Integrated turbine condition and health monitoring

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Abstracts

Health and condition monitoring is increasingly popular for offshore wind turbines due to the need for condition based rather than fault driven maintenance strategies and insurance requirements. The traditional health and condition monitoring approaches consider each monitoring source as a separate entity, which has its own dedicated measurement system, and its data analyzed independently from the others. However the availability of an integrated data set offers the possibility to acquire much faster detection and deeper understanding of the degradation mechanisms thriving faults by investigating the complete picture.

Objectives

This work leverages this potential by suggesting an integrated monitoring approach by combining traditional vibration spectra, SCADA data and turbine loads calculated online using other sources (e.g. strain gauges or advanced physical models) with advanced numerical data models for anomaly detection. The main goal of this work is to discuss the concept of the integrated monitoring approach on farm level and focus on three aspects in detail:

- Turbine under-performance detection
- The use of data-models for anomaly detection
- Dynamic load case detection for fatigue influencing events during the lifetime of the turbine.

Multi-Level Monitoring Approach

The fact that a complete dataset is available for each turbine allows the use of a multi-level monitoring approach. The decision whether action is needed is based on multiple monitoring metrics:

- Underperforming turbines are identified by power-curve monitoring
- Turbines with specific subcomponent issues are identified by alarm levels on health signals. The different wind turbine signals, such as temperature signals, vibration levels (general and at specific frequencies) are modeled by means of data-models to account for fluctuations in load and speed during the different turbine operating conditions.

Data-Architecture

Different sensor signals are available for each wind turbine. Combining this data in one integrated dataset offers significant advantages. An integrated communication architecture gathers the data from third party systems to allow integration in a scalable database

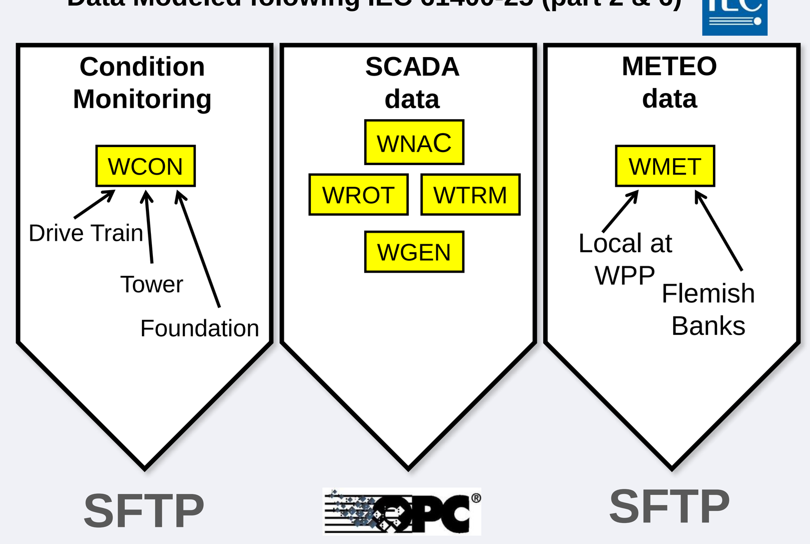

Figure 1: Input Data-Flows

To allow Integrated data-analysis a multi-layer architecture is used. A database interaction manages the data flows. Automatically data is loaded from the different monitoring sources, cleaned and preprocessed and stored in the database. **DYNA***Wind* toolbox is used for data-processing.

