ASTRIIS

Towards zero failure

Input data validation
Wind generation

Main bearing inner ring defect

AStrion

Automated Spectral analysis

Context of the use case

VALEMO is a wind turbine operator located in the southwest of France. Within the framework of the European KAStrion project, GIPSA-lab, at the origine of the AStrion solution, collaborated with VALEMO from 2012 to 2014 to instrument two wind turbines named WT6 and WT8.
OnDecember 30, 2015, the main bearing of the WT8 wind turbine failed, resulting in a major breakdown and a year's loss of operation.
A posteriori analysis of the data from the sensors in place, regularly recorded until 15 November 2015, allows us to detail very precisely how AStrion could have anticipated the fault and located it precisely, with 8 months of anticipation

We present here a use case corresponding to the diagnosis carried out by AStrion and allowing the identification of a defect on the inner ring of the main bearing of a wind turbine.

The information in this document is based on the analysis of signals measured during 2014 and up to 15 November 2015. They come from sensors, of accelerometer type, placed on different points of the machine: the main bearing, the input bearing of the planetary gearbox, the 1st and 2nd stages of the planetary gearbox and the main input and output bearings of the generator.

An encoder also attached to the generator's high-speed shaft allows angular resampling of the signals.

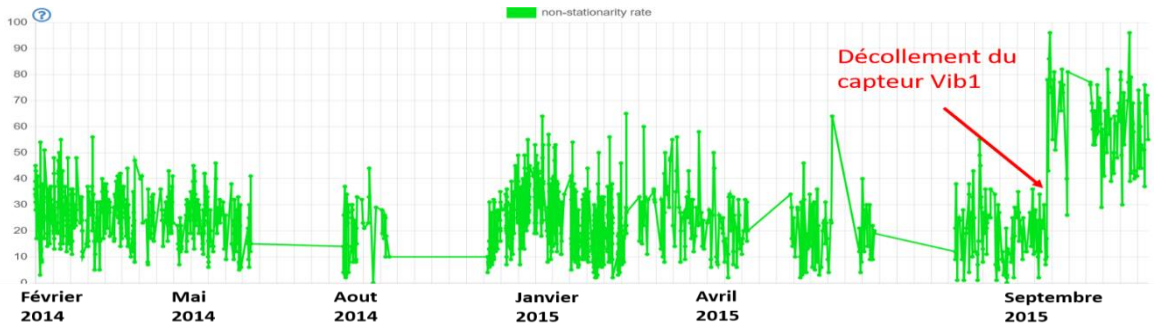
The first signs of bearing defects are seen up to 17 months prior to failure. These signs worsen over time, with milestones in November 2014, May, September and October 2015. **AStrion demonstrated its ability to both detect the defect on the inner ring of the main bearing, and also to track its worsening over time. It also demonstrated the relevance of the data validation algorithms.**

Spectral analysis, which is the basis of AStrion technology, is only relevant with signals of validated quality

One of the data validation criteria used by AStrion, the non-stationarity index, aims to validate the stationarity of each measurement. This index is calculated in the time-frequency plane estimated from a spectrogram. Then, for each frequency bin a hypothesis test is applied.

In the figure below it is thus easy to identify the evolution of this non-stationarity index over all measurements obtained with the Vib1 sensor located on the main bearing housing.

An important jump is visible in September 2015. Observation of the spectrogram and the non-stationarity detector in the time-frequency plane on one of the measurements after September 2015 shows the presence of shocks, which are phenomena with a wide frequency band. After a site visit, these shocks were explained by the fact that the Vib1 sensor was detached from the housing. The measurements of the Vib1 sensor are therefore unusable.



Evolution of the non-stationarity index of the signals measured during 2015 by the Vib1 sensor

The validation of the data is in this use case very interesting: it allowed to detect that the Vib1 sensor became unstuck in September 2015. Without this information, a normal analysis of these signals would have led to erroneous conclusions. However, as the vibration signals do not require a close measurement, it was possible to consider and interpret the measurements of the sensor connected to the main bearing by a rotating shaft.

