

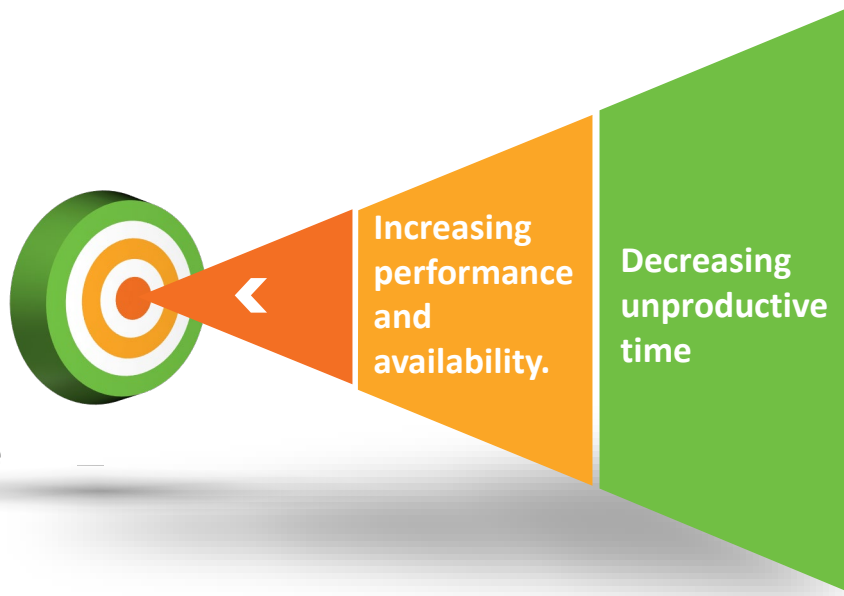


# O&M strategy optimization: Drivetrain & Blades Care

**Wind Farm Operators Forum**  
**13-14/03/2019 – Gdańsk, Poland**

# Successful Operation Strategy

- ✓ Higher production
- ✓ Lower Opex
- ✓ Reducing breakdown and catastrophic failure.
- ✓ “Everlasting” turbines life



**The highest impact on your production and incomes is given by main component failures and inefficiency.**

**You can mitigate both**



**The challenging goal can be achieved only if a proper Contract Structure with Service Provider is in place and a proper organization is settled in order to have better control of the fleet and to ensure maintenance quality**

# Optimise Cost of Energy

***Preventive maintenance is a key solution to predict and diagnose issues to enable timely responses before they impact asset performance***

**A proactive maintenance plan will help you to secure your wind assets well into the future. The end result is an optimized cost of energy.**

In an industry that requires maximum uptime to generate profitability, it is easy to see how downtime can mean the difference between success and failure.

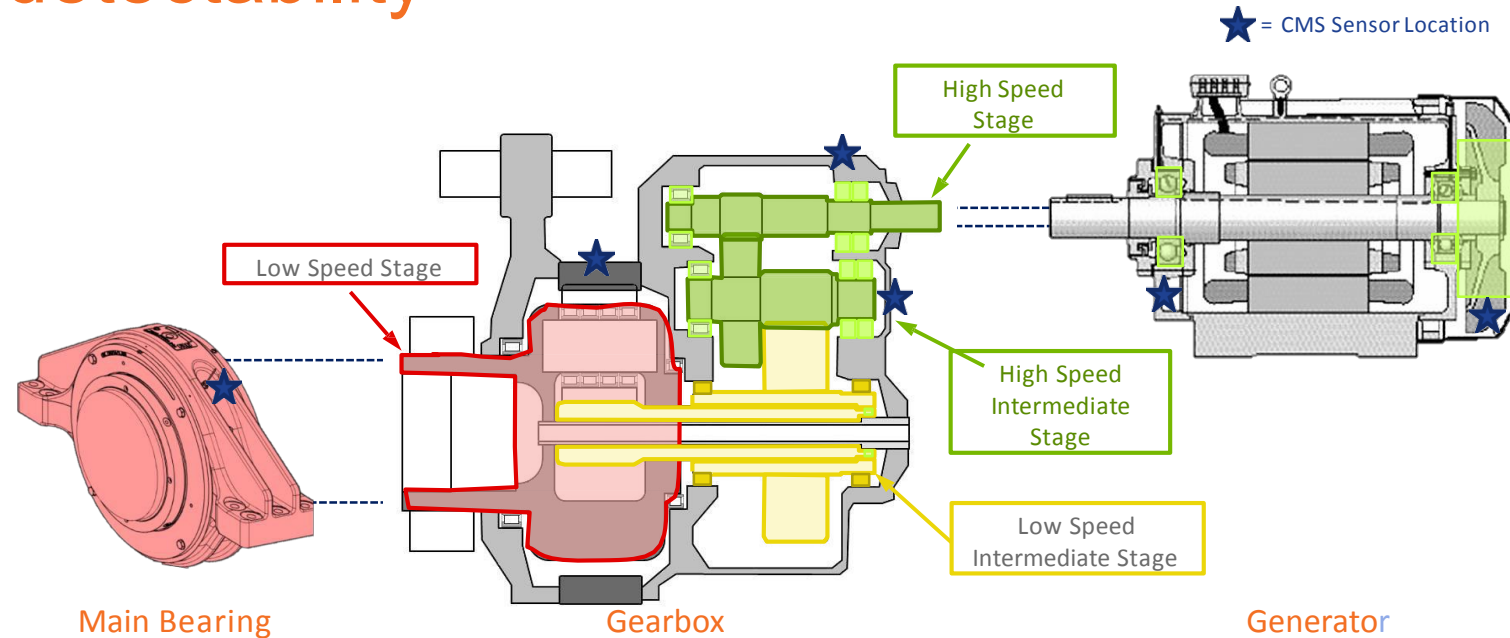
Turbulent wind conditions, subject turbines to damaging structural vibration levels and peak load stresses on drivetrains, gearboxes, and generators.

