ROMEO: Novel approaches for the diagnosis and prognosis of critical failures affecting offshore wind turbines

Wind Europe - 27th November 2019

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This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 745625.

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ROMEO, an innovative approach

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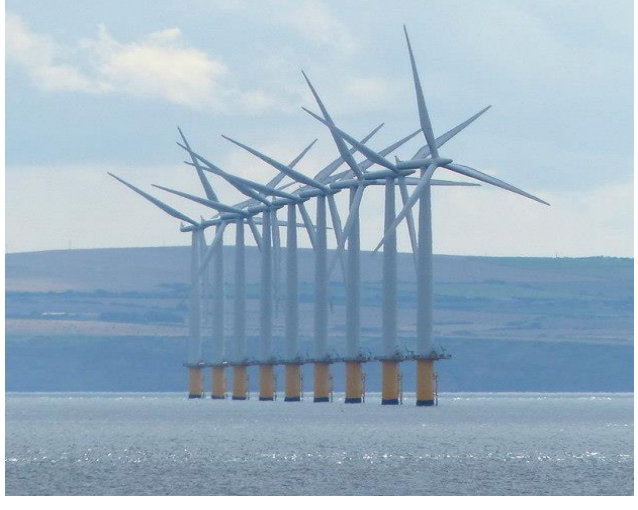
WP2: New diagnosis capabilities for future turbines.

WP3: Cross-platform diagnosis capabilities for running turbines.



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WP2: Incremental improvement / Putting right sensors in right places

- Development of new tailored monitoring solutions for specific failure modes
- Study of degradation and failure symptoms and how to capture/measure them at test bench scale, for testing & improvement purposes.

Main Bearing & Gearbox

- New detector to account for Displacement Sensors.
  - ✓ *Early detection techniques diversification.*
- Damage Classification Technique.
  - ✓ *Better understanding of failure mode and effects.*
- Imbalance Detection using Vibration Sensors.
- RMS Vibration calculation for Gears & Bearing

Blade Bearing

- New Diagnosis & Prognosis algorithms for:
  - ✓ *Rolling Contact Fatigue;*
  - ✓ *Structural Health Monitoring of the rings.*
- Tests running @ WINDBOX

Electrical Drive Train

- Forthcoming tests to be run @ EDF Electrical Lab

ROMEO diagnosis – New Turbines EDF

- Probematic for electrical drive train: most often

Apparent brevity of physical mechanisms

Lack of adequate observability

- Approach selected:

Small Scale bench Test (55kW) Adaptation For failure mode caracterisation

Physical algorithms: **Generator Transformer DC Bus**

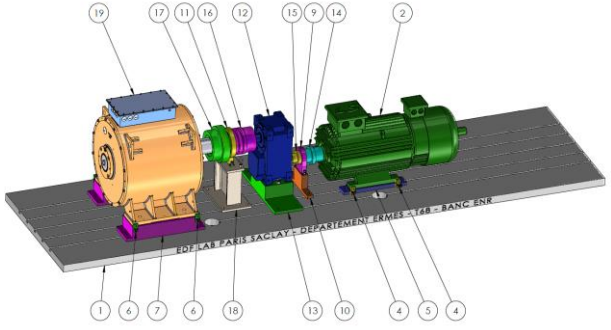
Datasets in normal and abnormal operation

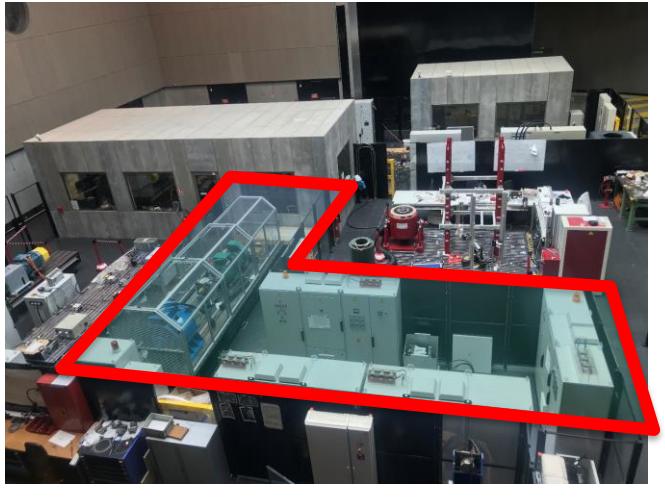
Implementation small scale bench test and algorithms