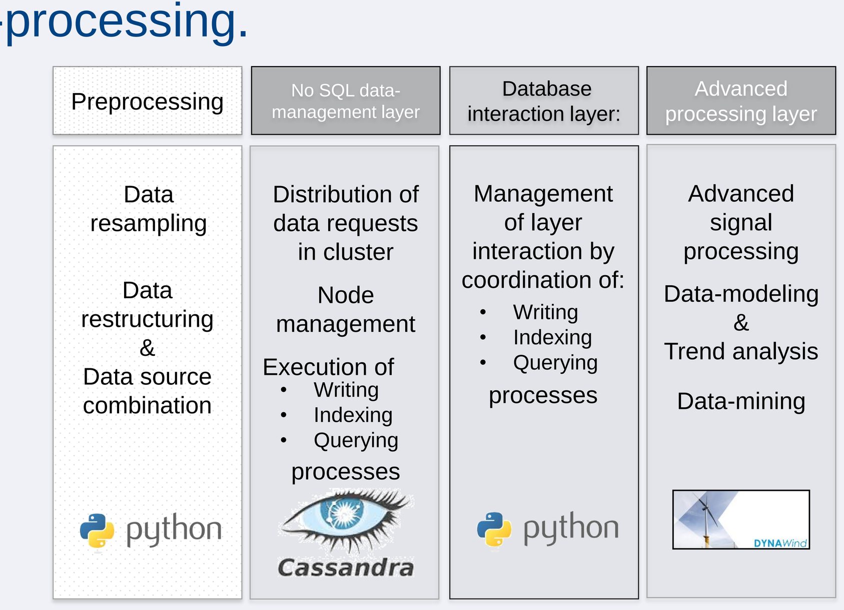

Figure 2: Data Processing Layers

Handling integrated multi-source monitoring poses several challenges, such as handling data variety (e.g. different time scales), data quantity and veracity. Scalable databases, such as No SQL Cassandra, allow distributed storage on multiple (geographically spaced) server nodes while maintaining one single dataset for analysis.

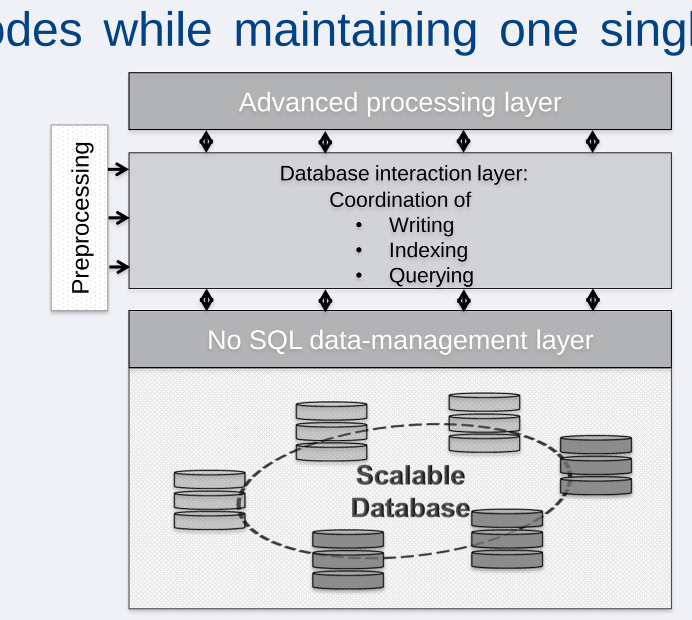

Figure 3: Data Architecture

Alarming

Monitoring Turbine Performance

One way to evaluate the performance of a wind turbine is by calculating the power curve. This can be done by applying some filters and by using the binning method, as explained in IEC 61400-12-2 [1].

To be able to compare curves to each other and the warranted curve, two metrics are defined.

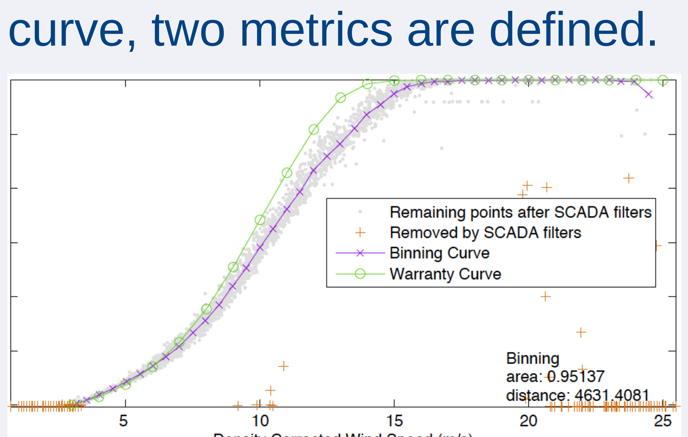
Figure 4: Filtered power curve

One is based on the area under the curves, another is based on the distance between the curves (figure 4). These two metrics can be used as health indices for the wind turbine.