If left unchecked for extended periods of time, it can lead to severe equipment failures that could have been prevented and expensive repairs that could have been avoided.

Turbine Conditions Monitoring solution ensures your wind turbines' uptime by early failure detection of cost-intensive components of each turbine's drivetrain such as the gearbox, main bearing or generator.

By receiving valuable information, you can plan repairs and maintenance and drive down the cost of energy

# CMS detectability



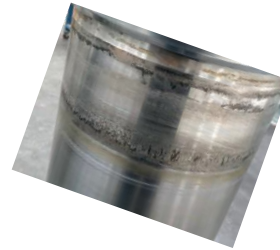
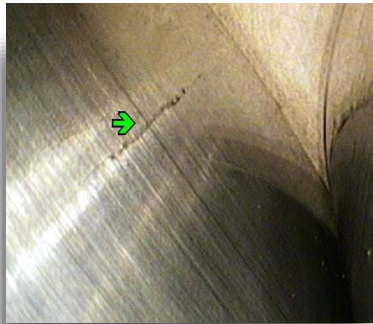
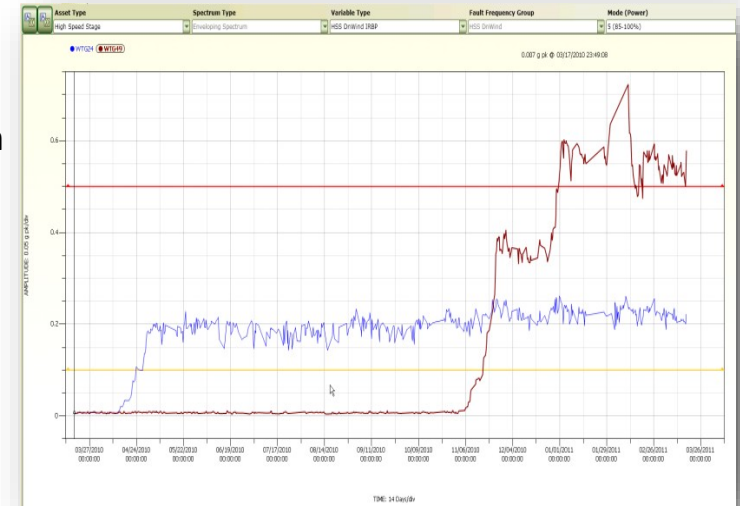
	Main Bearing	Gearbox								Generator		
		Low Speed Stage (LSS)		Low Speed Intermediate Stage (LSIS)		High Speed Intermediate Stage (HSIS)		High Speed Stage (HSS)				
		Bearing	Gears	Bearings	Gears	Bearings	Bearings	Pinion/gear	Bearings	Pinion/gears	Bearings	Grounding & EDM
Relative Failure Freq.*	Very Low	Low		Very Low		Medium - High				Medium		
Probability of Detection	Medium - High	Medium - High		Medium - High		Very High		Very High		Very High	Very High	
Up-tower repair capable	Currently Exchange Only	Currently Exchange Only		In Development		Yes				Yes		
* Relative Failure Frequency = Considering the total failures for that component												

