OROS
APPLICATION NOTE

Predictive maintenance on wind turbines

Monitoring and diagnosis of a wind turbine machine train

Fig. 1: Wind Farm

Introduction

With more and more wind farms installations, the challenge for operators is the maintenance of the machine. Corrective or scheduled maintenance are widely implemented in this industry. This method works but is not optimized.

The project described in this paper is to install a system on the machine train for the **predictive maintenance** of its elements: rotor, slow shaft, gearbox, speed shaft and generator.

There are multiple objectives:

> Improve the **maintenance planning** (operations organization and spare parts supply)

> Increase the **wind turbine life time**

> Improve the **Return On Investment (**ROI)

To realize this project, skills and technical knowledge of three complementary companies have been brought together:

> **La Compagnie du Vent**, wind turbine operator

> **Dynae**, specialized in the management and diagnostic of mechanical and electrical systems, of structures and rotating machinery.

> **OROS**, specialist in measuring noise & vibration

The plan was to install systems in several wind turbines and identify the best hardware and software configuration to optimize the machine train health follow up.

la compagnie du vent
GDF SUEZ

La Compagnie du Vent, GDF SUEZ Group is a french pioneer and a reference in renewable energy.Its objective is to produce, in a socially responsible manner, clean, green renewable energy.The company builds power stations in France and abroad for both itself and third party operators. It owns and runs 20 windfarms in France with, on the 30th April 2011, a total output of more than 230 megawatts.

http://www.compagnieduvent.com

Satellite

The Autonomous System for Temporary Monitoring:

> **PC free**

> **Robust**

> **Monitoring features**

> **History creation**

> **Event detection**

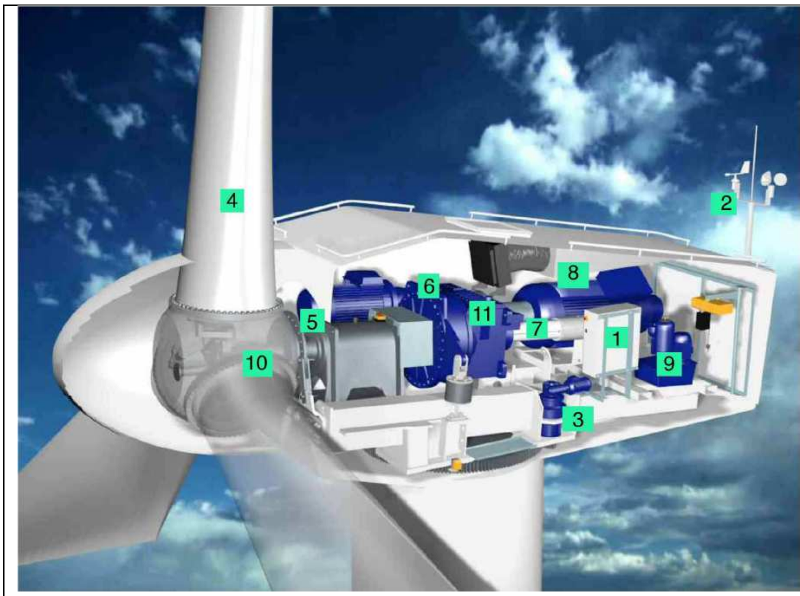
> **Optimized data saving**

Environment

Wind farms are unique sites. The environment has to be understood to choose the best instrumentation solution.

The challenge is to implement a system:

- In an isolated area
- In a nacelle, that are small places submitted to a high vibration level
- On a machine train with several critical components
- On an unstationnary machine, the wind turbine working depends on multiple external data like wind speed, pitch, …



1. Automate
2. Wind vane
3. Orientation motors
4. Blades
5. Slow shaft
6. Gearbox
7. High speed shaft
8. Generator
9. Hydraulic unit
10. Bearings
11. Disc brake

Fig. 2: Wind turbine drive train

From this observation the main specifications are determined. The system has to:

- Be Portable
- Be Tough
- Be Autonomous
- Support several types of physical quantities (acceleration, shaft rotating speed, wind speed, current, power)
- be remotely accessible
- Provide monitoring features like trend analysis
- Offer comprehensive tools for analysis, spectral, order and even current analysis

From these requirements, the OROS systems seem appropriate to realize the objective of this project. They will be installed in several wind turbines on a wind farm in the south of France.

Installation and configuration

A first measurement is done on a wind turbine to identify the main characteristics of this type of machine. With these first results, the hardware and software configurations will be optimized.

Instrumentation

The following information comes from the initial measurement:

> The system will be installed in the nacelle to reduce the cables length. Indeed the majority of measurement locations are on the top of the wind turbine.

