LEINE LINDE SYSTEMS

EMS
ELONGATION
MEASUREMENT SYSTEM

robust · reliable · fatigue-proof

STRAIN MEASUREMENT

for Wind Turbines

LEINE LINDE SYSTEMS GmbH

Hamburg

- Business Unit within HEIDENHAIN-Group of Companies
- Focussing on Wind & Renewable Energy
- Sales and Development of Products & Systems

LEINE LINDE SYSTEMS

Strain measurement in wind turbines

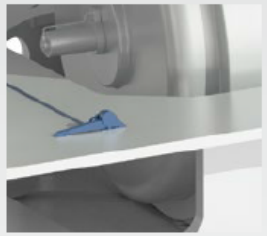
Critical sections for strain sensors

1 Rotor blade

Rotor blades are the point of origin for generating the power and major system loads in a wind turbine. Special sensors in the rotor blades, particularly those located in the root position of each blade, are used to measure these individual loads. The data collected by these sensors can be used for additional condition monitoring, as validation between calculated and precise measurement data and for implementing new control concepts. For more efficiency and yield.

2 Machine frame

The machine frame holds the main components (e.g. generator, gearbox) inside the wind turbine and serves as the link between rotor and tower. Wind turbine operation causes dynamic interactions among the individual components, which in turn subjects the machine frame to many complex loads. Sensor solutions used for this purpose are designed to measure the relative movement of the components in relation to each other as well as indicators for component wear and tear. The knowledge gained from these data enables adaptive WT control for load optimization. Costly downtimes can be reduced to a minimum.



3 Tower and foundation

The trend toward larger rotor diameters and higher hub heights also cause an increase of the load on the tower and foundation of wind turbines. At the same time, these components are major cost factors and represent an ever growing logistical challenge. A sensor-based, optimized WT control system can significantly reduce the loads in a wind turbine. This results in a noticeable reduction in component size and material cost.