Figure 5 Right gives the resulting values for the health index, based on the area under the curves, calculated for a year for the complete wind farm.

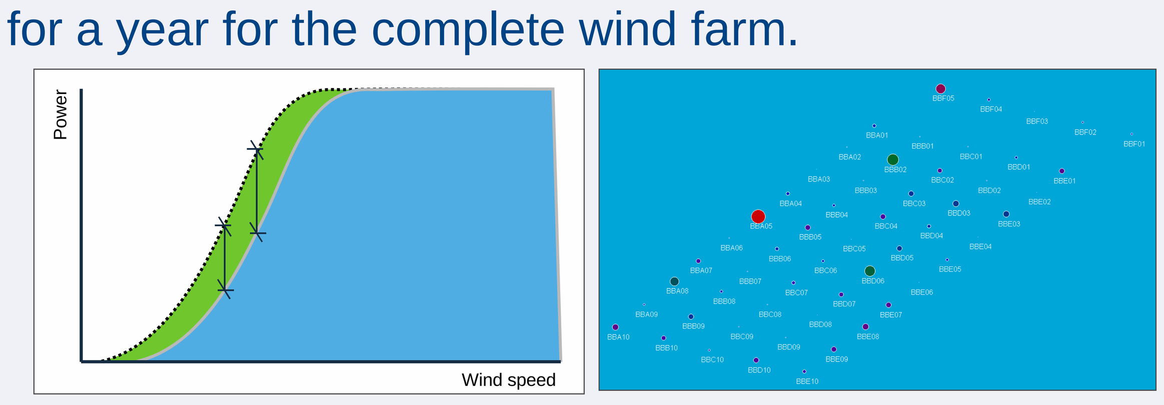
Figure 5: Left: Health indices based on the power curve The difference between the warranted curve (grey) and the measured power curve (dashed) can be defined by the distance between both curves (black) or by the ratio of the area under the measured power curve (green and blue) and the area under the warranted power curve (blue). Right: Health index calculated for 1 year, for all turbines of a wind farm. Turbines with performance issues are immediately detected as red dots.

Data-Modeling

Absolute alarm levels are inadequate for monitoring of wind turbine parameters, such as temperatures, vibration levels, etc. Due to constantly changing operating conditions affecting both loading and speed of the system, constant alarm levels would need to be set too high in order to avoid false alarm during e.g. turbine start-up. Therefore a linear model is made that filters out the influence of speed and load variation in order to only track the evolution of the monitoring parameter. Figure 7 shows an example. The black line represents the model, whereas the colored line is the monitored signal. This signal is classified in Sigma bands according to deviation from the model. Figure 8 Left shows the corresponding risk index of the fault. This is the cumulative energy in the red zone. This is the zone outside of the 3 sigma band. Performing this analysis for all turbines in the farm results in an overview risk index plot for the monitored parameter, as showed in Figure 8 Right.