Validation online and offline on small scale

Upscaling methodology: from small scale to full scale

Validation full scale and portability





ROMEO, combined innovation

- Fault detection: The fact of noticing the condition or performance degradation of the system.
  This may occur at any point of the fault state, preferably early enough to provide actionable intelligence.
- Failure diagnosis: The identification of the most likely failure mode, based on the given conditions of the system.
  This can happen prior or after the functional failure.
- Failure prognosis: A forecast (or prediction) of the degradation of the system – in terms of remaining useful life, survival probability or predicted future condition – based on the given conditions of the system.

ROMEO, combined innovation

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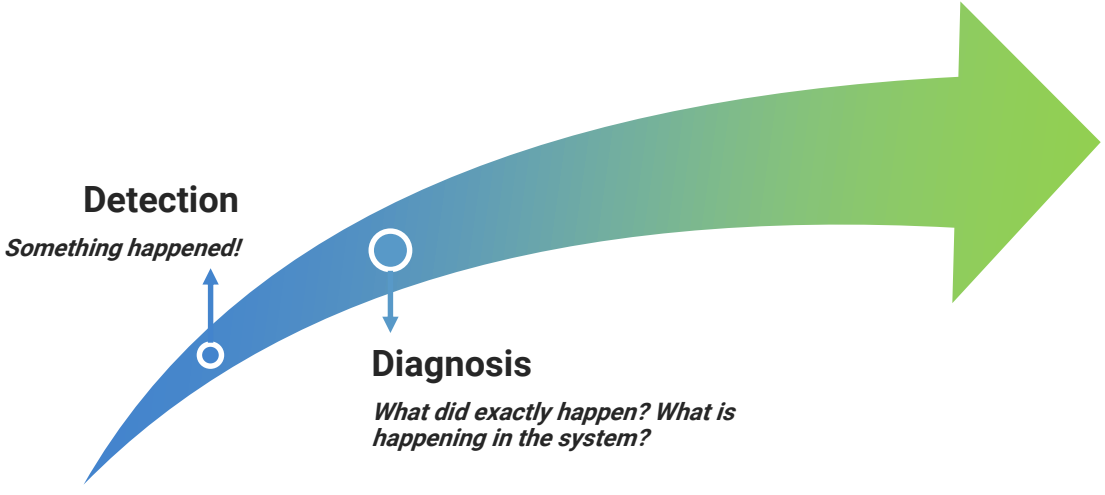

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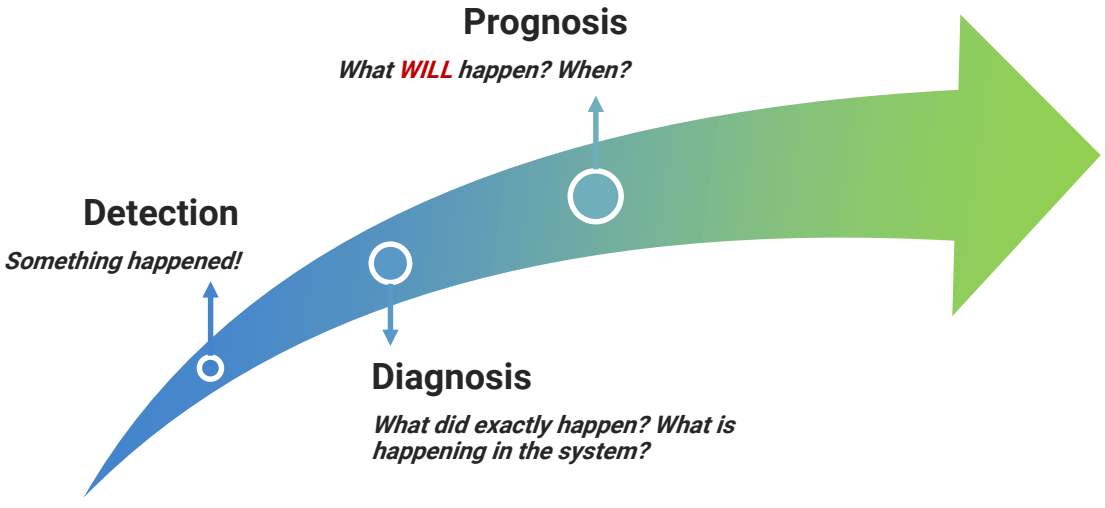