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# CMS

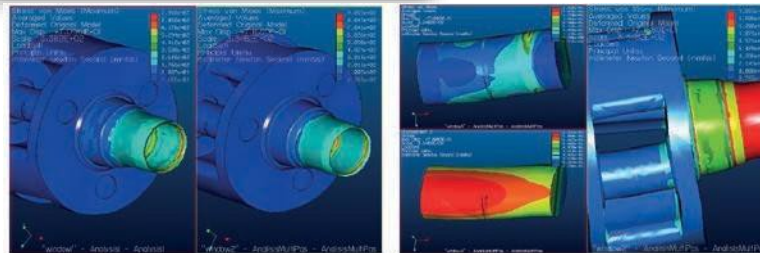
## Condition Monitoring System increases productivity and profitability by:

- Giving you a complete overview of the condition of turbines in all wind farm sites
- Increasing wind turbine production by prevention of costly breakdowns
- Reducing repair costs
- Improving cost efficiency of maintenance and services
- Lowering insurance premiums
- Lowering warranty costs
- Documenting turbine life cycle



## Early detection & Preventative repair

- Advanced warning allows for:
- Reduced secondary damage
- Up tower repair
- Scheduled V.S. Unplanned downtime
- Defect prognosis & estimation of remaining life





**Wind turbines can easily be retrofitted to extend the turbine lifetime and increase uptime**



**Profitability of a wind turbine is measured by:**

- Wind resources
- Price per kWh
- Availability
- O&M costs

You know you have no influence on the first two, but availability and O&M costs can be positively affected by the right monitoring solution and maintenance strategy



# Case Story 1

## Retrofitting the turbines was well worth the investment

Prior to end of warranty at one of our wind farms we decided to retrofit CMS in our turbines. We installed CMS about eight months before the end of warranty and over that time the data collected was analysed and used to Prioritise where videoscope inspections should be carried out. Increasing vibration levels were seen at five turbines, which correlated with IMS bearing damage to the inner race. The visual inspections confirmed the findings and showed the early stage of failure. As a result we were able to keep the turbines running until new bearings arrived.

Downtime was scheduled and the bearings were replaced in-situ under warranty. Similarly, CMS indicated an inner race fault on three HSS bearings. Visual inspections were carried out, but due to restricted access no damage was found. We continued to run the turbines but ordered three replacement HSS bearings. When we replaced the three bearings, we visually inspected the removed inner raceways. On one inner race, two hairline cracks could be seen. The other two bearings are undergoing crack testing at present.

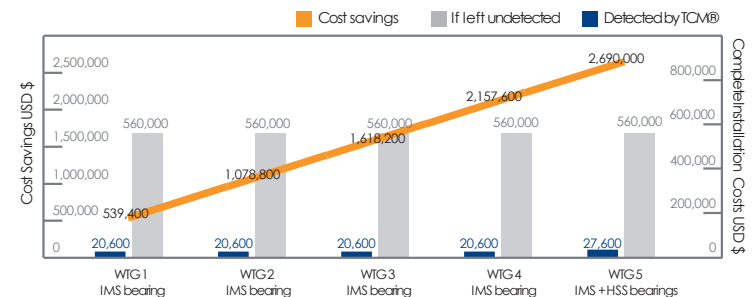
CMS allowed us to identify bearing damage before it became significant enough to cause secondary damage in the gearboxes. This allowed us to order the bearings and plan turbine downtime to change out the bearings in-situ. Having such advance warning of failures is crucial in maintaining turbine availability and avoiding high replacement costs associated with complete gearbox failure."



**In the course of eight months, failure on five gearboxes with CMS retrofit was avoided!**



**Cost Savings on Failing Components Detected by CMS**



# Case Story 2

## Success in Saving Gearboxes

Thanks to CMS, a cracked high speed shaft was detected early and replaced before it failed, potentially damaging a very expensive gearbox.

