracy (>90%), low fraction of false alarms (<10%)
- High level of automation: automatic selection of training data sets and retraining schemes
- Applicability under different operating conditions (terrain complexity, atmospheric conditions, wind classes, etc.)
- Transferability of algorithms between turbines, so as to train the models on one turbine and apply to another similar one (in case little or no historical data is available)
- Combination with error log data from SCADA to improve fault detection

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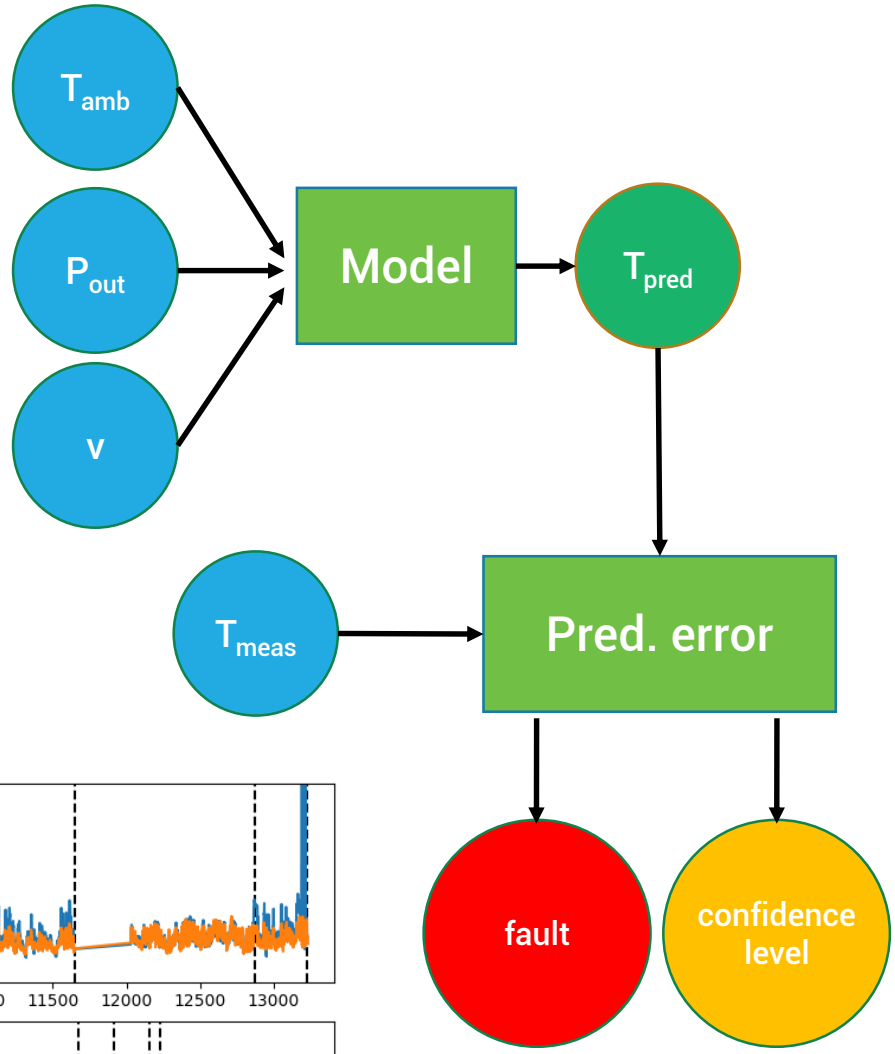
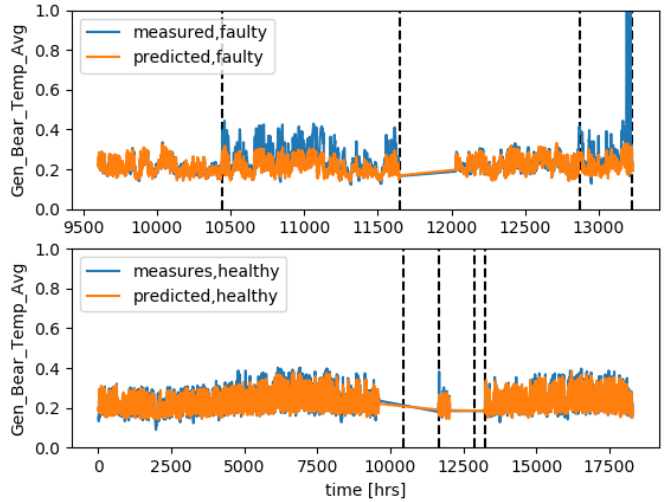
Modeling Approach 1/2