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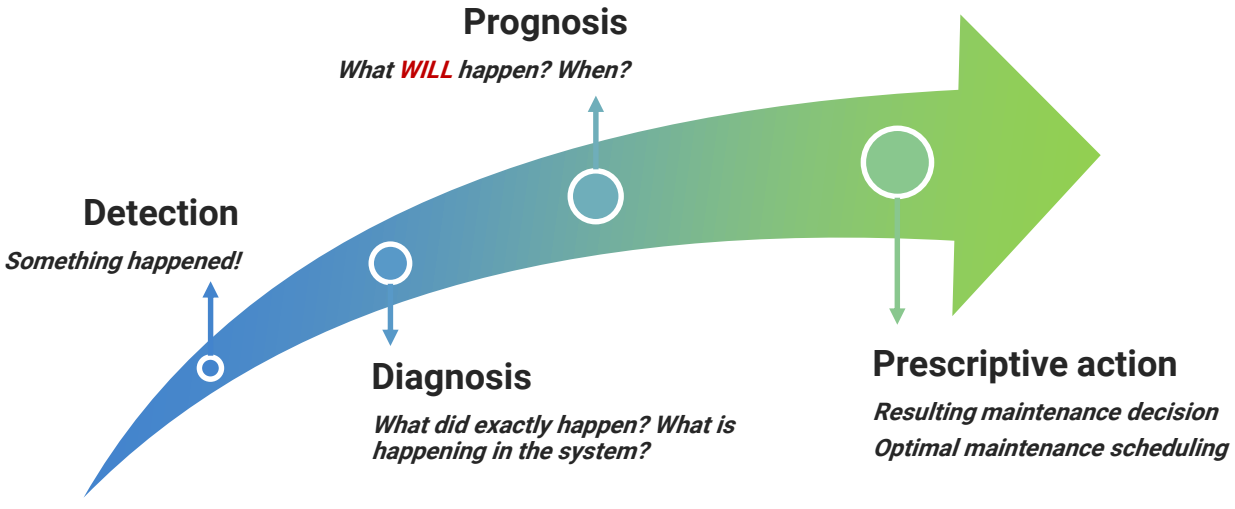

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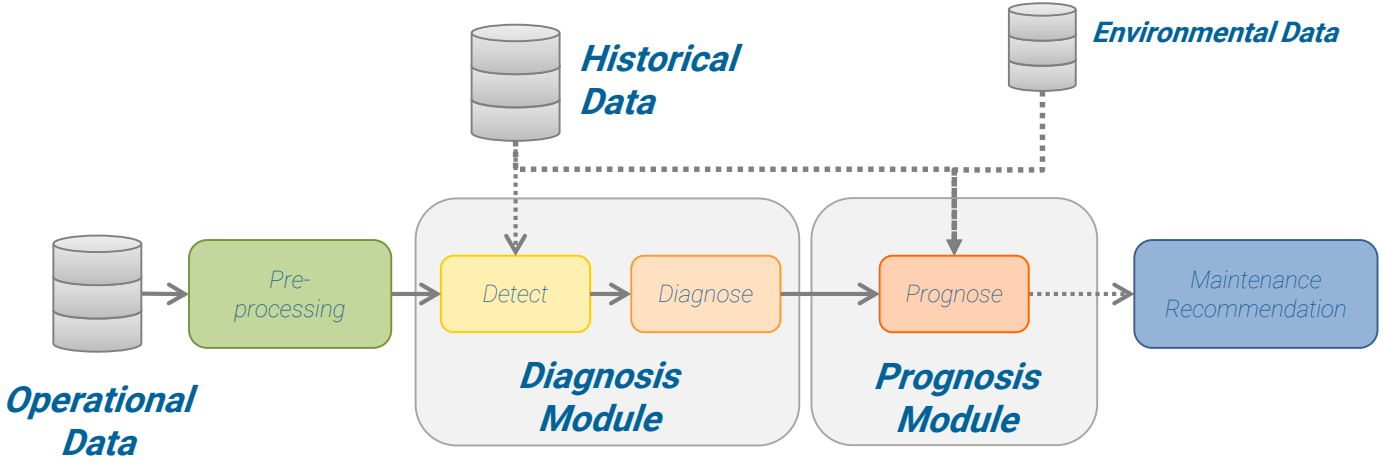