LEINE LINDE SYSTEMS

Strain measurement in wind turbines

APPLICATIONS

Calculation of Loads

- Research & Development
- Validation & Certification

Measurements of Turbine Dynamics

- Mode of operation
- Resonance
- Condition monitoring

Turbine Control Integration

- Extended monitoring
- New control strategies

REQUIREMENTS

Robust against

- Temperature & Humidity
- Lightning strike
- Dirt

Reliability

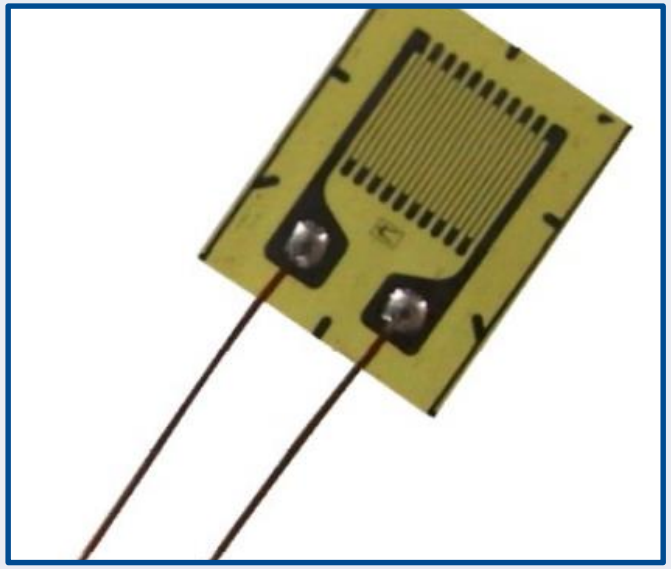
- Long lifetime
- Failure detection

Installation

- Easy installation
- Easy exchange
- Easy retrofit

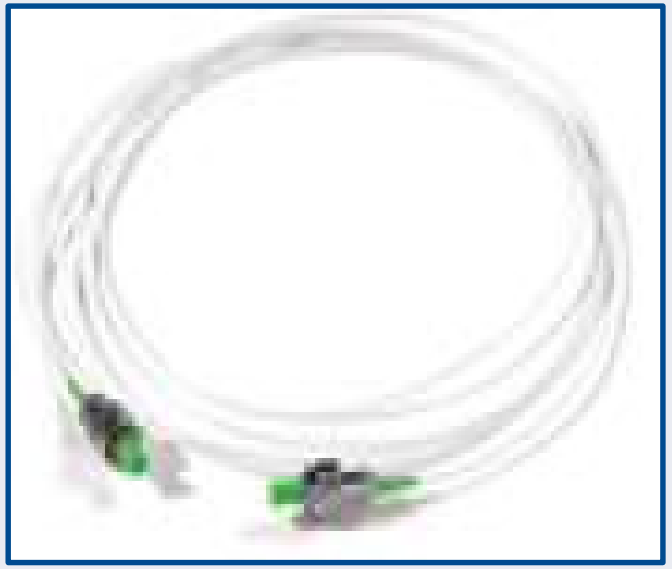
State of the strain sensor art

Electrical sensor



Strain gauge

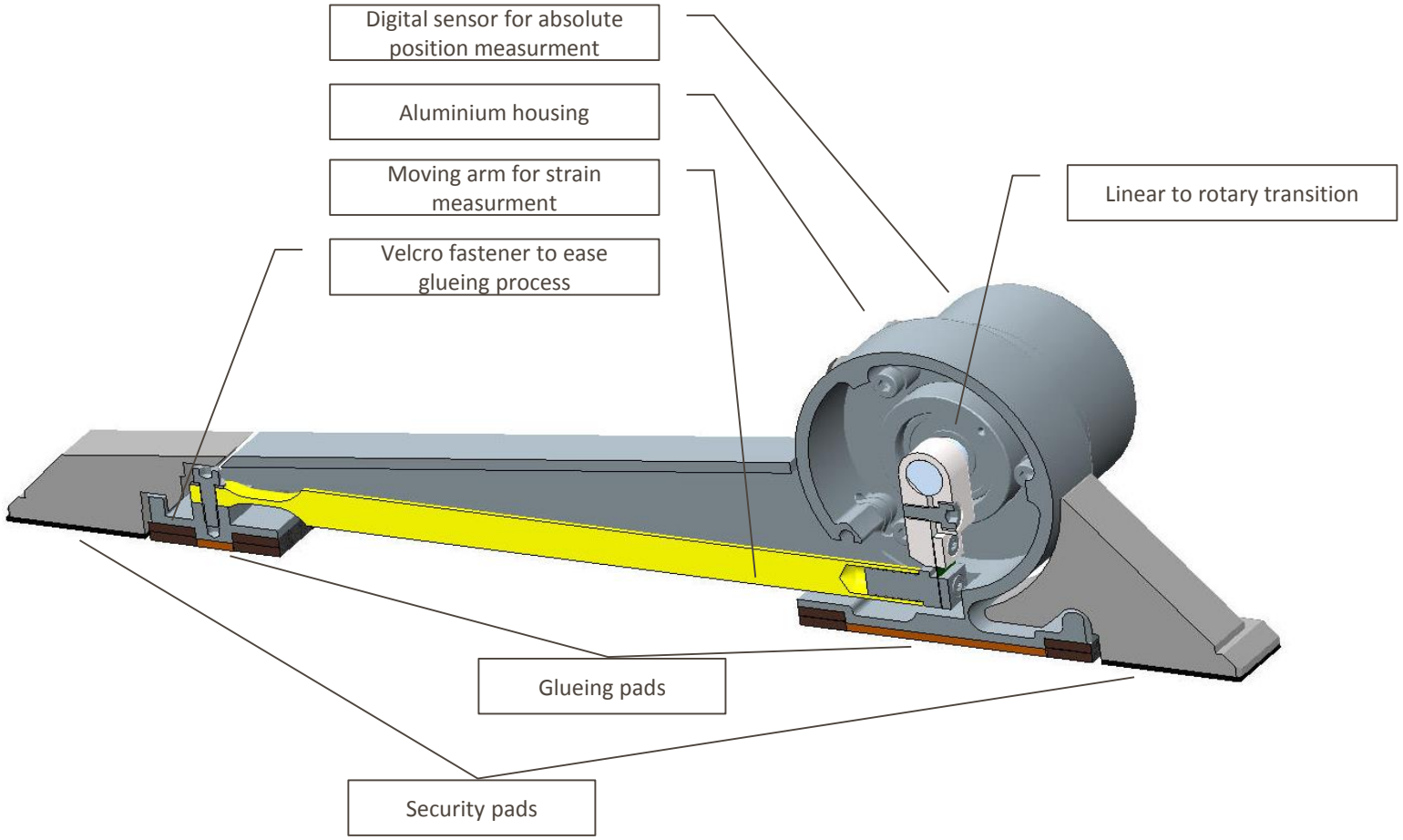
Optical sensor



Fiber Bragg

ESR x25 Series

Main components



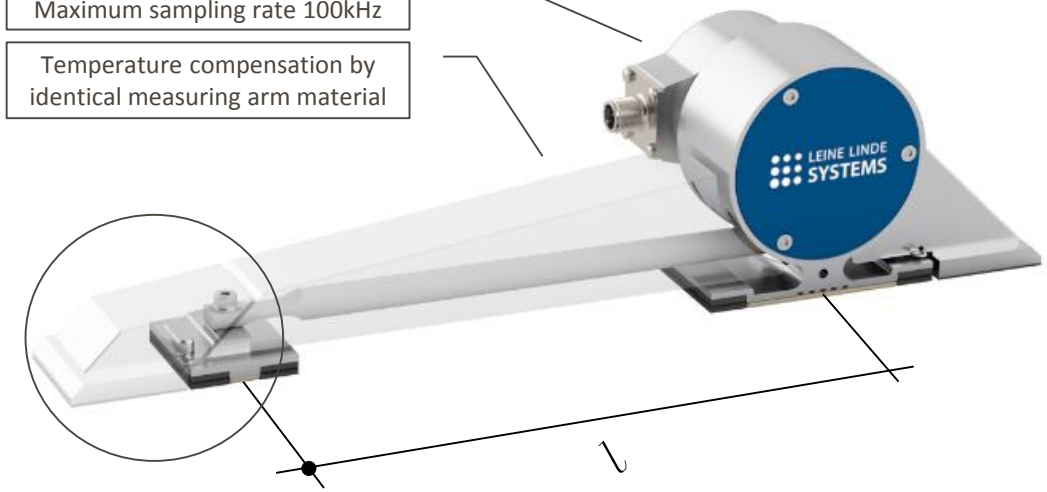
Stressless measurement of strain between two points
Passive compensation of temperature effects

ESR x25 Series

Measurement principle

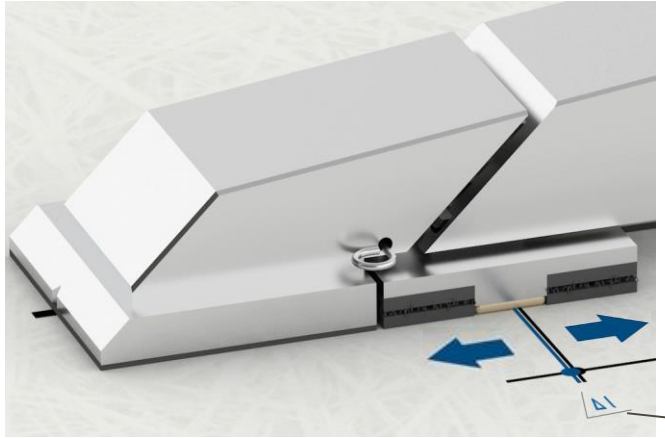
25bit rotary encoder
Maximum sampling rate 100kHz

Temperature compensation by identical measuring arm material



Basic function:
Measuring the change in length between two points along the „length l“

The change in „length l“ between two fixed points is transmitted to the measuring electronics via a measuring arm