When applied to a sufficiently long and correctly sampled signal, the Fourier transform is able to provide an estimate of the entire frequency content of a signal with a very high spectral resolution. However, it is preferable to apply various tests on the signals beforehand to ensure the validity of the measurements.

The main idea is to exploit the Fourier transform, a tool very well adapted to the study of vibrations

As the measurements are made over a range of rotational speeds, it is important to compensate for wind speed variations. Indeed, a global Fourier analysis will be more easily interpreted if the signal is stationary. The signals are therefore angularly resampled by AStrion from a synchronous speed measurement. The time signals are then scaled in angles and the frequency signals in order. This module is systematically applied to wind turbine measurements.

In order to estimate the basic global and general signal properties, the first step of the data-driven AStrion approach is to collect the basic information about the nature of the input signal

Amplitude saturation test

This is a simple test that detects amplitude saturation in the signal.

Shannon sampling test

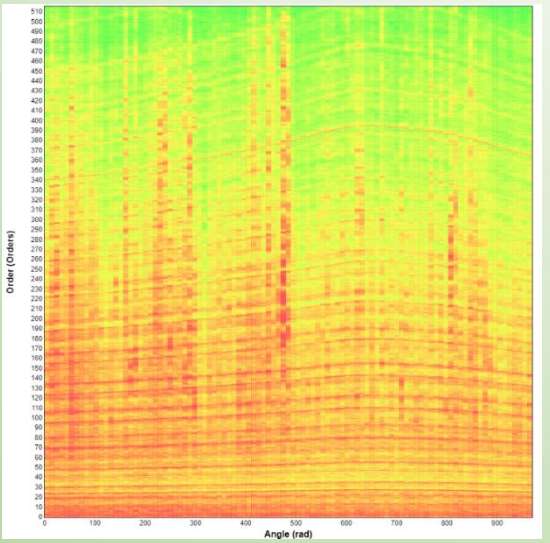
The purpose of this test is to detect potential problems in recovering the signal from its spectrum. Three tests are performed: correctly sampled signal, determination of the last significant frequency and checking for the presence of an anti-aliasing filter.

Stationarity test

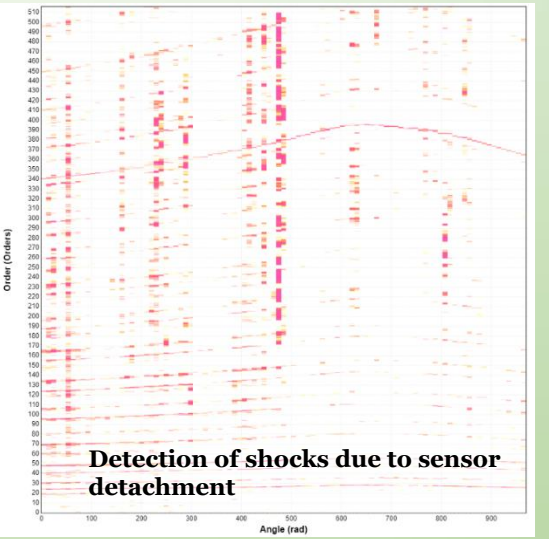
A signal is statistically stationary if it is characterised by time independent moments. The second, third and fourth moments are calculated on consecutive segments of the signal. Exceeding a threshold on the cumulative sum indicates the position of the shocks and then a non-stationar signal.

Periodicity tests

These tests validate the hypothesis that a signal considered corrupted by noise is periodic in time. Two criteria are calculated on the autocorrelation function of the signal, a periodic signal having a periodic autocorrelation function.
One of the tests has the ability to estimate the global signal-to-noise ratio of the signal, a valuable indicator for setting the parameters of the spectral analysis.



Signal spectrogram



Extraction of non-stationarities from the Spectrogram

Prior to any analysis, AStrion examines the sensor data and ensures its validity by checking that it is not saturated, poorly sampled or non-stationary.

Indicators of signal periodicity and an estimated value of the overall signal-to-noise ratio are available to expert users