> The measurement locations and type of transducers are identified. More than **9 gears and 20 bearings** have to be continuously monitored. The figure 3 shows the machine train with all the measurements points.

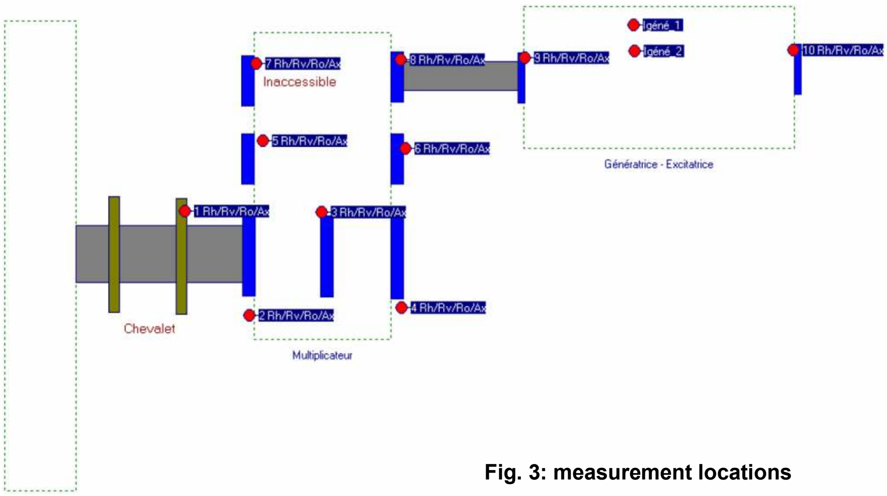


Fig. 3: measurement locations

To obtain a comprehensive view of the machine train, we need to install:

- 14 accelerometers
- One current probe

And we will collect signals from:

- The high speed shaft tachometer
- The slow shaft tachometer
- The anemometer fixed on the roof of the nacelle

> The system has to be autonomous and support power cuts. No one site support is possible even if the system is de-energized due to a power fluctuation, the system must automatically restart.

> Due to the nacelle configuration, the added instrumentation has to be as compact as possible and must not interfere with the regular work of the maintenance services.

With these specifications, we chose to install **a Satellite system with an OR36 and a SmartRouter in a DOCK PACK.**

The DOCK PACK offers:

> 16 dynamic inputs

> 2 oversampling inputs for tachometers

> 4 low sampling inputs for parametric information

> 90 Gb Internal hard disk

Fig. 4: Satellite system with 3G and WIFI modems in the DOCK PACK package

Communication

An important specification of this project is the communication. It is essential to be able to remotely access the system in order to display results, download data, and modify settings if necessary. The first option is to use an optical fiber, widely used on wind farms. Here, no fiber was available. Another solution is implemented using 3G between the office and the wind farm as well as
WIFI between wind turbines inside the farm.