- Model: Artifical Neural Network ANN
- Input time series:
  - Ambient Temperature, T_{amb}
  - Power Output, P_{out}
  - Wind Speed, v
  - … more
- Output time series:
  - Predicted Temperature, T_{pred}
- Prediction error = measured – predicted temperature ($T_{meas} - T_{pred}$)
- Large prediction error ⇔ fault





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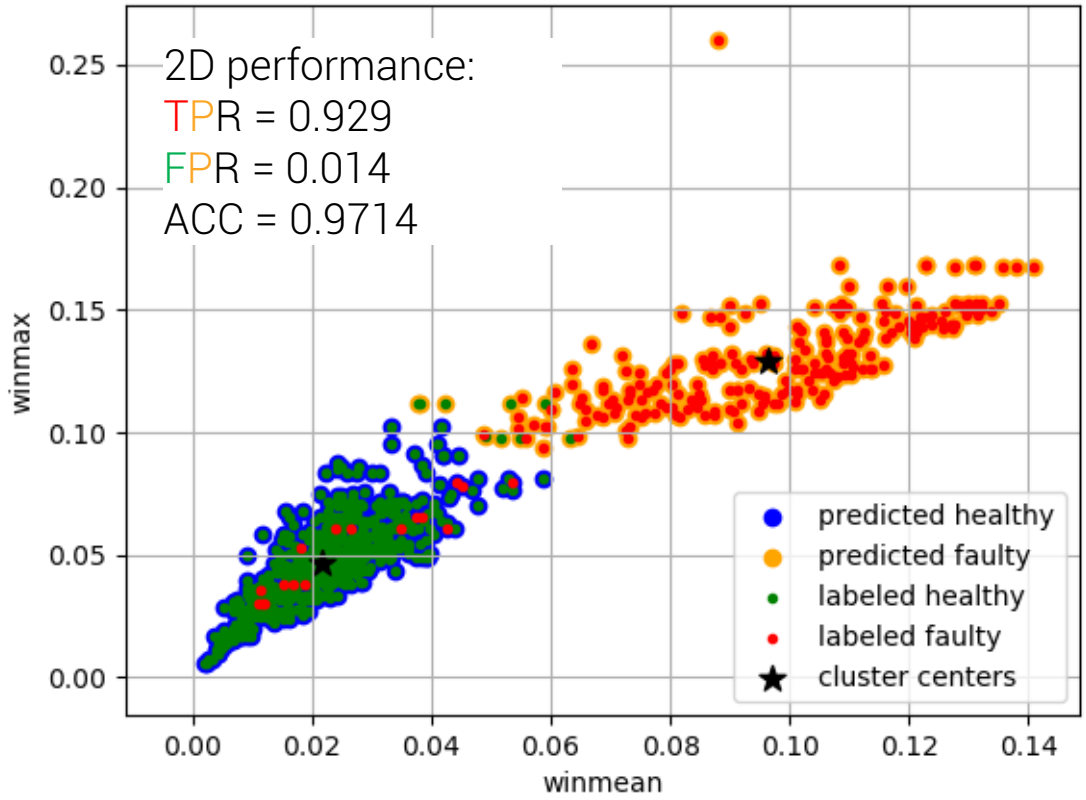
Modeling Approach 2/2

But how do we translate the prediction error into an alarm?