Maximum deflection of +/- 5000 με
Resolution of the strain sensor 0.025 με

calculation of dynamic structural characteristics by scanning Δl

LEINE LINDE SYSTEMS

ESR x25 Series

Strain sensor with integrated electronics

High precision

- 25bit single turn encoder
- Resolution (Strain):
  0.025 με (200mm measureing length => 5nm)
- Measurement range:
  ± 5000 με (200mm measureing length => 1mm)
- Temperature compensation by adapted measurement arm

Reliability

- Sensor based on proven encoder technology and high-volume production
- Protection Class
  IP64
- Lightning protection acc. IEC61400-24
- Stressless and fatigue-proof measurement

Integrated diagnostics

- Temperature check
- Sensor range reserve
- Plausibility checks
- Electronical name plate
- OEM memory area

ESR 125

Installation – adhesive version

Ready for use in 30-45min
(incl. preparation of test point, installation, hardening)

ESR 125

Recommended 2-component adhesive

PLEXUS	MA 300	MA 310
Working time (at 23°C)	3 to 6 minutes	15 to 18 minutes
Fixture time (at 23°C)	12 to 15 minutes	45 to 55 minutes
Recommended temperature during application	+18°C…+30°C	+18°C…+30°C
Temperatures below 65°F (18°C) or above 85°F (30°C) will slow down or increase cure rate.		