"In August 2012, we received an alarm: **High Speed Pinion on Turbine L01**. Thereafter, we visually checked to see if we could see some cracks on the gear teeth. Additionally, we checked the in-line oil filter to make sure there were no shavings from the metal. When we didn't see any signs of cracks or shavings, we decided that we would start up the Turbine again. But after two days, we received the Same allarm again.

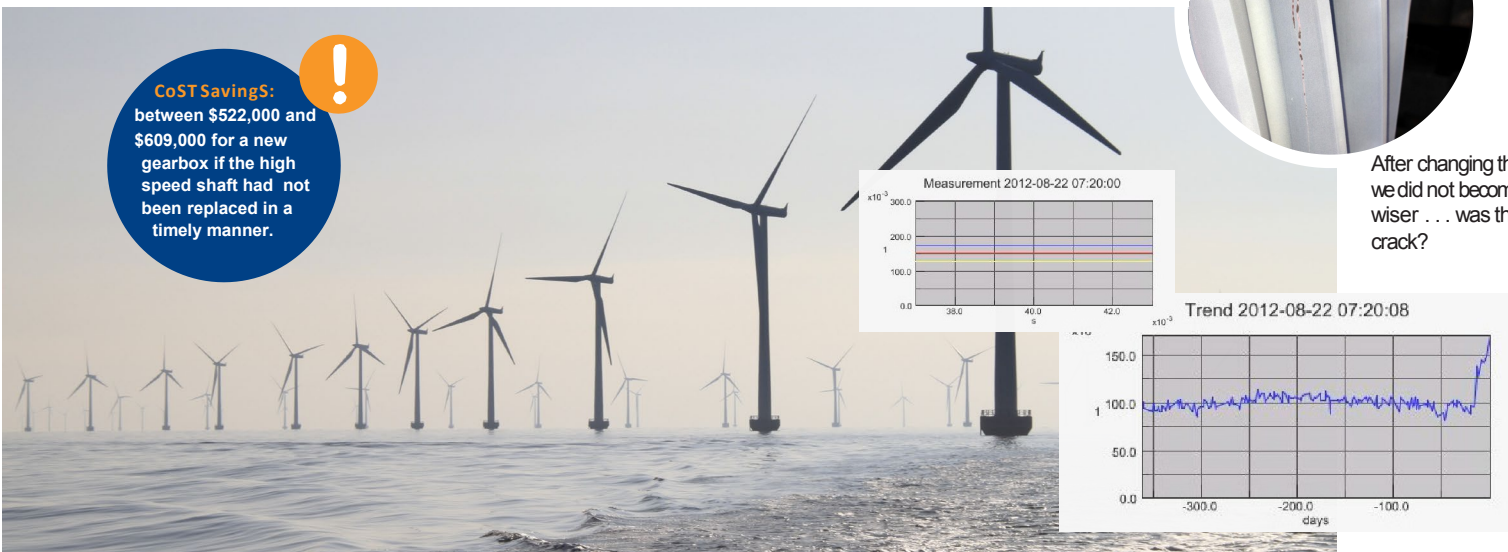
find any cracks or metal shavings, so we started the wind turbine again, and immediately ordered a new high speed shaft.

The reasoning behind the purchase of the new shaft was a simple calculation . . . if there was a tooth that might break off and ruin a gearbox, the replacement costs for a new gearbox would be around \$522,000-609,000 including a jack-up rig, whereas the replacement of a new shaft would only cost \$17,500.

was a really good decision to replace the shaft. We were finally able to see the crack."



After changing the shaft we did not become much wiser . . . was there a crack?



alarm Type	RedMask
Location name	L01
Sensor name	Highspeed
Measurement name	rms_cep_HS_Tr
Condition	WPS-active Power 1657-1909.
From Time	2012-08-08 23:04:31
To Time	
Last Time Red	2012-08-22 07:02:25
Fault Frequency	0.04
Fault Interval Width	50.00
acknowledgeStatus	ack
acknowledged by	TCMEnterprise
acknowledgeTime	2012-08-20 12:34:51



# Blade Special Care

Blades are one of the most critical component for a wind turbine been directly responsible for the performance of the machine

O&M providers and blade manufacturing companies tend to inform just what is necessary, leaving turbine owners defenseless towards the future.