- Clustering algorithms to separate "healthy" from "faulty" data.
- 2D and 3D kmeans clustering



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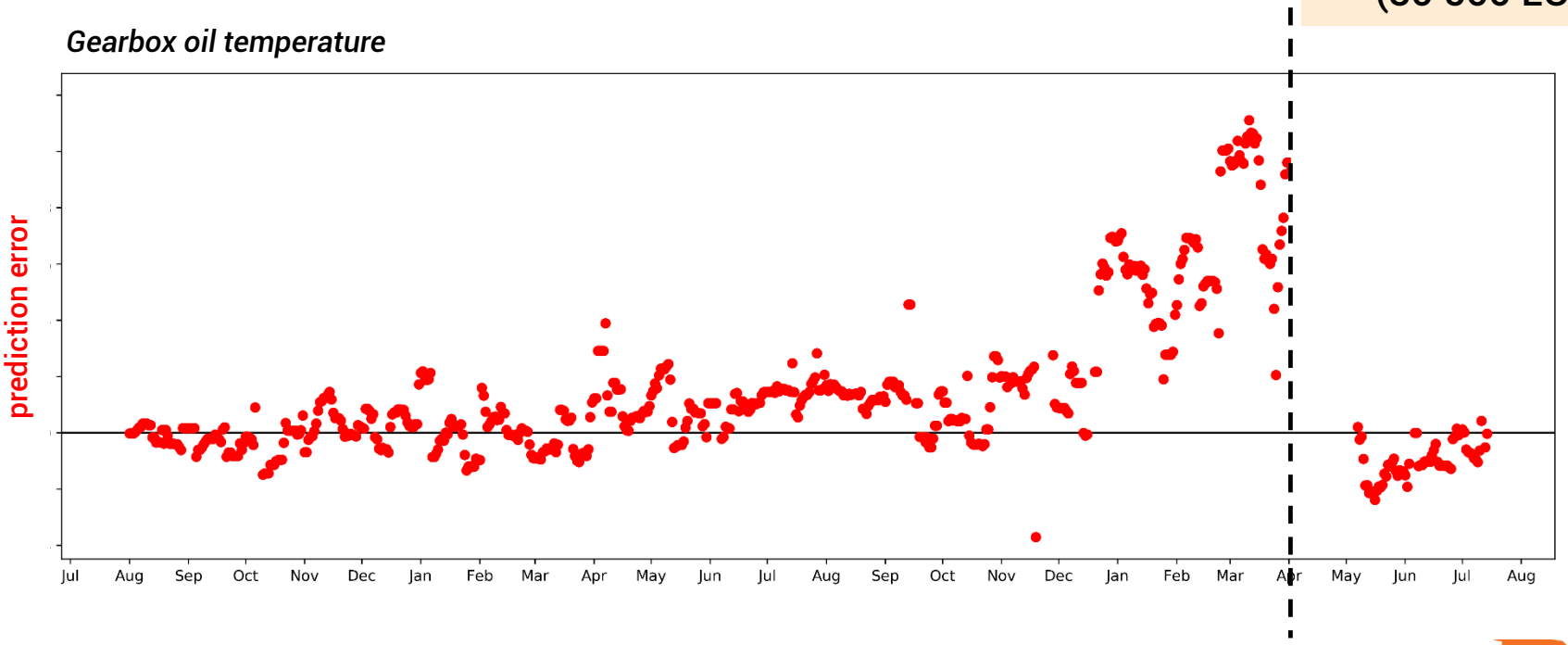
Case 1: Gearbox 1/2

- Owner was not monitoring independently the temperatures of the main components
- The gearbox had to be replaced.