ESR x25 Series

Sensor variants

- **Adhesive installation**
- **Material**
  - *GFRP*
  - *CFRP*
  - *Austenitic steel*

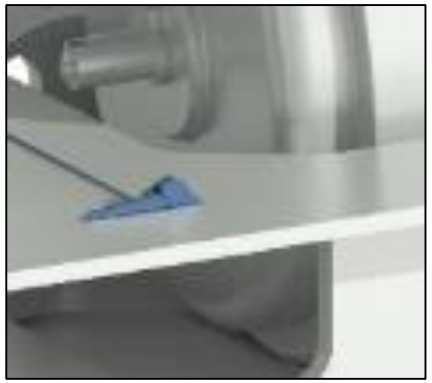
- **Adhesive adapater plate with threaded holes**
- **Material**
  - *GFRP*
  - *CFRP*
  - *Austenitic steel*

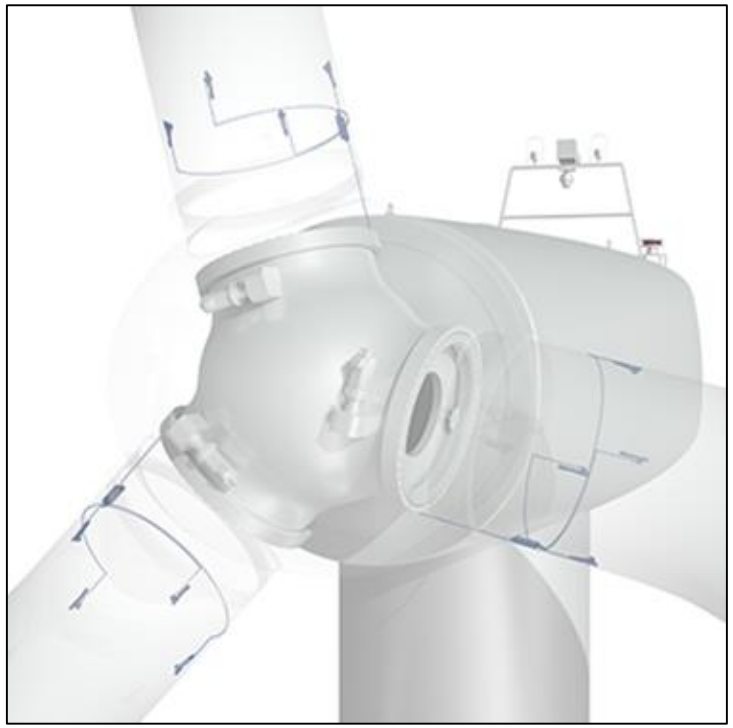
- **Screw-on version**
- **Material**
  - *GFRP*
  - *CFRP*
  - *Austenitic steel*

Application examples

Strain measurement on WTG-components during operation

Rotor blade	Main frame	Tower
• Root section • Middle section	• Generator support • Torque arms	• Top • Bottom