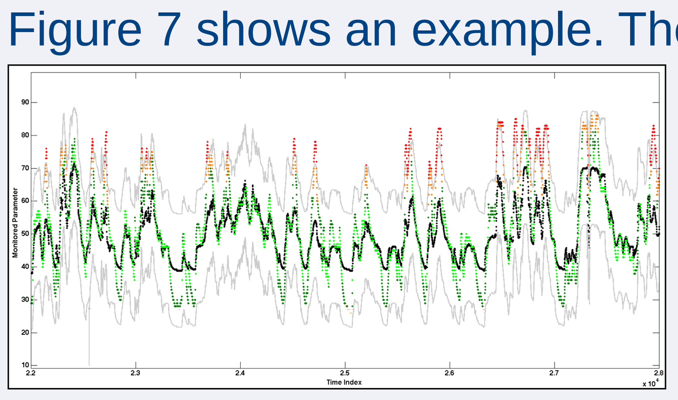
Figure 7: Turbine monitoring partner response in time including alarm band and statistic classification

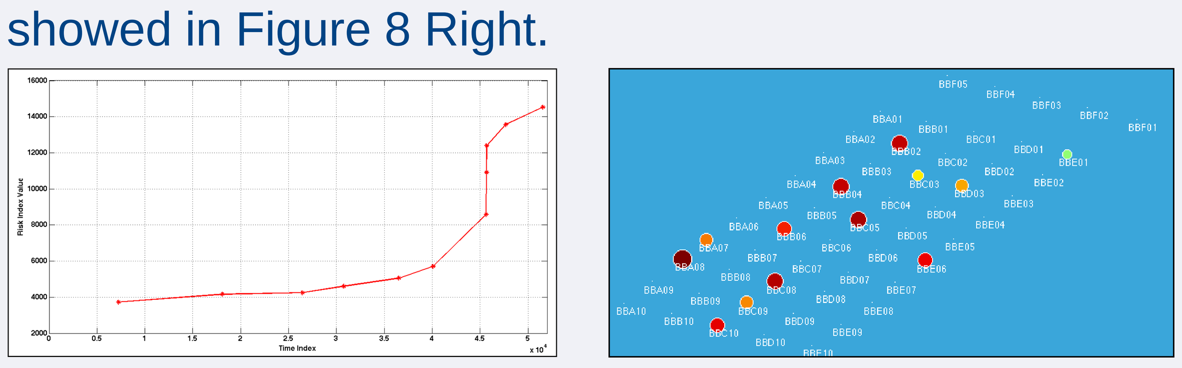
Figure 8: Left: Health index calculated for 1 year for one specific turbine

Right: Health index calculated for 1 year for all turbines of a specific farm

Lifetime

Load Case Detection

Fatigue life of turbine structure and rotating components is significantly influenced by dynamic turbine events such as starts and stops. A typical torque and rpm signal is shown in Figure 6. The availibility of time signals allows for automated detection and classification of these events. This is one of the inputs for remaining life calculation.

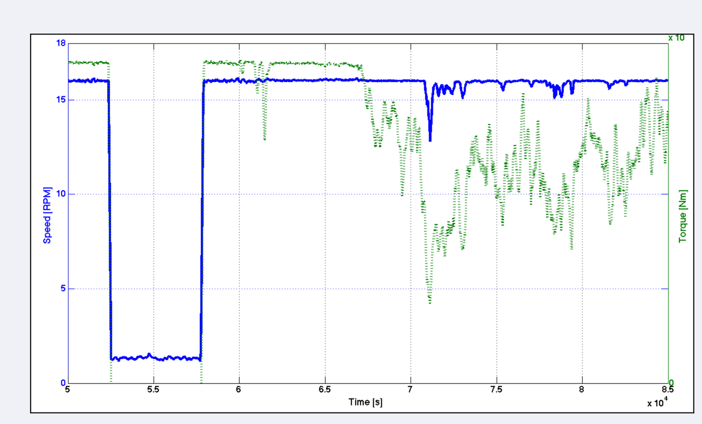
Figure 6: Time evolution of torque and speed during turbine operation. A stop event is clearly visible.

Structural Health Monitoring

The integrated dataset contains tower acceleration and strain signals that are used in structural health monitoring. Details on these analyses are documented in EWEA Offshore 2014 conference posters:

- PO 085
- PO 106

References

[1] International Electrotechnical Commission.Wind Turbines - Part 12-2: Power performance of electricity producing wind turbines based on nacelle anemometry. 2008 (Draft)

Acknowledgements

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