- **Turbine offline for 28 days**
- **380 MWh of Energy Loss (30'500 EUR)**

Gearbox oil temperature



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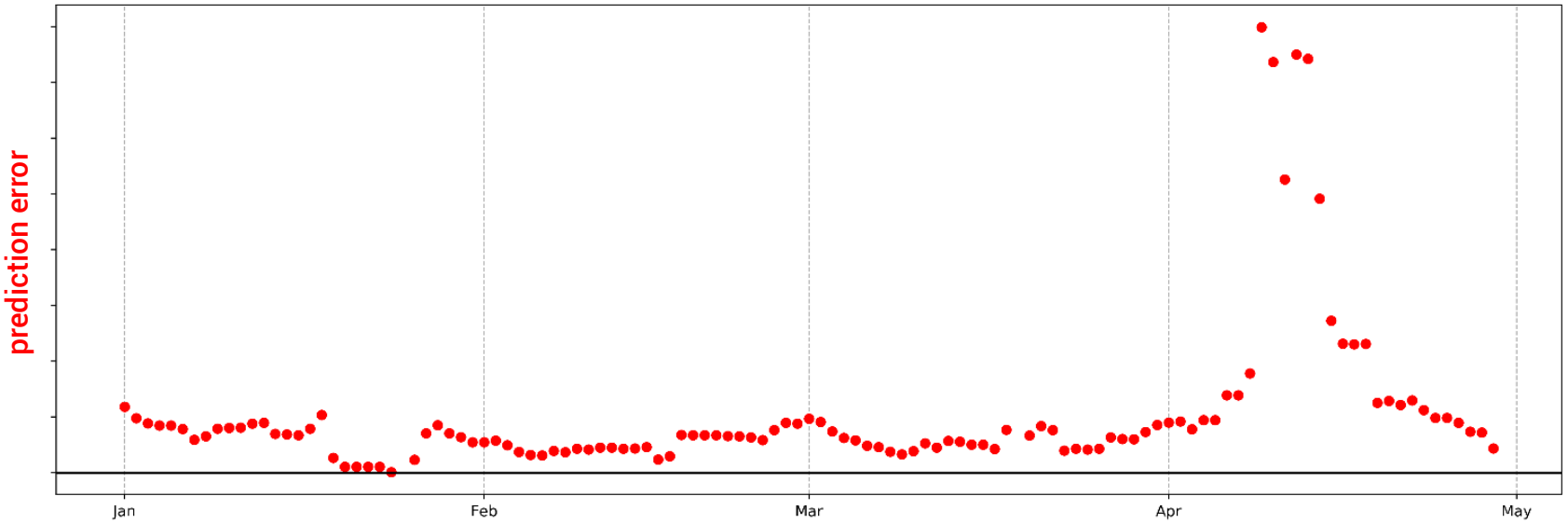
Case 2: Gearbox 2/2

- The same Owner started to monitoring independently the temperatures of the main components
- Increase in gearbox oil temperature was detected
- The reason was quickly identified (gear oil pump)
- Major problem on gearbox was avoided, without large effort.

