Understanding the behaviour of a wind farm under real conditions: a complete study case

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Connecting wind turbines

Abstract

An important cause of underperformance in wind turbines is their lack of adaptation to the real and local conditions. Wind turbine's settings and control systems are parameterised to optimise their functioning under reference conditions. These conditions can strongly differ from those experienced on-site and therefore lead to sub-optimal performances.

We demonstrate how an optimisation of the power output, the availability and the maintenance schedule are attainable through the understanding of the specific behaviour of each wind turbine.

A study case of 6 operating wind turbines of the same wind farm is presented. Multiple results such as rotor balance diagnosis, vibration analysis, turbulence and curtailment impact studies demonstrate the unused potential on current operating wind turbines.

Objectives

The main objective of this work is to provide tools for continuous and long term wind farm optimisation. The steps taken to do so can be summarised as:

- Improve the quality of the data acquired from the operating wind turbines;
- Use the new data to identify underperformances;
- Provide optimisation solutions to improve the power output of the wind farm.

Methods

Our approach is based on the IoT and Smart Sensors technology (fig. 1) that allow to embed intelligence into the wind turbine, to create a network of connected turbines and to take advantage of the computing capacities available on cloud systems.

Our results were obtained by equipping 6 operating wind turbines (850 kW rated power) of a wind farm with a connected smart-sensing device embedded with multiple sensors, such as accelerometers and compass.

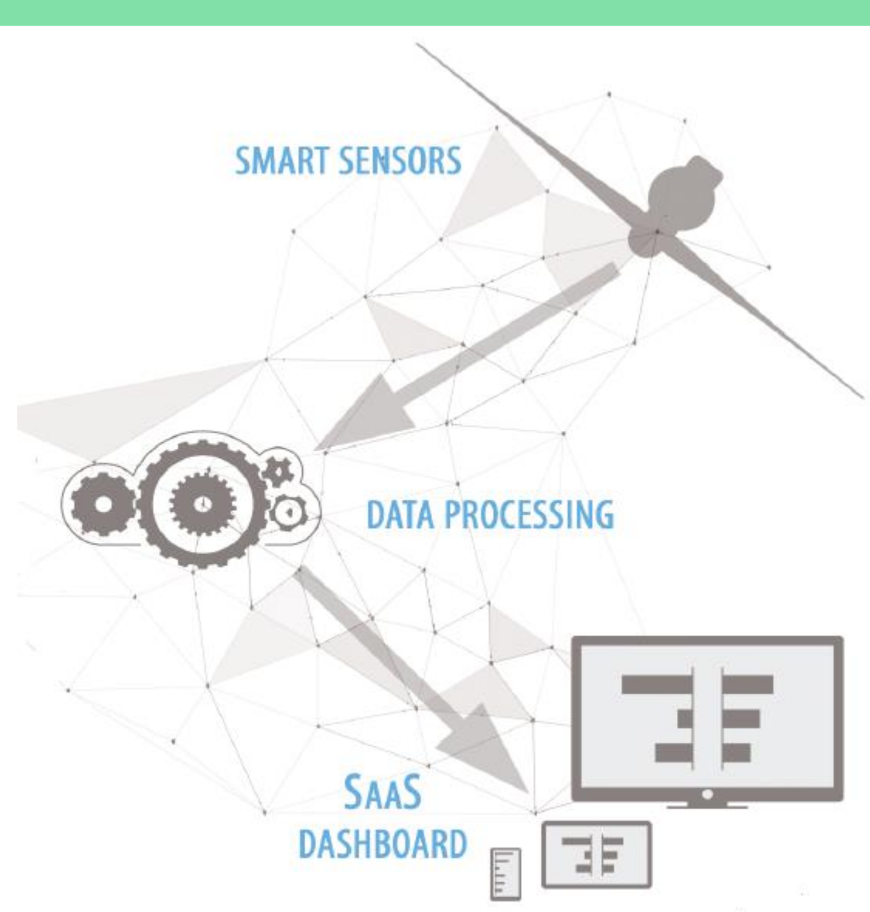

Fig. 1 – Illustration of the data flow between smart sensors and the web portal through a cloud server

An example of an installed device is shown in figure 2. The acquired data is sent, through a GSM connection, to a cloud server. Specially developed data analysis algorithms are applied to the data in order to detect underperforming wind turbines.

The results are then made available to the wind farm owner and/or operator through a web portal.

In this work, two main results are presented: the rotor balance diagnosis and the overall vibrations analysis, both obtained by analysing the acceleration data in the frequency domain.

Fig. 2 – Example of smart-sensing device installed on the met mast that supports the wind sensors of the turbine

Results

Rotor Balance

Imbalance of the rotor can occur for a number of reasons although it can generally be divided into two categories: mass imbalance or aerodynamic imbalance. Both types of imbalance will induce extra structural oscillations at the rotating frequency of the rotor, called the 1p frequency, as they create a difference in the forces produced by the individual blades.

Our data analysis algorithms were developed to monitor the acceleration peaks at the 1p frequency from the data acquired by the installed device, quantifying therefore the forces caused by the imbalance of the rotor. In addition, the perfect external conditions, such as stable wind in speed and direction, for the analysis are selected for each turbine. The selected results are then statistically treated in order to provide a diagnosis of the rotor balance status of the wind turbines. The results obtained for one of the wind turbines are presented on figure 3.