Managing blade maintenance directly will allow you to:

Have 100% of information gathered

Combine knowledge with historical data

Monitor the wear and tear process with an accurate blade inspections plan

Predict failures

Improve aerodynamics

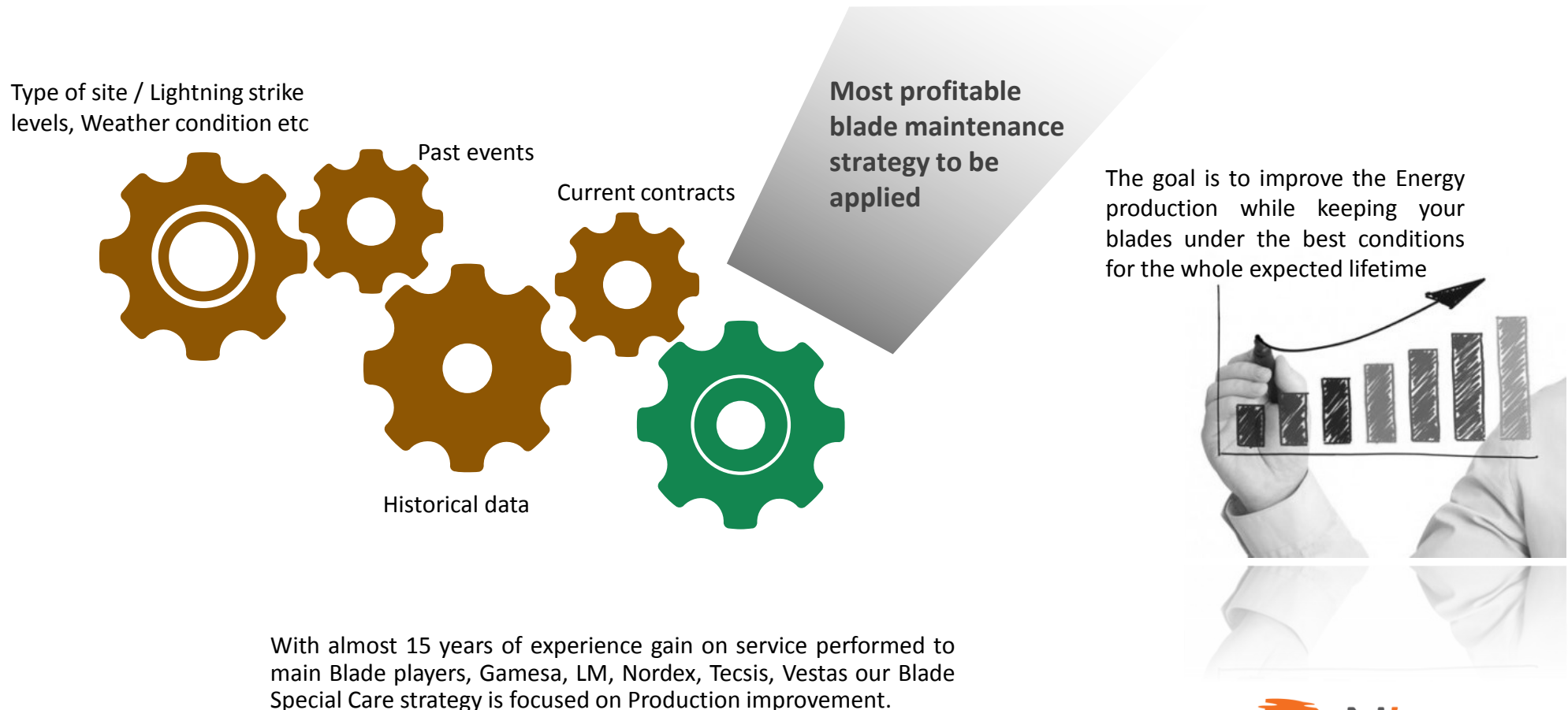
Find and follow up serial defect

To change this unpleasant and dangerous situation and in order to reduce the related risk, internalise blade know-how.

# Blade Strategy Definition



Each site has its own particularities: age, height, rain, snow, wind, air particulates, sun exposure, type of blade...etc. Hence, wind blade maintenance must be treated not as a global maintenance and should be tailored



With almost 15 years of experience gain on service performed to main Blade players, Gamesa, LM, Nordex, Tecsis, Vestas our Blade Special Care strategy is focused on Production improvement.