Gearbox oil temperature



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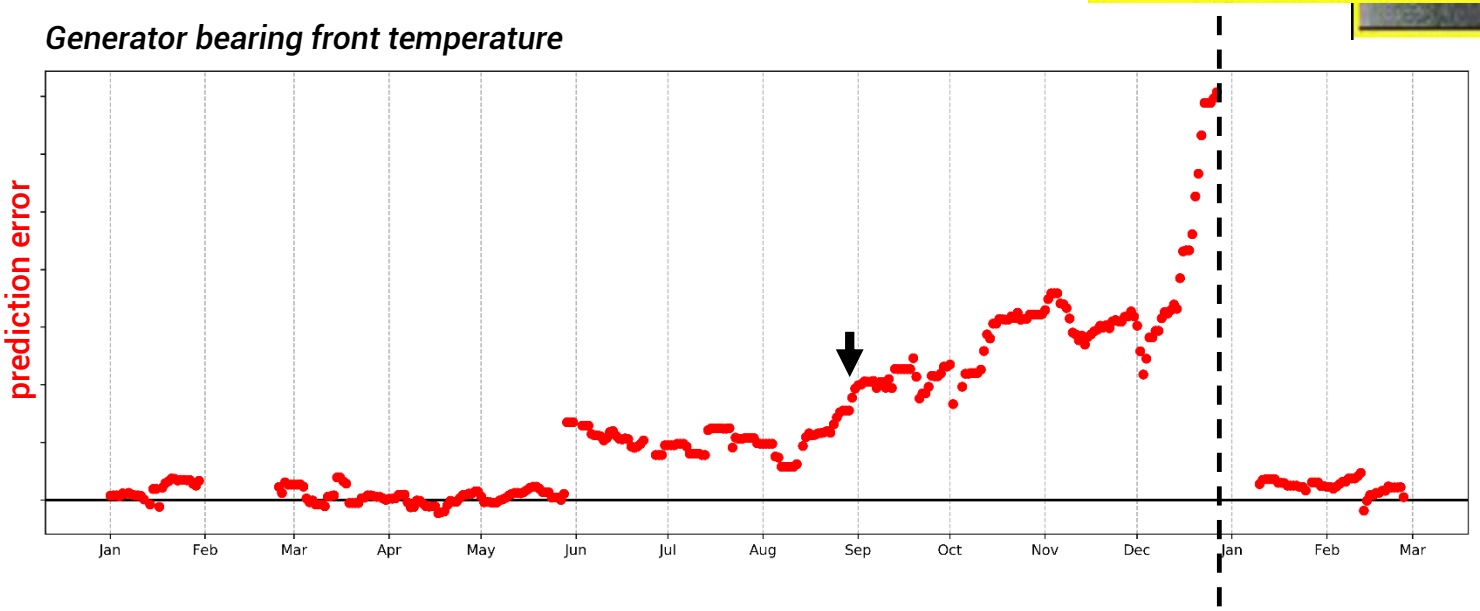
Case 3: Main Bearing

- Owner alerted OEM due to temperature increase.
- OEM performed video endoscopy.
- The damage was categorized in level 2-3 out of 5.
- Owner achieved to have component replaced before failure.
- This allowed to minimise downtime and production loss.
- Contractual availability would not be affected due to force majeure (site accessibility).

Generator bearing front temperature



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Case 4: Generator Cooling

- Owner alerted OEM due to temperature increase.
- OEM performed visual inspection in the turbine and found the generator cooler duct detached. (the hot air was blowing inside the nacelle instead of going outside).
- As a consequence, the turbine was operating at a curtailed power output.
- No penalisation on contractual availability !

Weekend Order Record Form

General Ver: V4

Notification		Date: 30.01.2018	Workcenter: [redacted]
Serial number	[redacted]	Equipment description	

Tech. 1 [redacted]
Tech. 2 [redacted]
Tech. 3
Tech. 4

Time

Hora entrada: 30.01.2018 11:40	Hora salida: 30.01.2018 13:15
Hora parada: 30.01.2018 11:43	Hora Marcha: 30.01.2018 13:00

Storage Location: 1360

Description of work performed:

Temperatura alta en nacelle

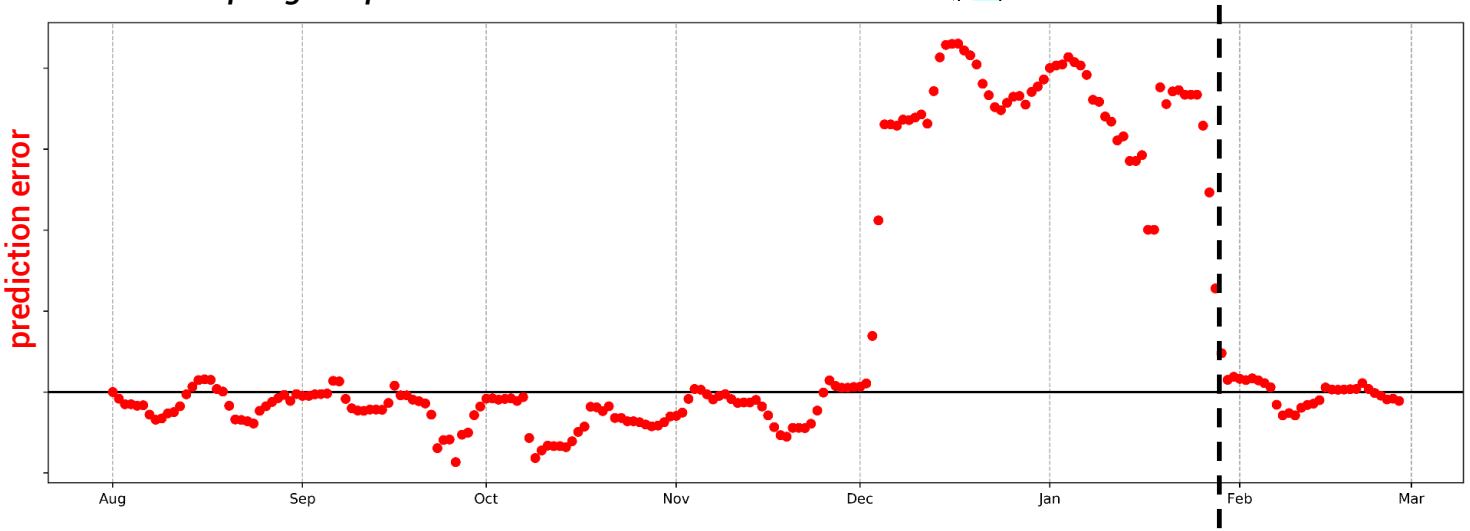
Se encuentra acoplamiento del cooler de generador suelto, se coloca. Da alarma de oil leakage in hub y se procede a vaciar tanque de fugas unos 5 litros. El nivel de aceite de grupo hidraulico esta ok.

