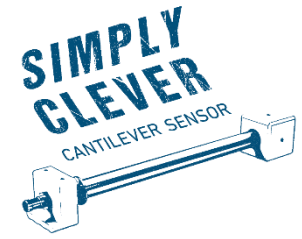


CLS Cantilever Sensor

Wie aus einem Sensor eine gesamte Lösung wird

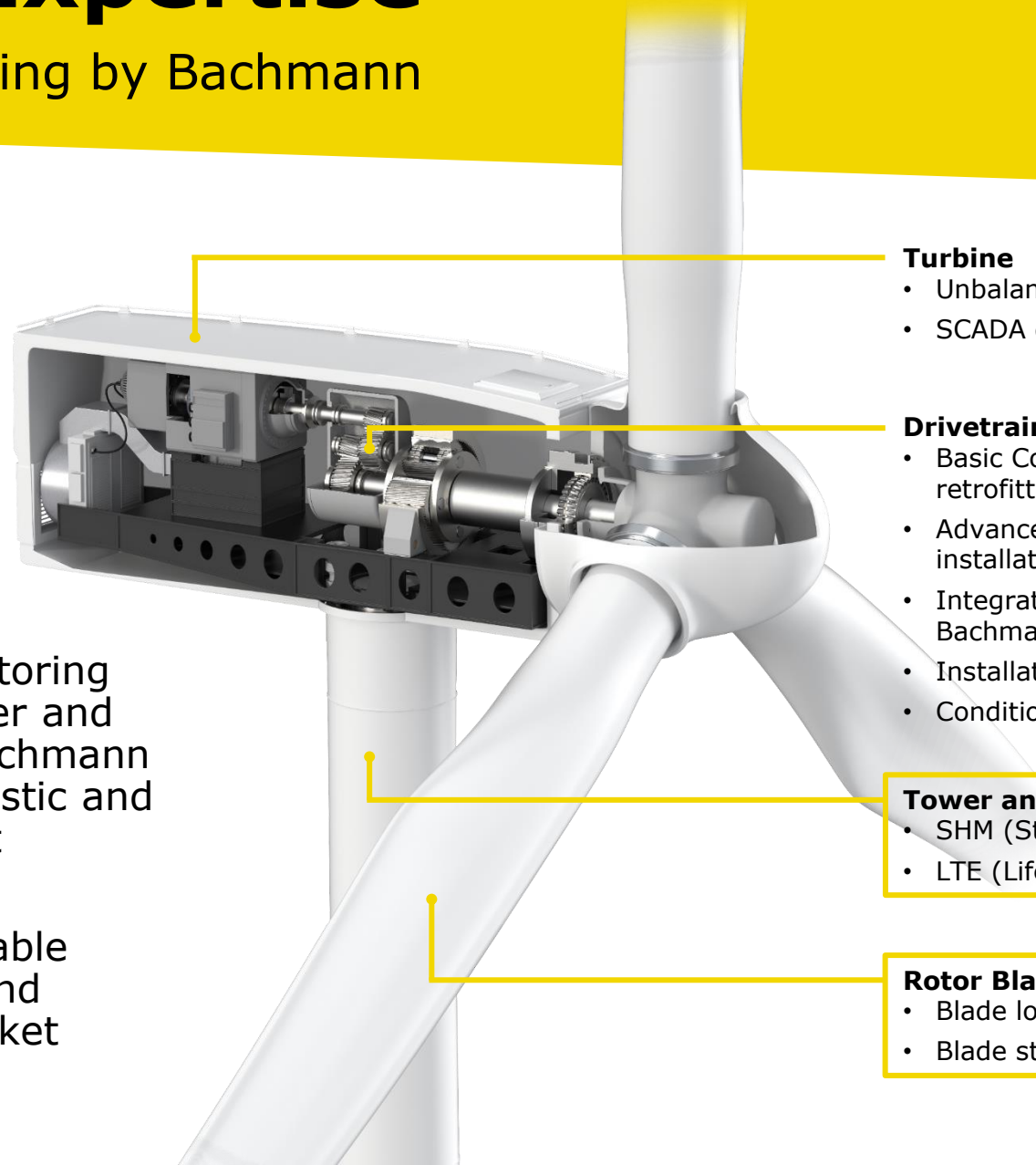


bachmann.

Holistic Expertise

Condition Monitoring by Bachmann

- As a condition monitoring system manufacturer and service provider, Bachmann offers a unique, holistic and coordinated product portfolio.
- There is no comparable range of products and services on the market



Turbine

- Unbalance detection and monitoring
- SCADA data integration and visualization

Drivetrain

- Basic Condition Monitoring for replacement and retrofitting
- Advanced Condition Monitoring for OEM installations
- Integrated Condition Monitoring for turbines with Bachmann controllers
- Installation und remote monitoring service
- Condition Monitoring with 3rd-party CMS

Tower and Substructure

- SHM (Structural Health Monitoring)
- LTE (Life Time Extension)