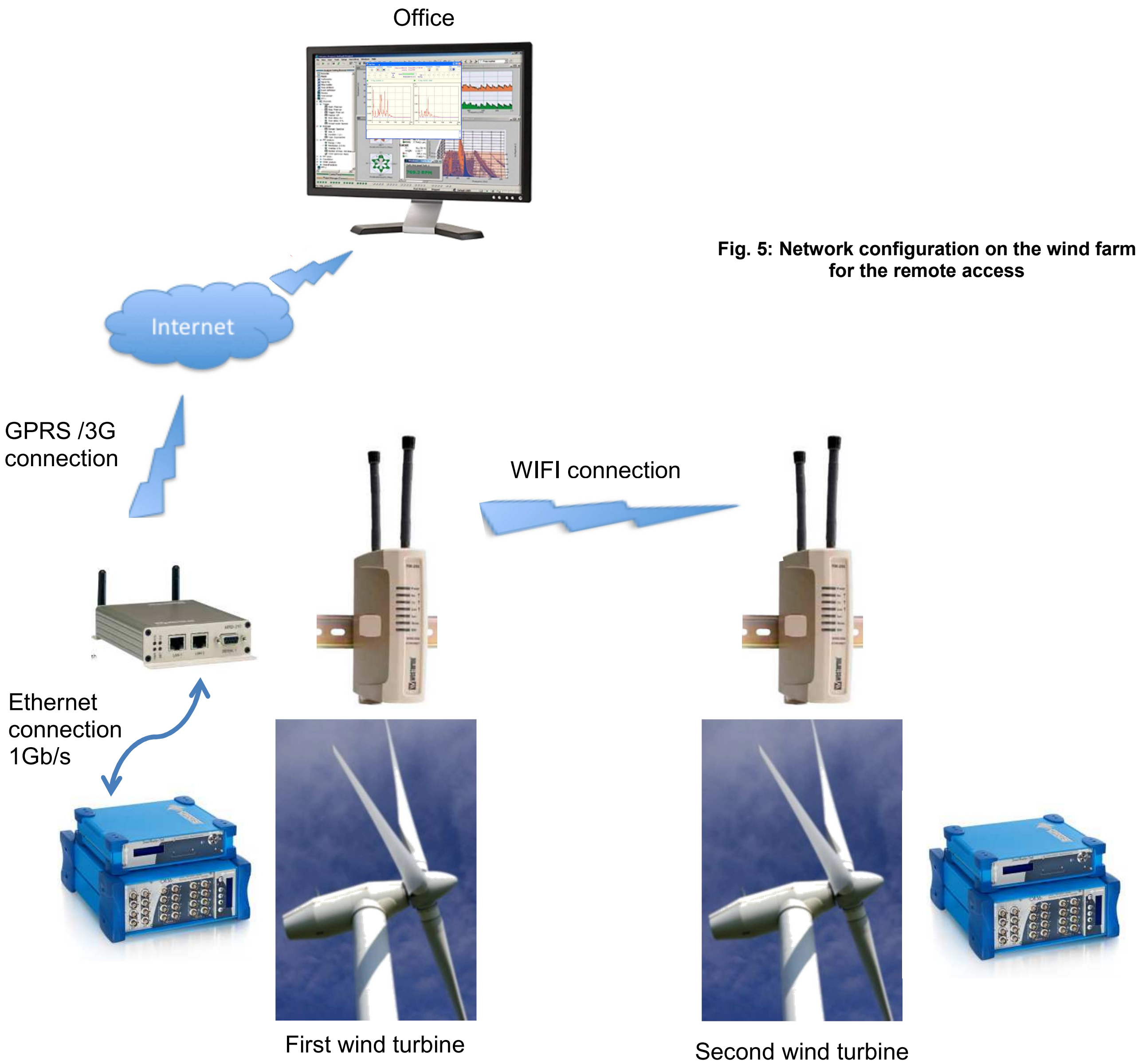


Fig. 5: Network configuration on the wind farm for the remote access

Software configuration

From the first results, we note also that the dynamic behavior of the machine is highly non-stationary. Based on these initial results, the first identified step of the measurement campaign is to install a smart acquisition software to record signals in stable conditions only. Moreover, the signals have to be recorded in the same environmental conditions to be able to compare the results and follow the evolution of defined indicators.

Thanks to **NVGate and SysTeo** software **trend analyses** as well as **advanced analysis** at specific time are performed.
For trend analysis and the history, the following data are saved regularly:

- Current RMS value
- Wind speed value
- Generator rotating speed
- Spectrum and other spectral results of each dynamic input

Trigger conditions are defined on the generator rotating speed and the intensity value. When these values are reached, a time domain signal is recorded for 60s.
Then stability criteria are identified and checked on the time signal. If they're good, the signal is saved on the hard disk for complementary analysis. These analyses can be done directly on the system thanks to the remote access and if necessary the time signals and results can be downloaded through the internet connection via a FTP server.

Analysis

Thanks to the instrumentation described above, pertinent data can be regularly analyzed to control the machine train elements health. Dynae, with its knowledge and experience propose a vibration diagnosis methodology dedicated to the wind turbine machine train. Because of the complexity of the wind turbine mechanical behavior, it's not possible to obtain accurate results with basic vibration analysis.
Before talking about diagnosis, we must come back to the specifics of wind energy systems. The Wind turbines generate electrical power which depends directly on the speed of the wind. The figure below shows the power curve of a wind turbine in kW as a function of the wind speed in m / s.