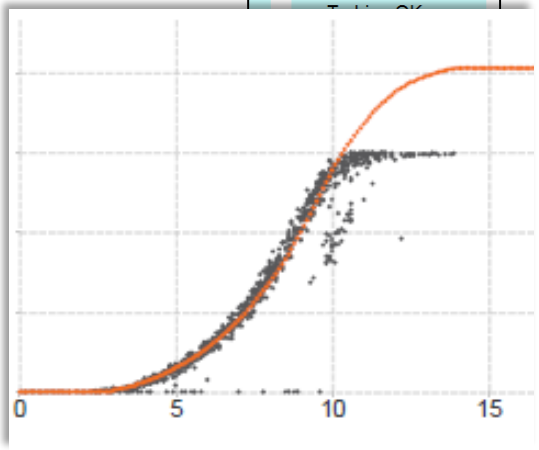
Counters

Main generator: 8950

Small Generator

Generator slipring temperature





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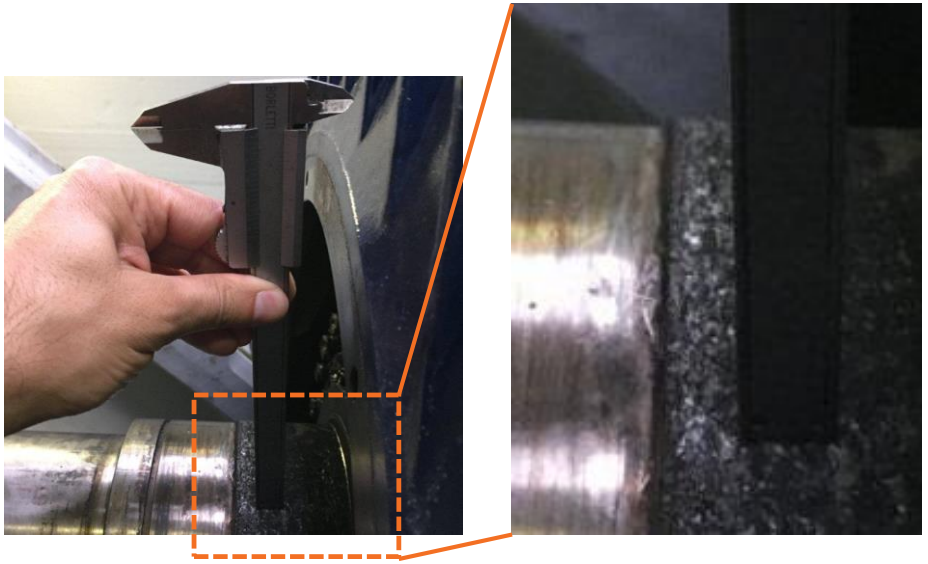
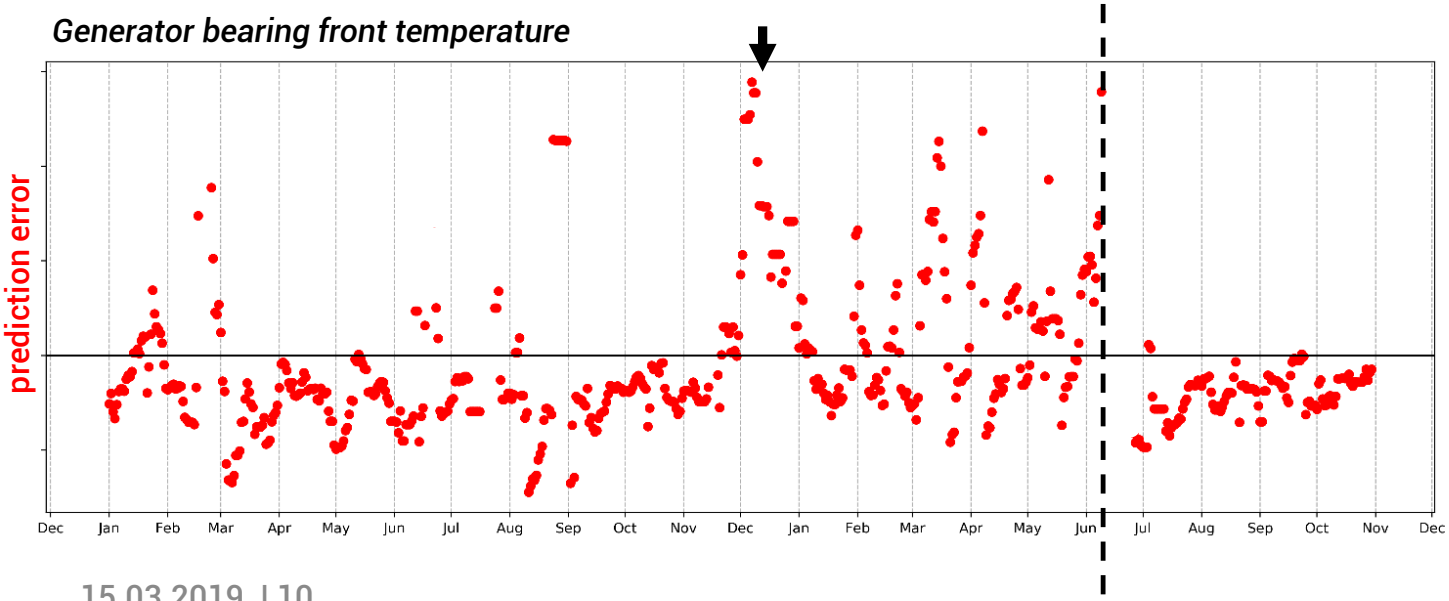
Case 5: Generator Bearing 1/2

- Owner alerted OEM due to temperature increase.
- OEM purged the greasing system of the bearing.
- Again temperature rise observed on bearing
- When OEM inspected the turbine it was too late to do uptower repair.
  Inner ring of bearing was loose on the shaft, causing very strong vibrations, and noise!
- <u>The generator had to be replaced.</u>
- NOTE: Vibration monitoring system is installed on this wind turbine.