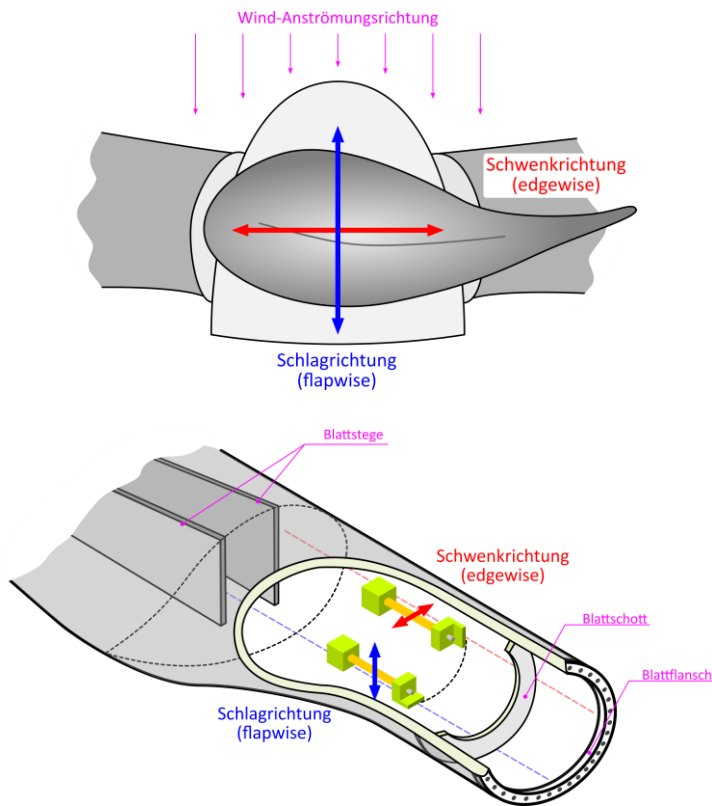
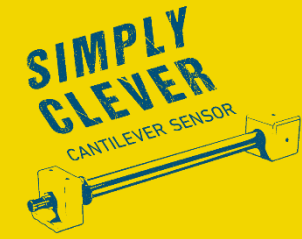
Rotor Blade

- Blade load measurement
- Blade structural monitoring



The Challenges

Blade Load Acquisition & Monitoring



A

LCoE reduction

High-capacity turbines,
strong cost pressure



B

Increasing power output, rotor diameter and blade loads



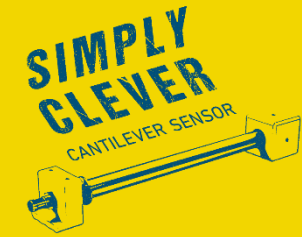
C

Demand for further blade monitoring applications



The Goals

Cantilever Sensor



■ **Simple:**

Conversion of strain- to simple displacement measurement, easy to install – no complicated optical to electrical signal transformation

■ **Robust:**

Long service and operational life with little maintenance necessary due to forceless sensor element

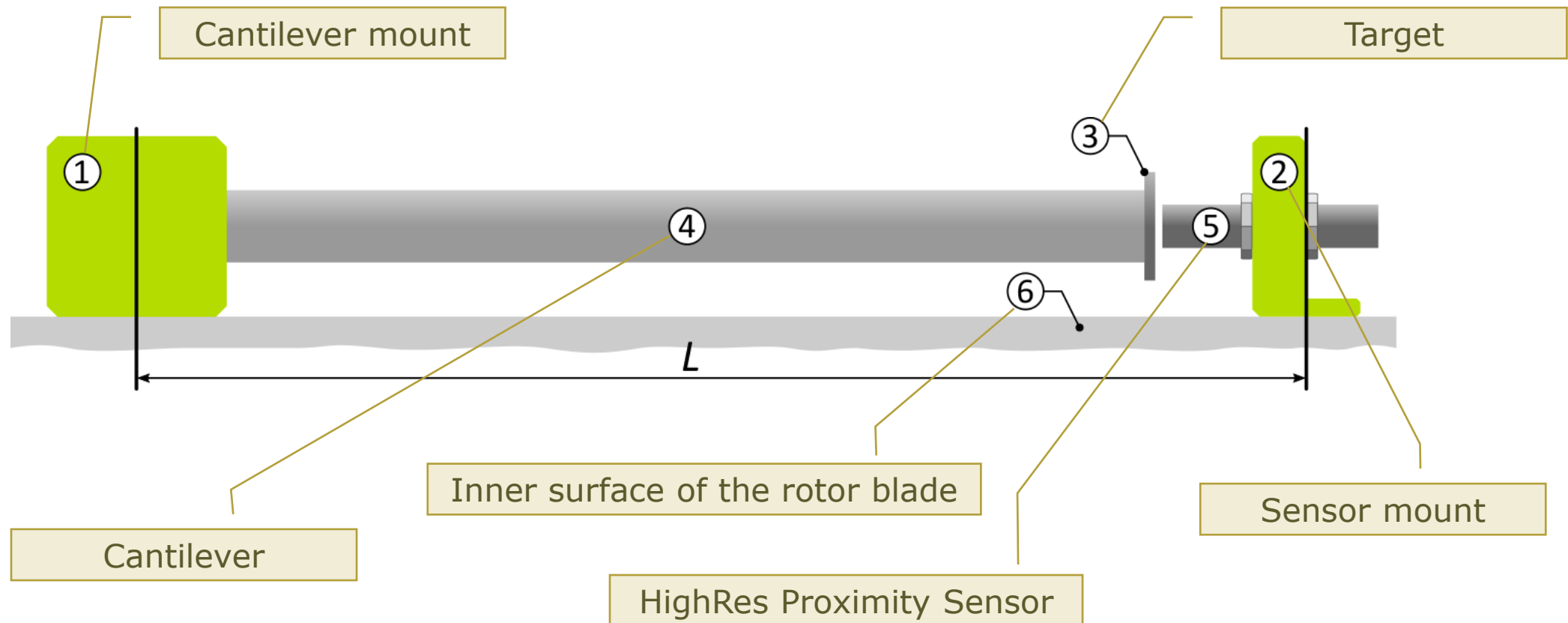
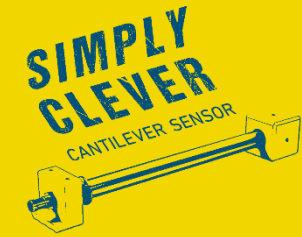
■ **Reliable:**