# Blade Care Tips

To better adapt the blades to the specific site condition, several actions can be considered



Special treatments to Blade pitch angle,

Average misalignment loss production equal to 1,5%



Vortex generator

Production increase, maintenance optimization



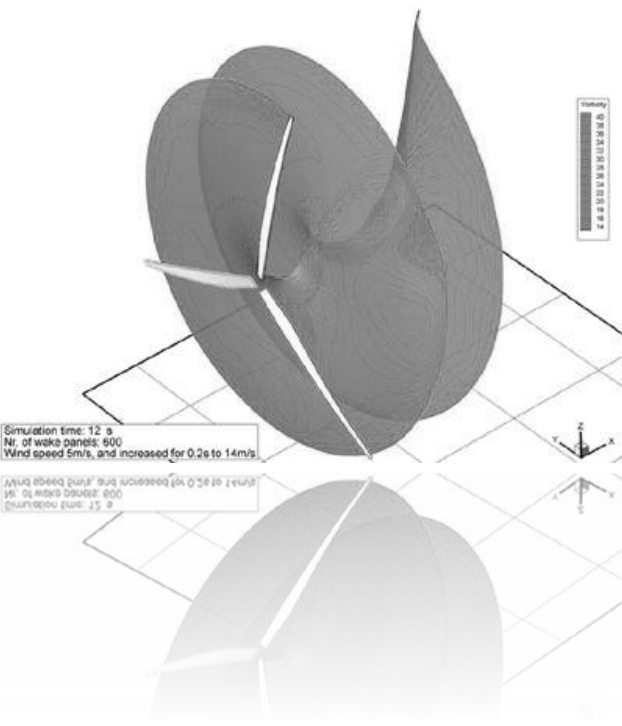
Blade stiffness

To better fit in turbulent wind site



Blade tip or trailing edge reinforcement etc.

Erosion protection for longer maintenance interval



# Blade Special Care

## Blade inspection and Data analysis

Blades inspection has to be done at least once a year to control damages categorization and blade status in order to apply corrective measures if necessary.

Specific inspection may be decided after analysis of the data gathered for example:

- Inspections on height after ground inspections if necessary to retrieve more information about the blade / damages found.
- Conductivity test if the blade shown lightning damages or LPS bolt deteriorated and every time a blade needs to be repaired.
- Inner inspections of the root in case of damages nearby the area affecting trailing edge leading edge or central laminates.





# Blade Special Care

## CAMERA & DAMAGE ANALYSIS SOFTWARE:

Our inspection system developed with Braendler, not only inspects but also categorize the damages found, creating a database that allows to analyses recurrent damages, takes real measures and produce our inspection reports. The high-resolution camera together with the software, standardize system guaranty that all inspection will be done in the same way.

















This is very important to analyse the information gathered from years past, comparing not on type of damages but also progression with real data.

The camera is able to measure and locate the damage on the blade with a 99.9% of accuracy.

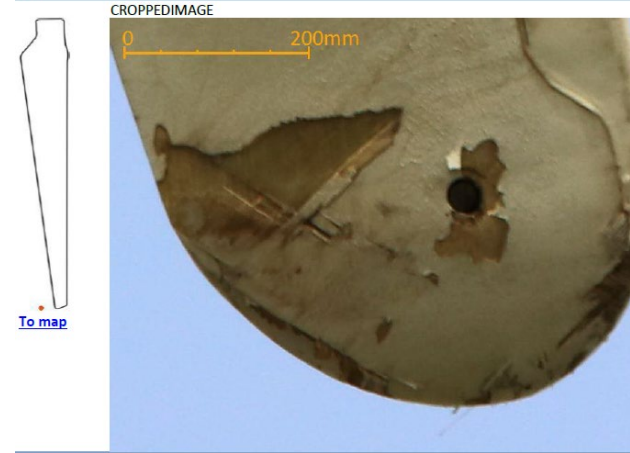
### CATEGORY DEFINITION

Damages are classify by five categories starting from 1 to 5 depending the severity and time of repair response.

Generally time of repair response should be apply automatically unless blade expert decide to repair before or after depending the needs of the project or grouping damages in the same blade or turbine.