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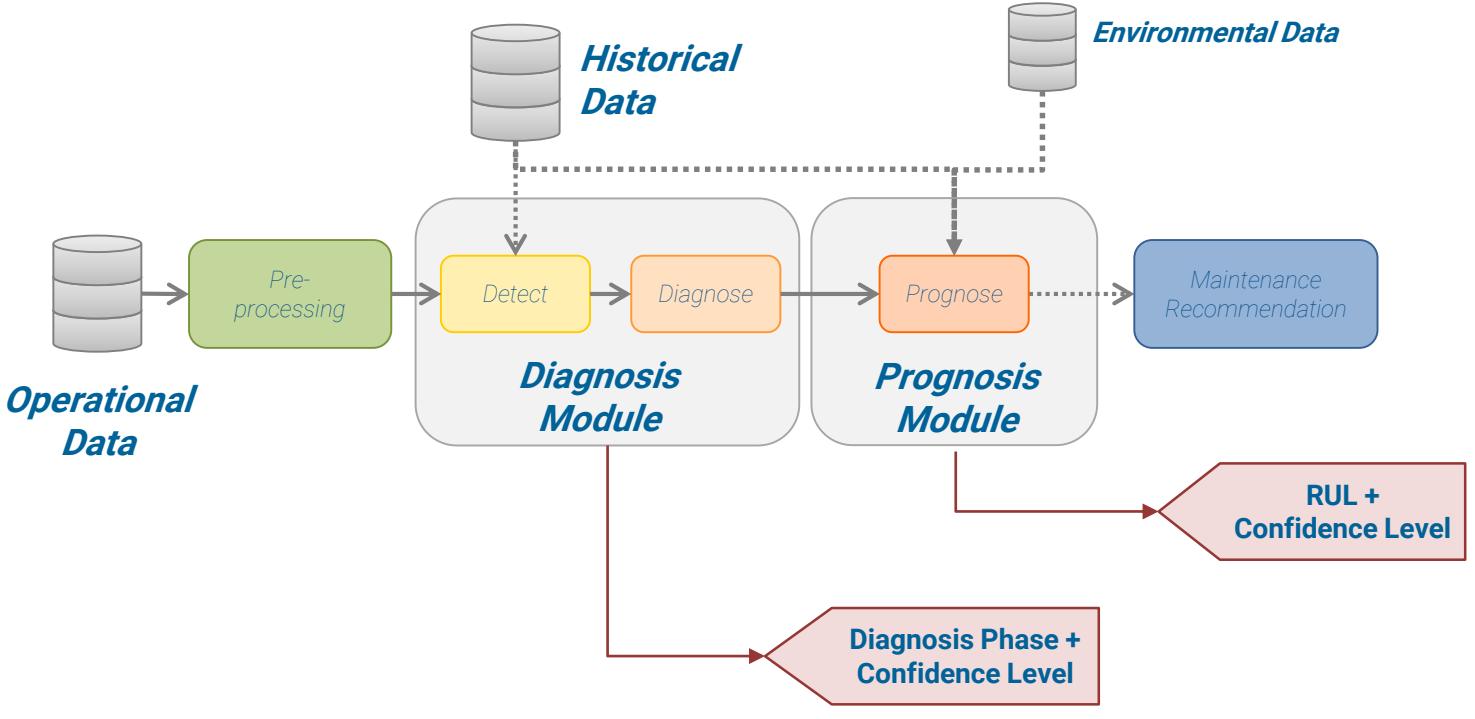