Extremely accurate and reliable data, industry-prove technology



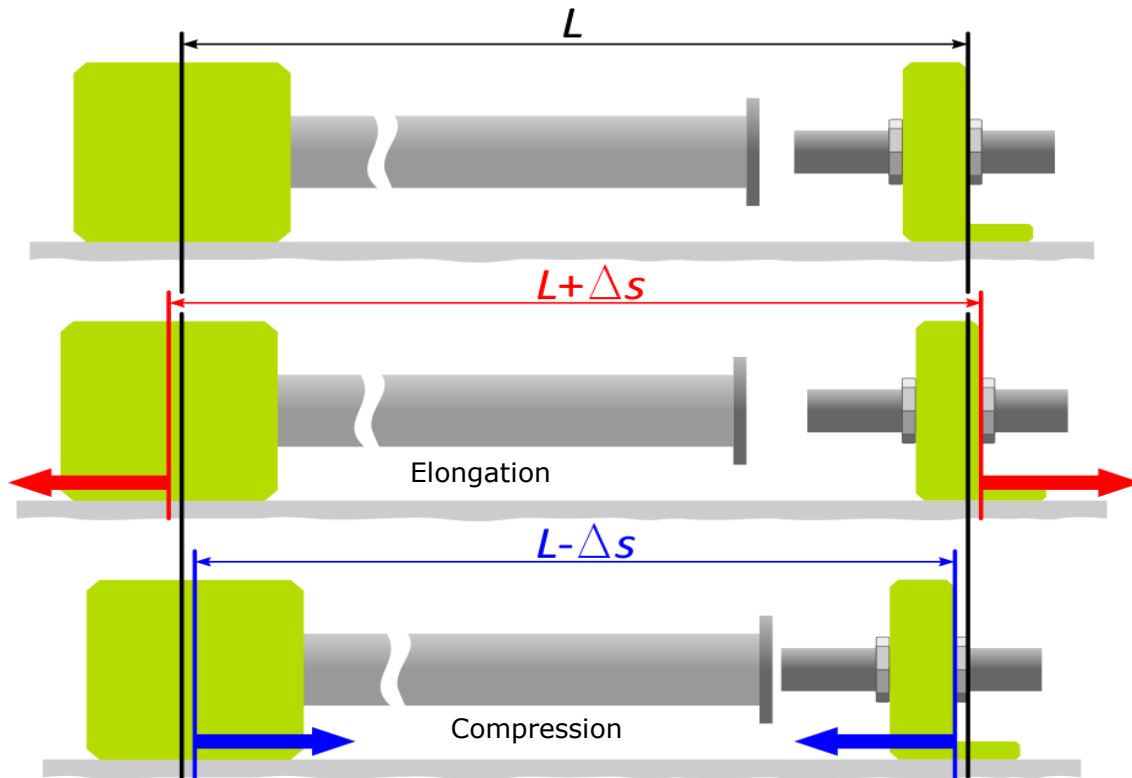
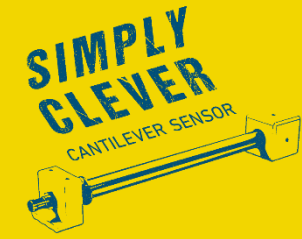
The Principle – What it looks like

Cantilever Sensor



The Principle – How it works

Cantilever Sensor



- Blade loads causing strain or compression of the blade surface increase or decrease the length of the sensor element
- Output signal comparable with an electric strain gauge or fiber-optic strain sensor



The Principle – What makes it different?

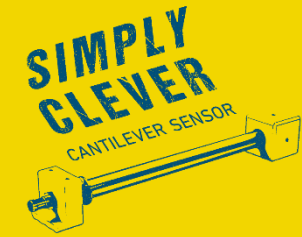
Cantilever Sensor

- Robust design with inductive displacement sensor
- High precision over wide temperature range $-40 \dots +75^{\circ}\text{C}$
- No additional optical/electrical signal transformation due to standard 4-20 mA current signal
- Industry-proven lightning protection
- Simple thermal strain compensation by material match
- Integral and forceless measurement
 - Not subject to any mechanical and chemical aging
 - Very durable over long time
 - Guarantees long-term measurement stability
 - Minimizes the influence of local inconsistencies



The Comparison

Cantilever Sensor



CLS300 vs. optical and electrical strain gauges

A stylized icon of a comparison table with three columns and three rows. The first column contains three horizontal bars. The second and third columns contain 'X' and checkmark symbols respectively, indicating a comparison between different sensor types.

—	X	X	✓
—	X	✓	✓
—	✓	✓	✓

- **Signal quality:** Not affected by adhesive mounting of sensor
- **Lifetime:** Measurement without mechanical contact improves longevity
- **Direct signal:** No need for an optical-electrical converter
- **Easy installation:** Step-by-step instructions for any WTG technician
- **Easy commissioning:** No special measurement devices required