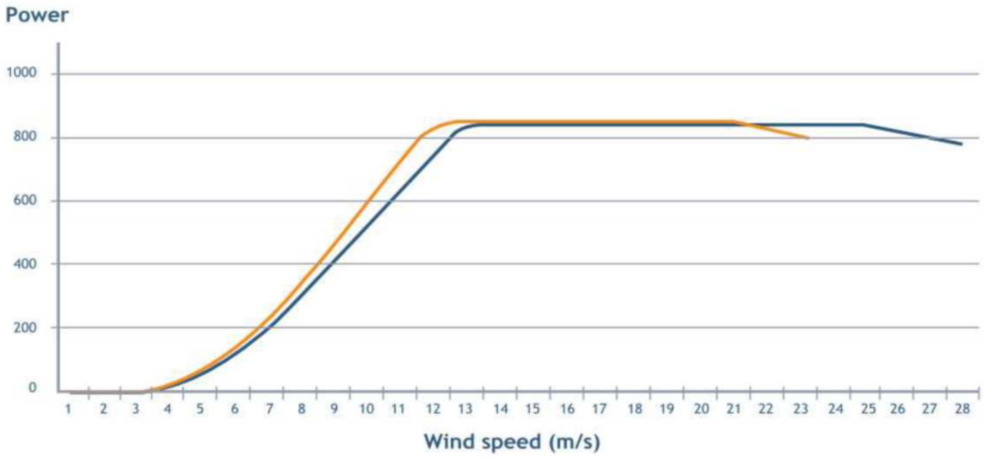


Fig. 6: delivered power as a function of wind speed

Depending on operating conditions, the mechanical forces should be even more important as the speed increases. Curiously, first measurements show that this assumption is not true. An illustration is given in Figure 7 where we can find the overall level in the frequency band [2-200Hz] in function of the rotation speed of the generator.

We can observe an increase in the vibration level between 900 and 1050 RPM and a decrease between 1050 and 1200 RPM. This trend shows a resonance at 1050 RPM.

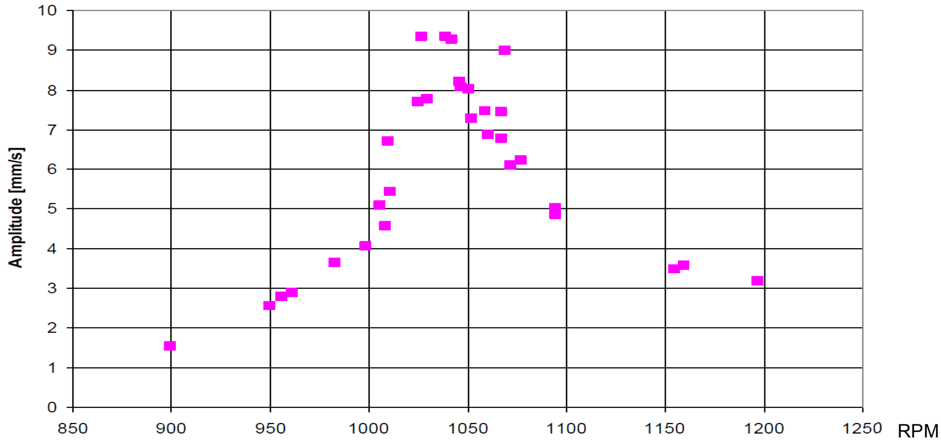


Fig. 7: overall level as a function of generator rotating speed

The first measurements show also that the dynamic behavior of this system is highly non-stationary. **Electric power supplied can vary by a factor of 2 in less than 2 seconds**. With such conditions, it is impossible to provide monitoring or a reliable diagnosis regarding the frequency and brutality of load fluctuations observed.

Fig. 8: generator intensity

The methodology proposed by Dynae takes in to account these observations. Based on results from FFT analysis and mainly **order analysis**, a list of indicators related to a type of faults like unbalance, misalignment, fatigue on bearings or gears, lubrication wear are identified. Their value and/or evolution allow us to locate the problem and detect failure or damage in the first moments.
For example a fault on the external ring of two bearings fixed in the gear box has been identified. From this diagnosis, Dynae can recommend the inspection of these bearings specifically and their replacement if necessary.

Conclusion

With this project, we developed and installed a smart system to measure and analyze the vibration of the wind turbine drive train. Thanks to the robust and reliable instrumentation, **measurements have been performed for two years.**
The expertise of the wind turbine drive train has been carried out and allowed the development of a methodology to detect faults through the use of relevant indicators**. The early nature of the detection and diagnostic reliability are ensured by the trend analysis of a large number of indicators**. The system monitors 3 times more indicators than a system installed on an industrial machine with equivalent power and complexity.

OROS, Leadership through Innovation

About Us
Now approaching 30-years in business, OROS' designs and manufacturing have been renowned for providing the best in noise and vibration analyzers as well as in specific application solutions.

Our Philosophy
Reliability and efficiency are our ambition everyday. We know you require the same for your measurement instruments: comprehensive solutions providing performance and assurance, designed to fit the challenges of your demanding world.

Our Emphasis
Continuously paying attention to your needs, OROS collaborates with a network of proven scientific affiliates to offer the latest of the technology, always based on innovation.

Worldwide Presence
OROS products are marketed in more than 35 countries, through our authorized network of representatives, offices and accredited maintenance centers.

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