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- Aims at developing a full set of cost-effective diagnosis and prognosis failure mode oriented solutions
- In-Depth investigation of component real behaviour & failure symptoms as observed in SCADA data
- Risk-based Diagnosis & Prognosis (D&P), implying important advances beyond the State-of-the-Art
- Ensure portability to contribute to enhance the understanding of failure occurrence in offshore wind farms

Wikinger Wind Farm – Adwen AD5-135

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- Selection of the 13 most critical failure modes
- Development of advanced D&P Physical Models for these 13 Failure Modes
- 5/13 diagnosis models running daily

Teesside Wind Farm – Siemens SWT2.3

EDF

- Selection of the 9 most critical failure modes
- Development of advanced D&P Physical Models for these 9 Failure Modes
- 4/9 diagnosis models running daily

Physical models to be combined with Machine & Deep Learning models

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Teesside Wind Farm – Siemens 2.3 MW

- Diagnosis & prognosis system oriented solutions
- EDF to build Physical Modules
- Ensure portability to contribute to enhance the understanding of failure occurrence in offshore wind farms
- Training datasets for Machine Learning with 5 years of operation

Module	Description
1	**Main bearing:** Failure early detection
2	**Pitch system:** Failure early detection
3	**Gearbox:** Failure early detection
4	**Transformer :** Inter-turn short-circuit or Cooling System
5	**Generator:** Inter-turn short-circuit of windings, rotor bars
6	**Generator:** Inter-turn short-circuit of windings, rotor bars & cooling system

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Wikinger Wind Farm – Adwen AD5-135

- Full set of diagnosis & prognosis failure mode oriented solutions
- SGRE to build Physical Modules
- Ensure portability to contribute to enhance the understanding of failure occurrence in offshore wind farms

Module	Description
1	**Gearbox:** Sliding Bearings Wear/Blockage
2	**Converter:** DC link capacitor degradation
3	**Converter:** IGCT failure
4	**Generator:** Rotor Demagnetization
5	**Generator:** Loss of insulation in the stator winding
6	**Blade Bearing:** Fatigue and wear of raceways detection module
7	**Blade Bearing:** Loss of structural integrity detection module
8	**Gearbox:** Cracks in gears detection module
9	**Gearbox bearings:** Wear of raceways/rollers detection module
10	**Main Shaft Bearing:** Fatigue/wear of raceways detection module
11	**Main Shaft Bearing:** Wear/fatigue of rollers detection module
12	**Main transformer:** Loss of insulation in the winding detection mod
13	**Main transformer:** Compromised structural integrity detection mod