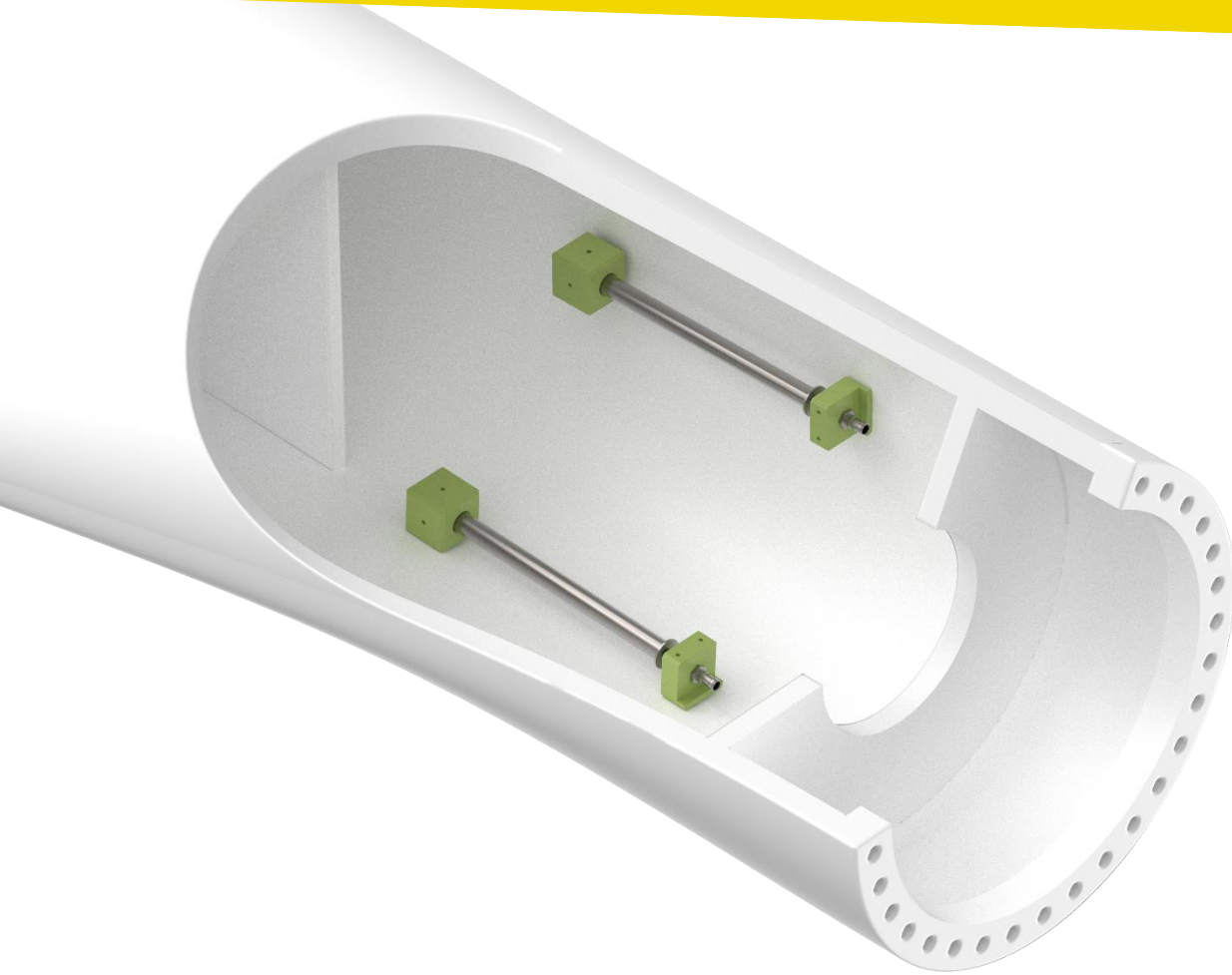
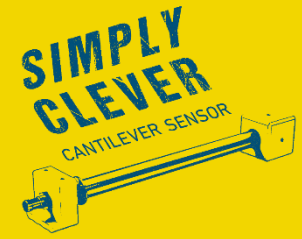
Lower cost for:

- Sensor and data acquisition hardware
- Installation and commissioning
- Replacements and downtime
- Production losses



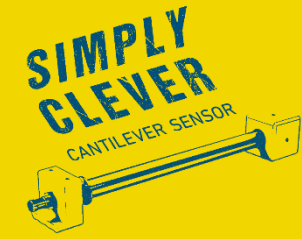
Installation

Cantilever Sensor

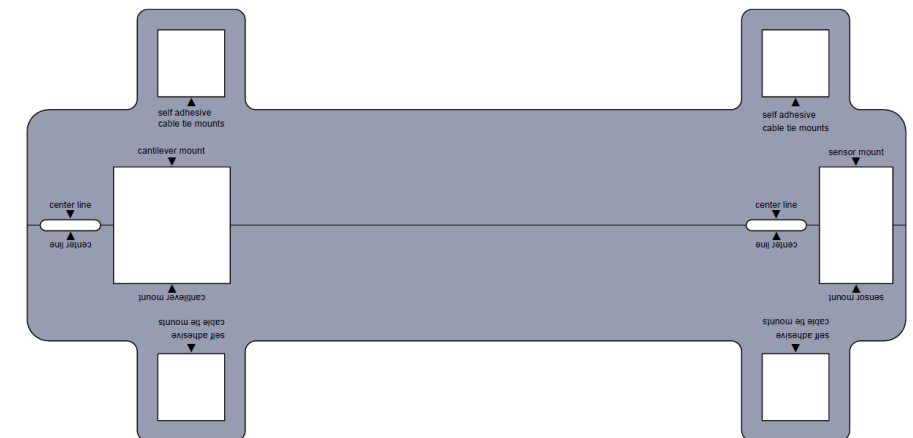


Installation

Direct Installation for Retrofit & Pilot Projects

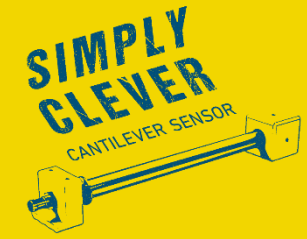


- Simple retrofit installation with pre-aligned sensor assembly
- Clear and simple step-by-step instructions including mounting template and smart installation fixture
- WTG Service technicians do not require special training or certification
- Ease of installation means reduction of installation and commissioning costs
- Reduced downtimes due to immediate WTG restart after installation