- **Turbine offline for 20 days**
- **395 MWh of Energy Loss (32'000 EUR)**

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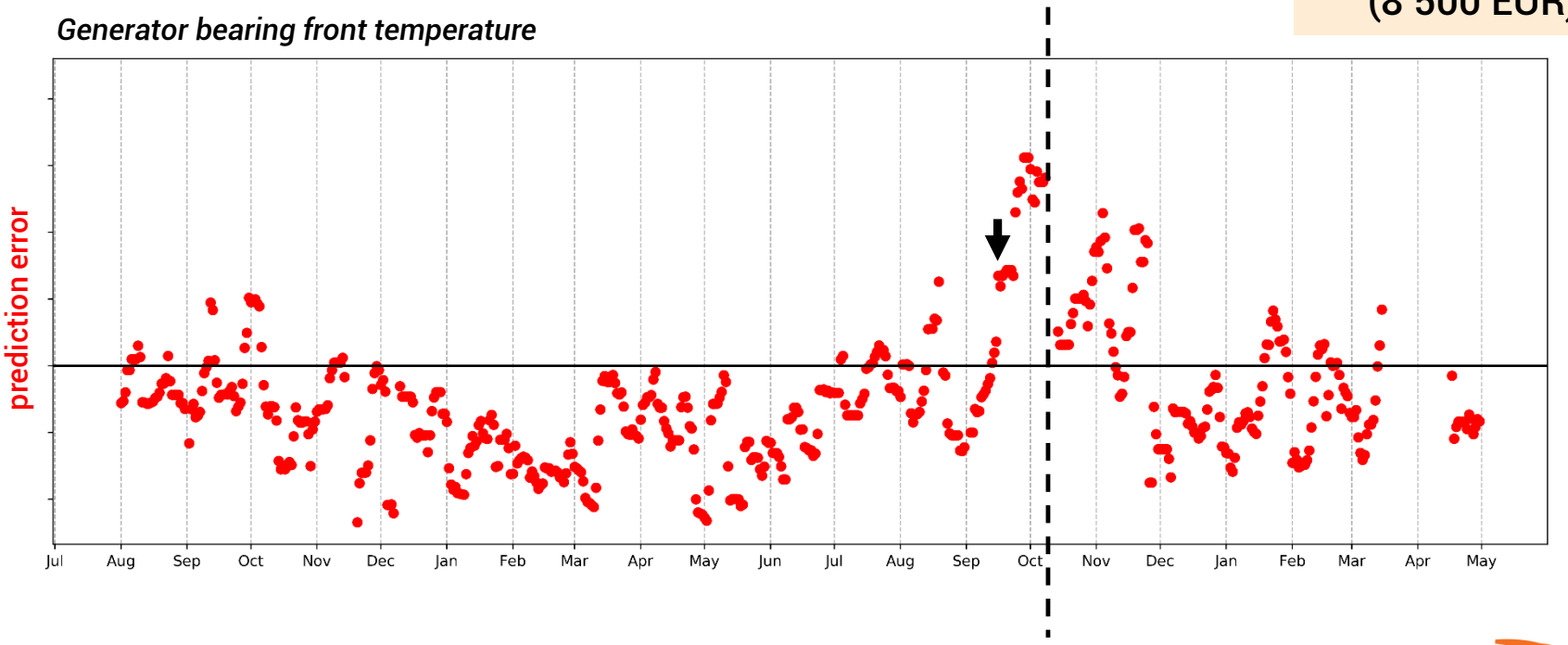
Case 6: Generator Bearing 2/2

- Owner alerted OEM due to temperature increase.
- OEM inspected the generator.
- The Generator was repaired uptower. as the damage was not yet so advanced (replacement of bearing).
- NOTE: Vibration monitoring system is installed on this wind turbine.

- **Turbine offline for 6 days**
- **105 MWh of Energy Loss (8'500 EUR)**

Generator bearing front temperature



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Findings & Conclusions

FINDINGS:

Wind turbines with full-scope O&M agreement are often operated until a component fails.

- What are the predictive maintenance strategies of the O&M providers?
- What are their real incentives to avoid failures?
- Availability guarantees? Insurance coverages?

Vibration monitoring systems (CMS):

- Installation costs
- Who is responsible to analyse the data?

Periodic site inspections:

- Noise
- Greasing of bearings, oil/grease probes
- Visutal inspections

CONCLUSIONS:

- **Predictive maintenance based on temperature signals from SCADA is an efficient way to prevent failures on main components**
- **It is beneficial if the Owner keeps an eye on the O&M provider**

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Dziękuje bardzo !

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