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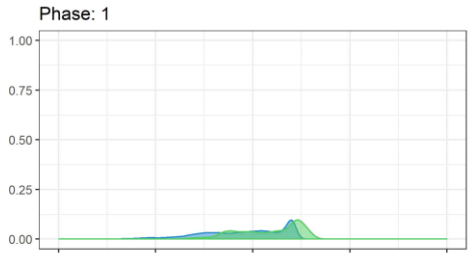
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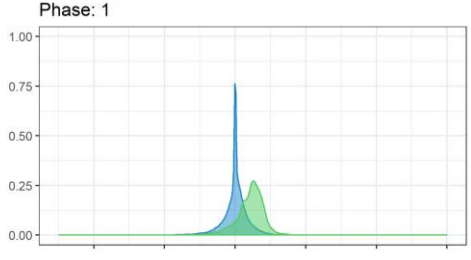
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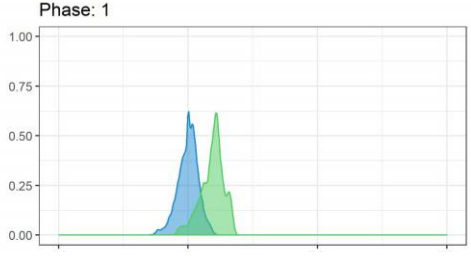
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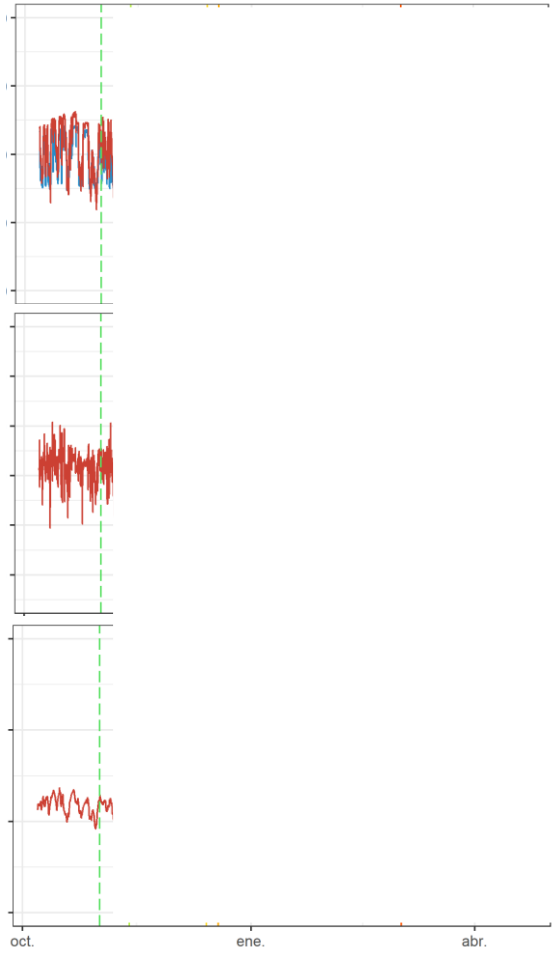
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ROMEO ML approach - IBM

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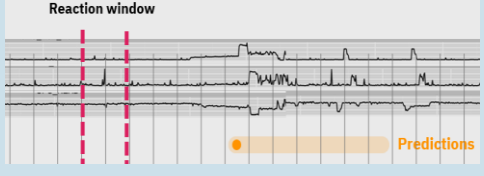
WP3.3: Machine Learning model selection and training

- Development of Machine learning models for specific failure modes
- Extracting an event series and a suitable Machine Learning dataset from a multitude of data sources (SCADA, CMS, etc.)

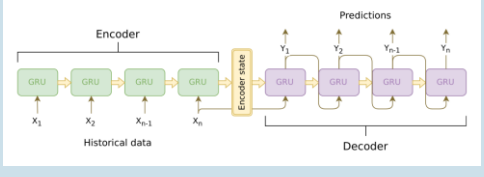
Classification models

- Developing models for predicting abnormal events given a reaction window
- CNN based models for representation learning and predictive classification



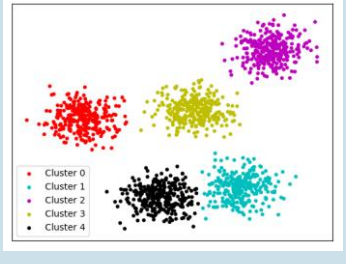
Regression models

- Developing RUL prediction models
- Using deep learning approaches such as seq2seq



Unsupervised models

- Detecting anomalous behavior of wind turbines
- Developing a clustering approach for component state identification