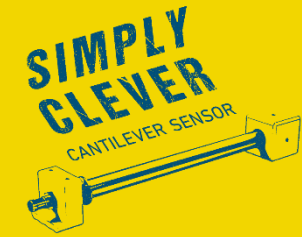
Installation

Direct Installation for Retrofit & Pilot Projects



Installation

2-Stage Installation for OEM Process Integration

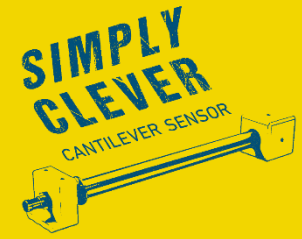


- Separate installation of pre-aligned sensor attachment points and cantilever sensor
- Easy integration into the blade production process reduces error rates
- Easy field installation after turbine erection
- Streamlined commissioning without any specialized measurement equipment



The Installation

2-Stage Installation for OEM Process Integration



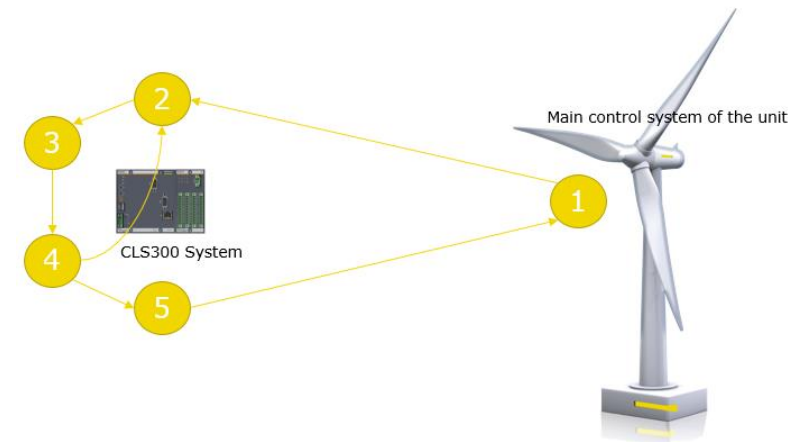
Smart Rotor Load System

Complete Solution for Blade Load Calculation including Auto Calibration

Data acquisition – auto-calibration – signal processing

- Cantilever sensors for blade load measurements
- CLS controller inside the hub (M200 components)
- CLS controller application for...
 - CLS raw signal acquisition
 - **Automated calibration procedure** for correction of sensor alignment and scaling of signals for calculation of calibration parameters (CANopen communication between WTG controller and CLS controller – trigger signals, operational parameters, status information)
 - **Parameter verification**
 - **Sensor/system verification**
 - Conversion of strain signals from CLS into bending moments in edge and flap direction
 - Continuous provision of blade bending moments and CLS controller status during WTG operation (CANopen)
 - Possibility of integrated solution for turbines with Bachmann hub control

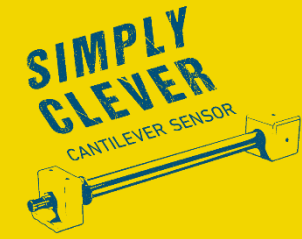
Automated Calibration Procedure



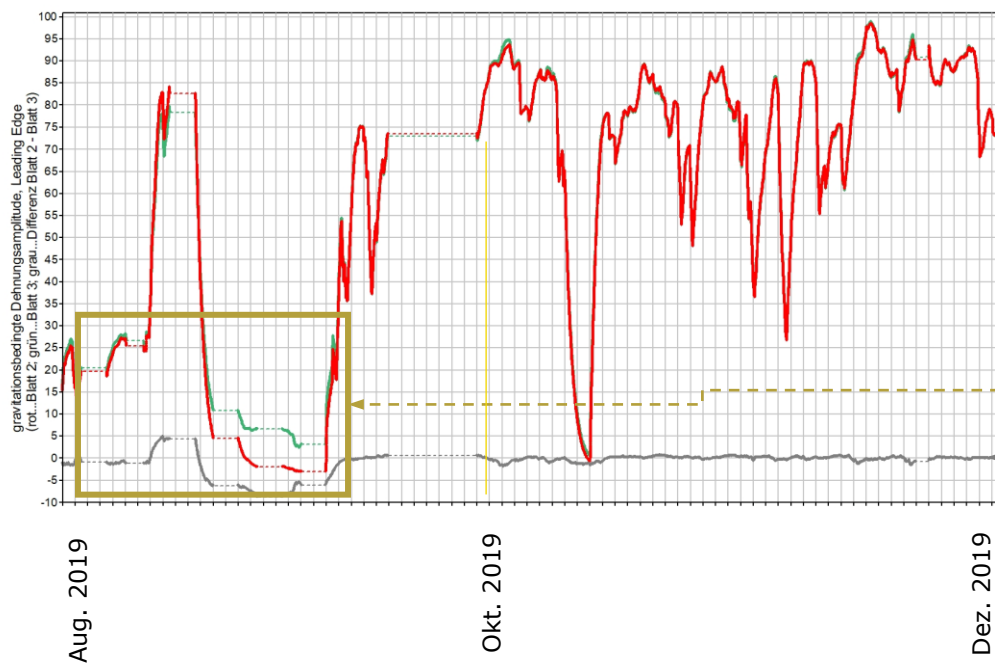
1. Main control system sends calibration command
2. CLS300 system records data
3. CLS300 system calculates parameters
4. CLS300 system verifies parameters
5. CLS300 system sets parameters and sends calibrated bending moment in operation mode to main control system

Structure Monitoring of Rotor Blades

Anomaly Detection based on Blade Loads



Example: Repair of leading-edge delamination of one blade alternating with operating slots