CATEGORY	DAMAGE	ACTION	TURBINE
	1  Cosmetic Readings of lightning system below 50mΩ	 No need for immediate action	 Continue Operation
	2  Damage, below wear and tear	 Repair only if other damages are to be repaired	 Continue Operation
	3  Damage, above wear and tear Readings of lightning system above 50mΩ	 Repair done within next 6 months	 Continue Operation
	4  Serious damage	 Repair performed within next 3 months. Damage monitored	 Continue Operation
	5  Critical damage	 Immediate action required to prevent turbine damage. Contact technical support	 STOP Operation <i>safety is not ensured</i>

Index	Blade	Side	Defect	Severity	Layer	Location [m]	Length [mm]
2e7953a3-17fc-42ee-ad9f-a481faaaf000	T14, B	Down Wind	LIGHT	4	Laminate	29	1170



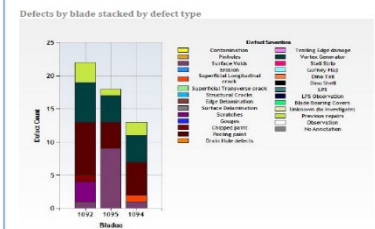
Index	Blade	Side	Defect	Severity	Layer	Location [m]	Length [mm]
b74289a0-2897-4923-8c96-a126db21a9b	52, 1094	Trailing Edge	Superficial Longitudinal crack	3	Filler	33.5	422

CROPPED IMAGE

0 100mm

To Map

Defects summary						
TYPE	Cat 0	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5 TOTALS
Peeling paint	0	0	16	1	0	17
Previous repairs	6	0	0	0	0	6
Vortex Generator	0	14	0	0	0	14
Scratches	0	0	3	0	0	3
Surface Voids	0	0	3	8	0	11
Superficial Longitudinal crack	0	0	0	1	0	1
Chipped paint	0	0	0	1	0	1
TOTALS	6	14	22	11	0	53



# Blade Special Care

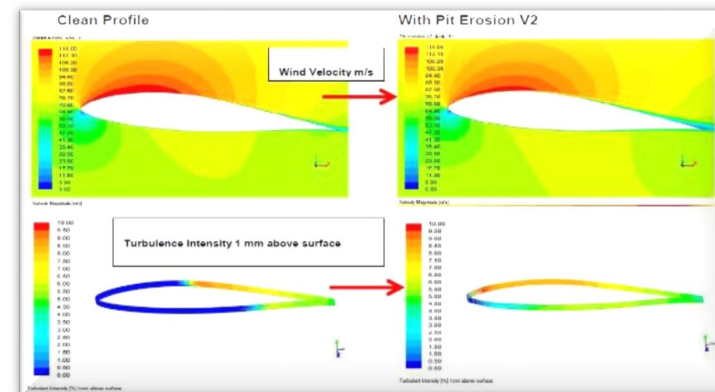
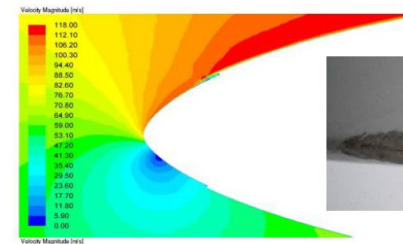
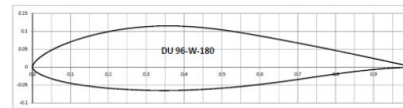
## EROSION STUDIES:

We have collaborated with an engineering company studying the behavior of the blade regarding erosion vs loss of production.

We are now capable to determine when and how we need to act depending the wear and tear of the blades considering the weather conditions, the turbine average production and the loss of productions. This type of analysis is not even considered by O&M providers since is not a priority and cost are in most of the cases bare by the owner.

Even though studies have their inaccuracies, every day we are, closer to get real data and therefore able to perform as it should be a tailored maintenance.

Effects of airfoil erosion on wind turbine performance			
		Input	Output
Tip Speed Ratio	8.50		
Radial section affected	outer section	next section	
	10.00%	10.00%	
Assumed operating values at radial section with clean airfoil:			
L/D ratio	125	125	
Axial induction factor	31.0%	31.0%	
Percentage of (eroded/clean) coefficients:			
Lift	93.0%	93.0%	
Drag	150.0%	150.0%	
L/D ratio	62.0%	62.0%	
Effective radius	95.13%	85.15%	
Local speed ratio	8.09	7.24	
Affected swept area	19.0%	17.0%	
Airfoil efficiency:			
Clean	90.8%	92.6%	
Eroded	85.1%	88.1%	
Power loss due to reduced extracted power (Lift loss)			
Power loss at radial section	0.38%	1.06%	1.06%
Power loss for turbine			
Power loss due to reduced airfoil efficiency (Lift/Drag loss)			
Power loss at radial section		6.23%	4.89%
Power loss for turbine	2.02%		
Total power loss			
Power loss at radial section		7.23%	5.90%
Power loss for turbine	2.39%		



# Blade Repair

Tailored from our inspections, we are able to advise or even perform your blade maintenance. Having a good understanding of the latest techniques, we approach each damage individually. Assessing damage by damage, we are indeed, able to optimize the repair campaign, reducing maintenance cost and keeping blades in good conditions to operate at full power.