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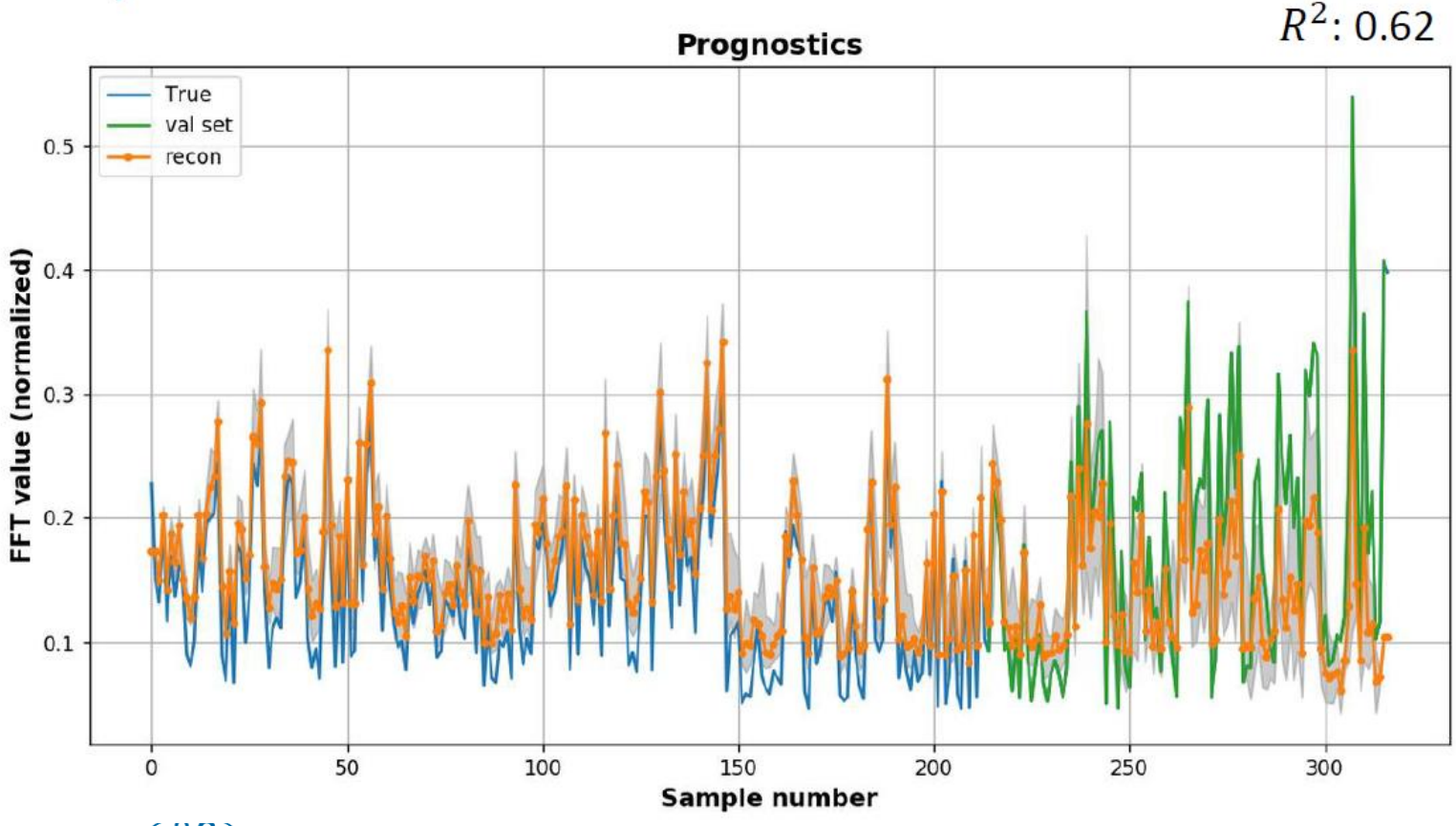
T3.3 Development of statistical degradation detection and failure prediction models for main failure modes



ROMEO – MAIN CHARACTERISTICS

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- Diagnosis and prognosis oriented: Either traditional or more advanced techniques will be used with the aim of detecting failures when the first symptoms are showing up.
- Holistic: Methodology to cover the diagnosis and prognosis of a Wind Turbine;
- Failure mode oriented: First studied failure modes according to criticality and diagnoseability.
- IoT: Integrated into the Internet of Things scheme of three big players on the wind industry.
- LCoE oriented: Each failure mode will trigger a the optimal maintenance decision.
- Demonstrated: Demonstrated and validated at full scale in three different real projects.

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ROMEO – SUCCESSES SO FAR

- First modules can run on the Cloud. ✓
- First two-edged module (Data Driven + Traditionally Designed). ✓
- Laboratory data retrieved for the first time. ✓
- Cross platform techniques. ✓

Thanks for your attention!

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