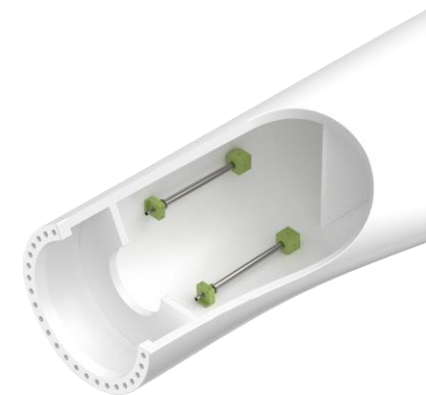


Trend of edgewise amplitude spans

Vergleich geschädigtes
● Blatt 2 mit
● Blatt 3

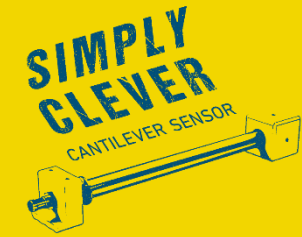
Zeitraum verschiedener Reparaturkampagnen

gebildete Differenz der Blattamplituden



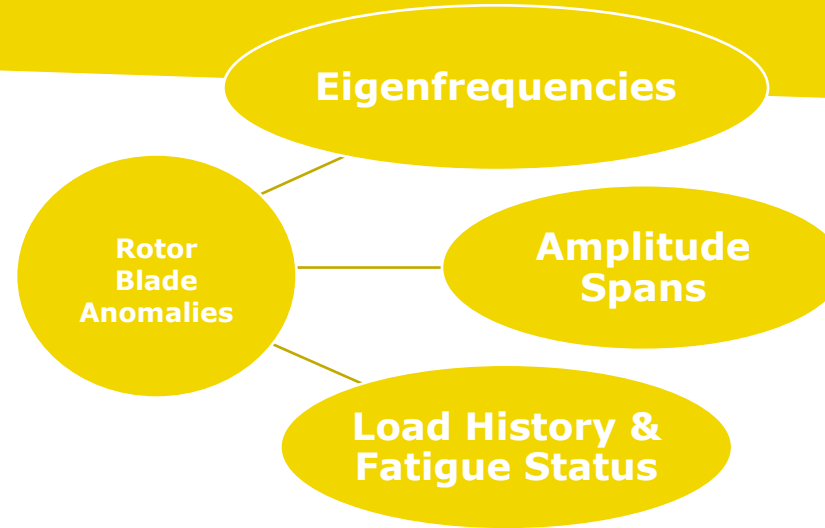
Structure Monitoring of Rotor Blades

From Anomaly to Damage Detection



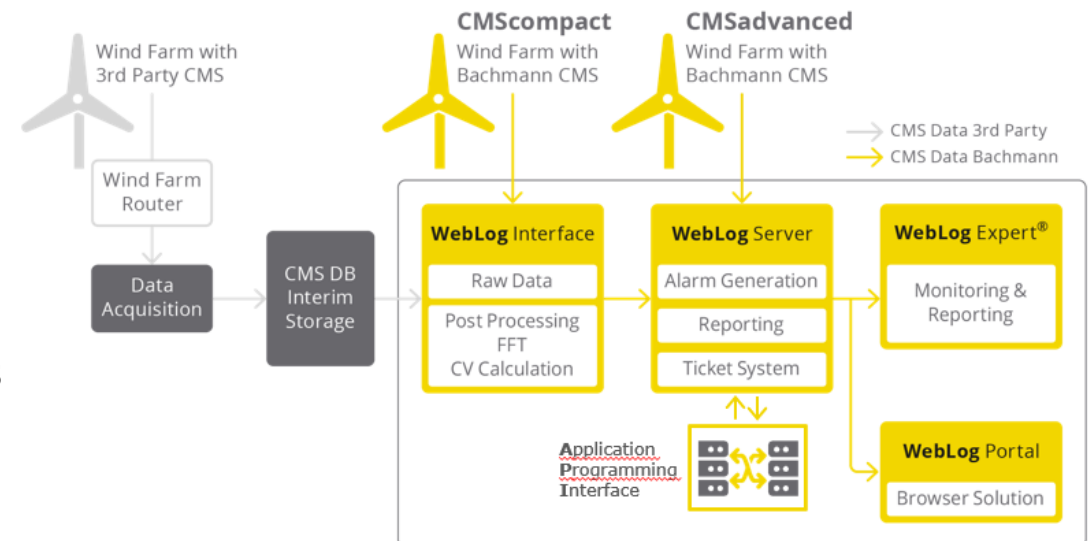
Use of established SHM toolbox

- Damage-sensitive indicators
- Eigenfrequencies
- Amplitude span indicators
- Load history & fatigue status



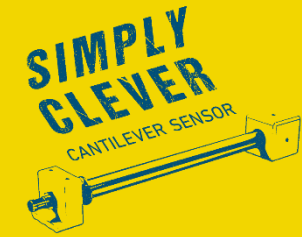
Outlook on damage detection

- International research activities and industry cooperation
- Test rig cooperation with blade & WTG OEMs & universities
- Transfer of knowledge from aviation to wind (e.g. Operation Modal Analysis) + extended algorithms
- Flexible WebLog API for future algorithms