# Case Story



## Falck Renewables Success in increasing production in a complex terrain wind farm

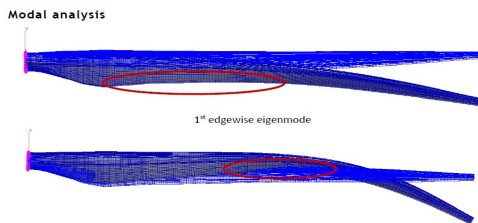
Petralia is a windfarm located in Southern Italy in a complex terrain area and with turbulent wind condition.

Shut down strategy needs to be implemented at the positions located leeward of terrain elevations.

A shut down strategy involves stopping the wind turbines on those angles where the generated wakes could be harmful to the appropriate operation of the wind turbines 2, 13, 18, 22, 27, 30 and 32.

Turbulence could be harmful for blade and create damages on trailing edge.

Due the turbulence blades bend edgewise mode creating non designed moves.



The proposed solution was to increase the blade structure to support higher forces.

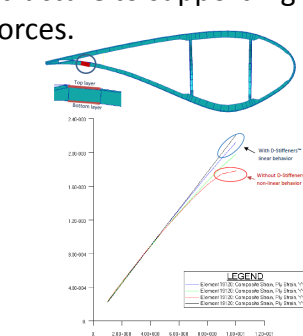
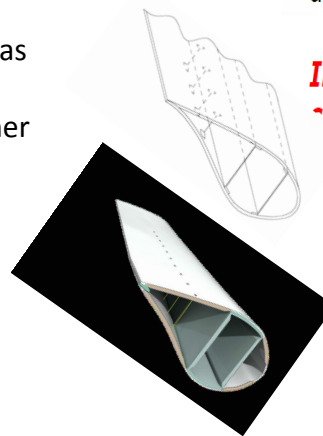


Figure 1: Blade and illustrating the buckling in the trailing edge. When the D-Stiffener™ is added, the buckling is reduced. With and without D-Stiffener™. With black and blue: state level of the same element after the D-Stiffener™ was installed.



Increasing the stiffness of the blade panels and the trailing edge assembly of the panels.

Reinforcing the blade to operate at full power.

**Impact of Sector Curtailment can be minimised.**



WTG	Production Lost by Sector Curtailment in 2017 (kWh)	Estimation of Lost production (k€)
12	26,452	4,153
16	447,403	70,242
17	102,724	16,128
22	36,295	5,698
23	44,090	6,922
26	39,141	6,145
29	101,460	15,929
2017 TOTAL LOSSES (kWh)	797,566	125,218
2018 TOTAL PRODUCTION (kWh)	33,362,114	
% of Lost Production due to SC	2.4%	

was made a study showing how the full energetic potential of the Wind Farm would have been restored using the D-Stiffener™ as solution Results shows the D-Stiffener™ will increase the buckling capacity by 35%.

The lost AEP will be restored as the blades are able to withstand increased loads due to the increased buckling capacity

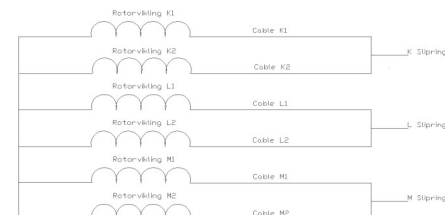
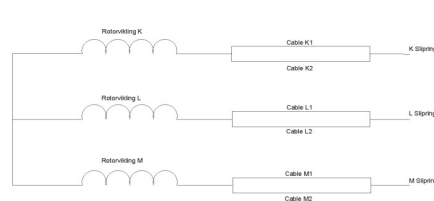


# Generator – Open Discussion



- Special issues ?
- Lead time ?
- Serial defects ?

*Let's discuss together !!*





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