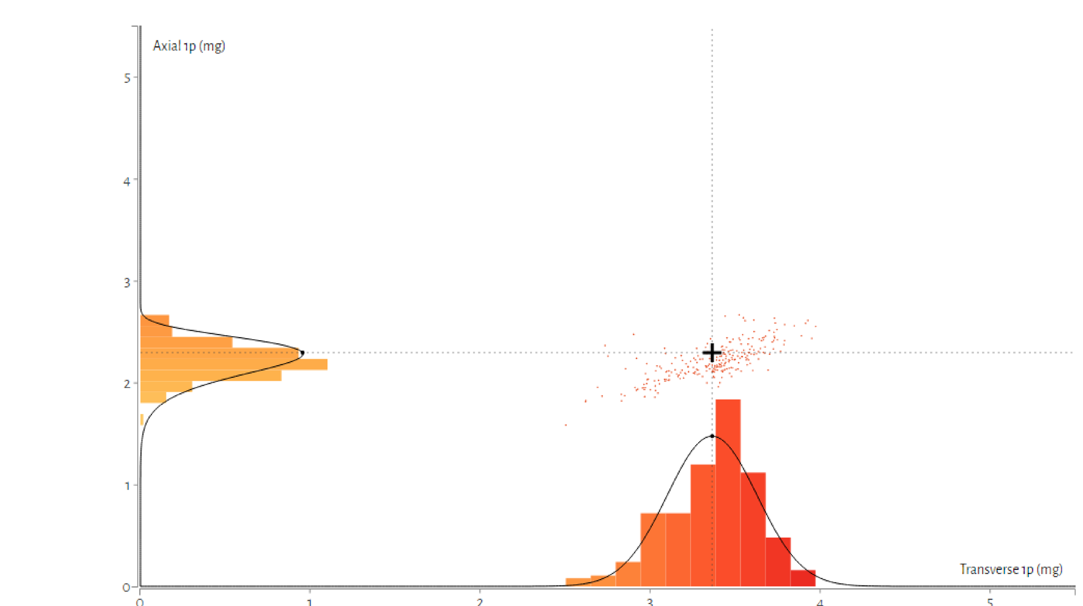

Fig. 3 – Representation of the distribution of the measured 1p acceleration peaks on the axial and transverse axes. The coordinates of the represented cross correspond to status of the rotor balance of the wind turbine.

Overall vibrations

Monitoring the efforts on the structure of wind turbines is important as it can prevent a loss in its life expectancy. Furthermore, if a reliable information of the nacelle direction is available, a sectored analysis allows one to quantify the impact of certain particular functioning conditions, such as, complex terrain and wake effects.

Detecting the sectors with higher and lower working loads permits the optimisation of the power output and life expectancy by tuning the wind sector management applied to the wind farm, as demonstrated in figure 4.

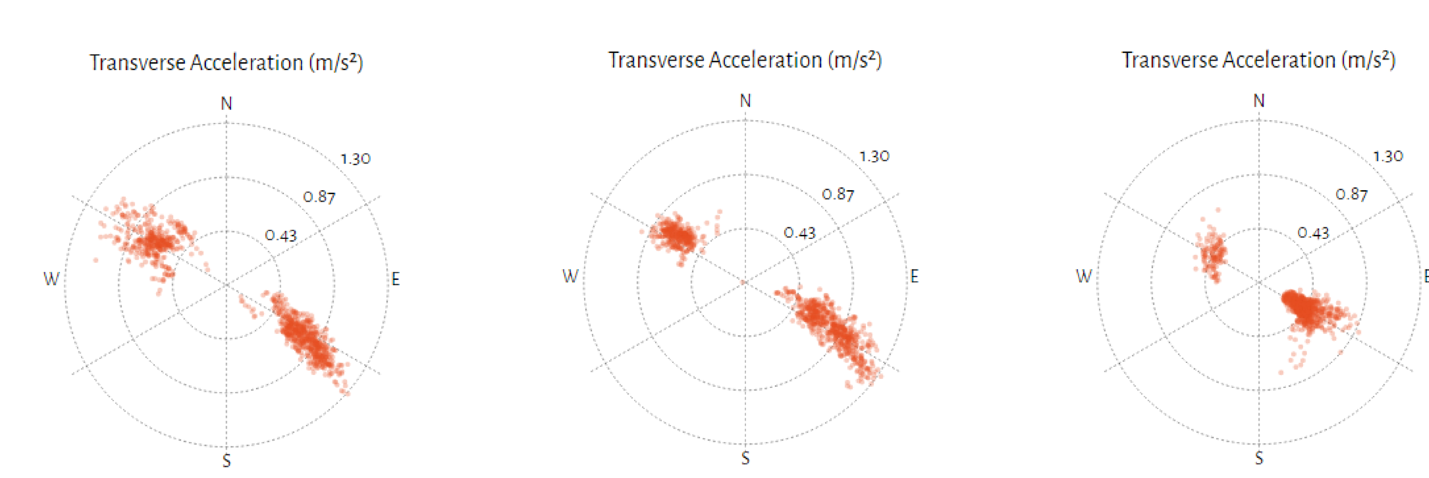

Fig. 4 – Measured vibration roses from 3 of the equipped wind turbines. A curtailment is applied in the NW wind sector in all 3 turbines to reduce the structure fatigue. Results show that the curtailment is unnecessary for 3rd turbine as it presents lower vibration levels in this wind sector.

Conclusions

Adapting wind turbines to the local conditions is the next step towards wind farm optimisation. Our results show that simple strategies and analysis can permit a gain on both the power output and life expectancy of wind turbines.

Multiple results were obtained and made available to the wind farm owner and operator: an online and continuous monitoring of the rotor balance status of each wind turbine; overall and comparative vibration analysis of the structures; sectored analysis of the vibrations levels quantifying the impact of particular working conditions, such as wake sectors and curtailments.

This work represents the first step towards wind farm optimisation: a broader and more complete approach could unveil the complete potential of the wind energy industry.

References

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