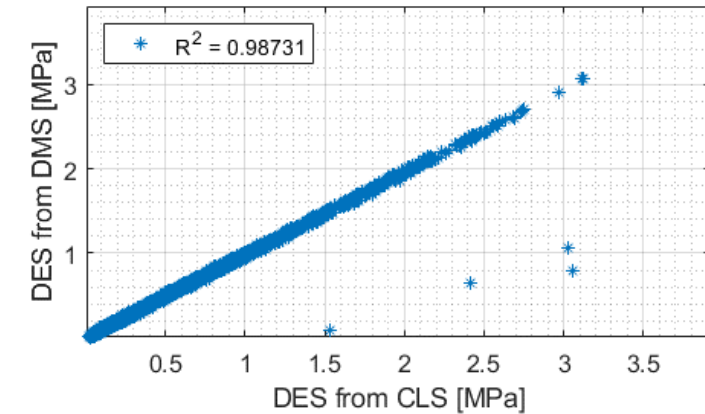
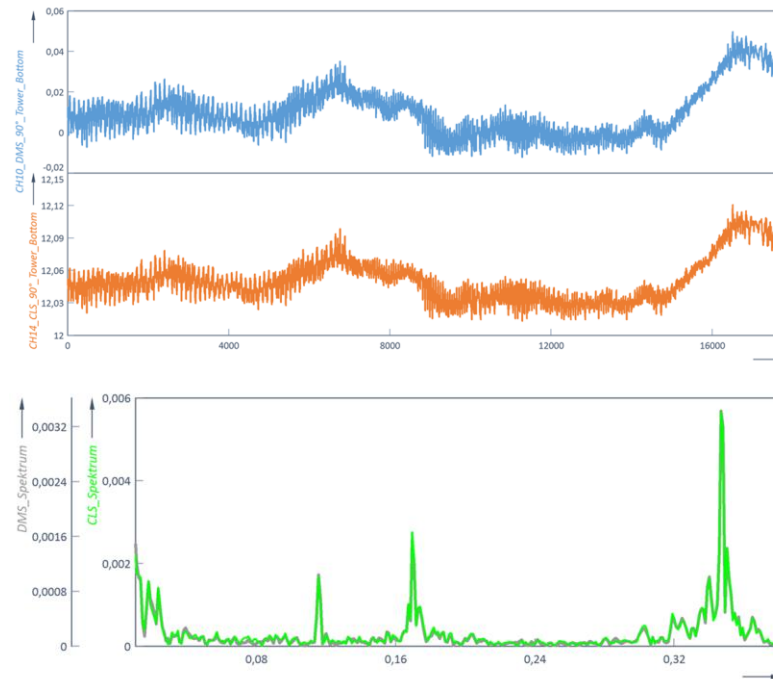


SHM of WTG Towers

CLS: Comparison with Strain gauge (DMS) showed very good agreement



Installation at tower bottom of a Vestas V126-3.3MW



*DES = Damage Equivalent Stress (Fatigue Load)

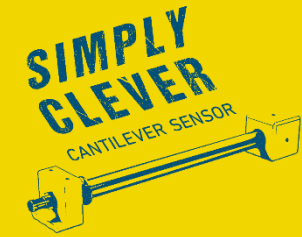
Suitable for SHM fatigue load monitoring

CLS compared to standard strain gauges:

- Increased long-term stability
- Minimizes the influence of local inhomogeneities
- Easier installation
- Corrosion protection stays intact

Optimized Lifetime Extension

CLS Data to support LiTE^{plus}

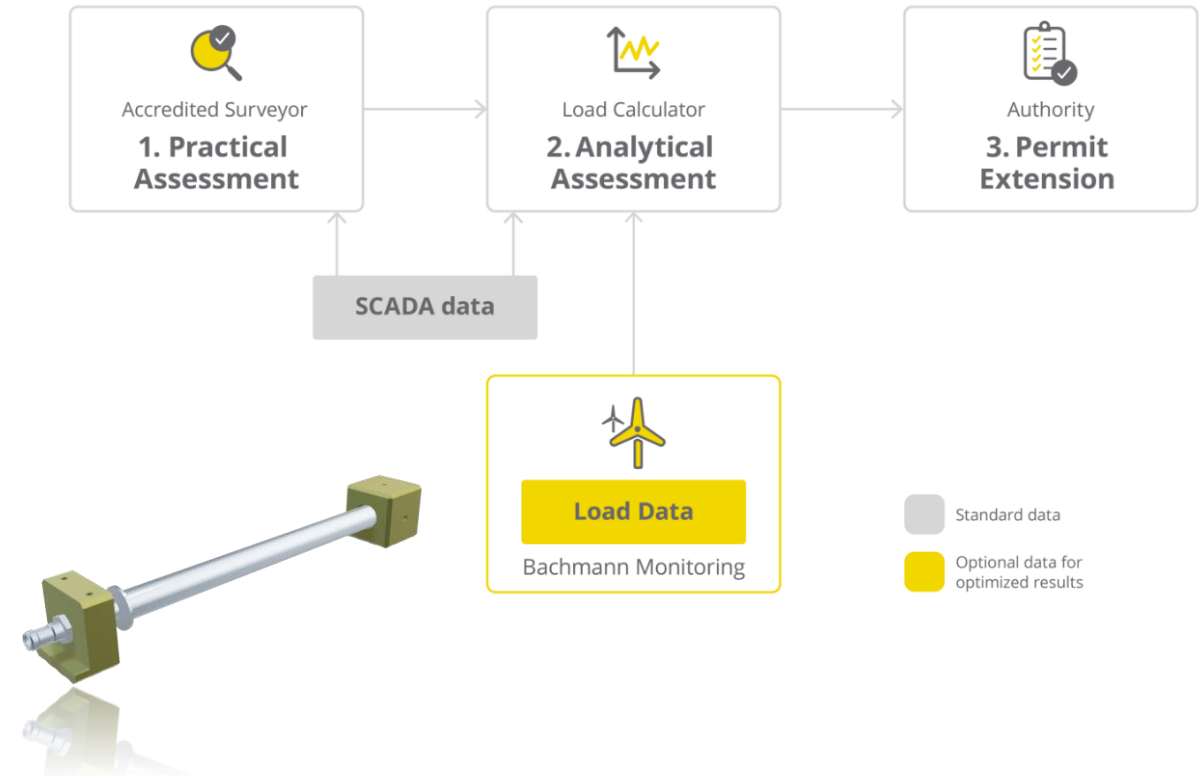


Load measurement data to support analytical LTE assessment

- Eigenfrequencies of the tower and foundation structure
- Fatigue loads of tower and foundation structure

- LiTE^{plus} helps increasing the calculated remaining useful lifetime
- **Smart measurement system to save costs**
- Combination of measurement and simulation to transfer results to farm situations and other components
- Increased safety due to monitored operation within LTE period

Application of SHM for lifetime extension assessment



Single sensor – variety of use cases

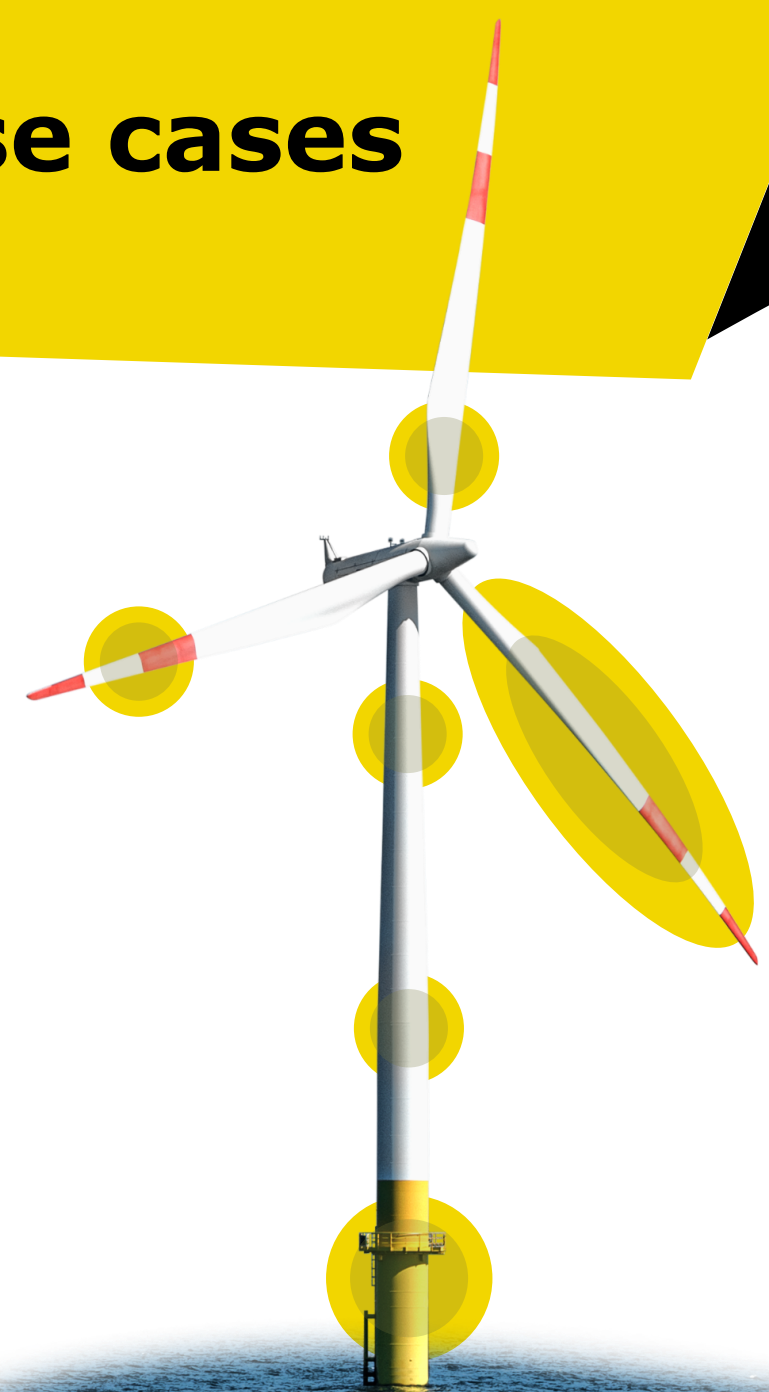
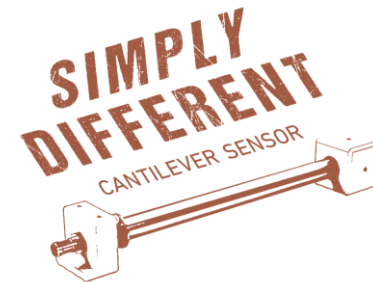
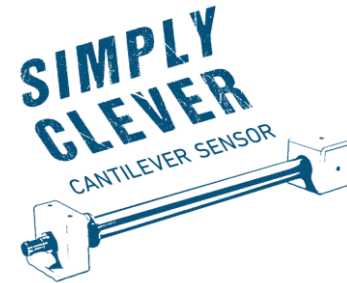
Cantilever Sensor

Blade

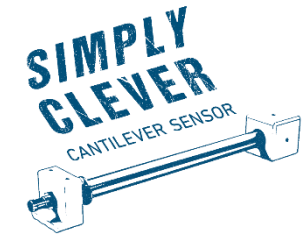
- Load measurement in WTG rotor blades
- Input for IPC and/or max. load control
- Detection of structural abnormalities
- Input for load history processing
- Synergy effects through combined applications

Tower

- Load measurement in WTG towers & sub structures (SHM)
- Detection of structural abnormalities
- Lifetime extension optimization LiTE^{plus}



We look forward to a dialogue



Questions

?



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