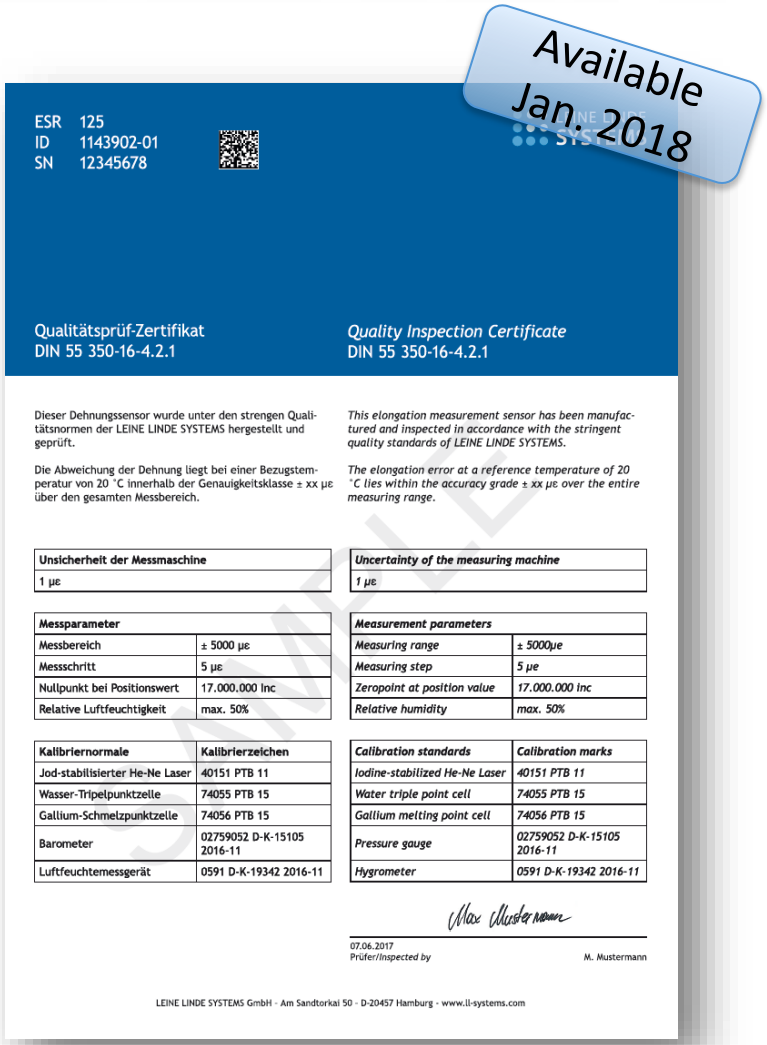


LEINE LINDE SYSTEMS

ESR x25 Series

Measurement reports and certificates

- Each ESR sensor is tested for proper functioning and measured for precision during manufacturing process
- Based on article and serial number a quality inspection certificate is supplied with each sensor
- Optional: On demand a DAkkS calibration according to DIN EN ISO/IEC 17025 can be performed



Available Jan. 2018

ESR 125
ID 1143902-01
SN 12345678

Qualitätsprüf-Zertifikat
DIN 55 350-16-4.2.1

Quality Inspection Certificate
DIN 55 350-16-4.2.1

Dieser Dehnungssensor wurde unter den strengen Qualitätsnormen der LEINE LINDE SYSTEMS hergestellt und geprüft.

Die Abweichung der Dehnung liegt bei einer Bezugstemperatur von 20 °C innerhalb der Genauigkeitsklasse ± xx µε über den gesamten Messbereich.

This elongation measurement sensor has been manufactured and inspected in accordance with the stringent quality standards of LEINE LINDE SYSTEMS.

The elongation error at a reference temperature of 20 °C lies within the accuracy grade ± xx µε over the entire measuring range.

Unsicherheit der Messmaschine	*Uncertainty of the measuring machine*
1 µε	*1 µε*

Messparameter		*Measurement parameters*	
Messbereich	± 5000 µε	*Measuring range*	*± 5000µε*
Messschritt	5 µε	*Measuring step*	*5 µε*
Nullpunkt bei Positionswert	17.000.000 inc	*Zeropoint at position value*	*17.000.000 inc*
Relative Luftfeuchtigkeit	max. 50%	*Relative humidity*	*max. 50%*

Kalibriernormale	Kalibrierzeichen	*Calibration standards*	*Calibration marks*
Jod-stabilisierter He-Ne Laser	40151 PTB 11	*Iodine-stabilized He-Ne Laser*	*40151 PTB 11*
Wasser-Tripelpunktzelle	74055 PTB 15	*Water triple point cell*	*74055 PTB 15*
Gallium-Schmelzpunktzelle	74056 PTB 15	*Gallium melting point cell*	*74056 PTB 15*
Barometer	02759052 D-K-15105 2016-11	*Pressure gauge*	*02759052 D-K-15105 2016-11*
Luftfeuchtemessgerät	0591 D-K-19342 2016-11	*Hygrometer*	*0591 D-K-19342 2016-11*

07.06.2017
Prüfer/*Inspected by* M. Mustermann

LEINE LINDE SYSTEMS GmbH · Am Sandtorkai 50 · D-20457 Hamburg · www.ll-systems.com

EMS system tests

COMPARISON:

- Numerous comparative measurement to electrical strain gauges

ENVIRONMENTAL:

- Climatic chamber tests for evalution of the sensor adhesive connection

ACCURACY:

- Several measurements to check sensor accuracy and repeatability

LIGHTNING:

- System immunity test due to lightning currenty according to IEC 61400-24

LAB TESTS

- Measurement during rotor blade fatigue tests (>50 m)

FIELD TESTS

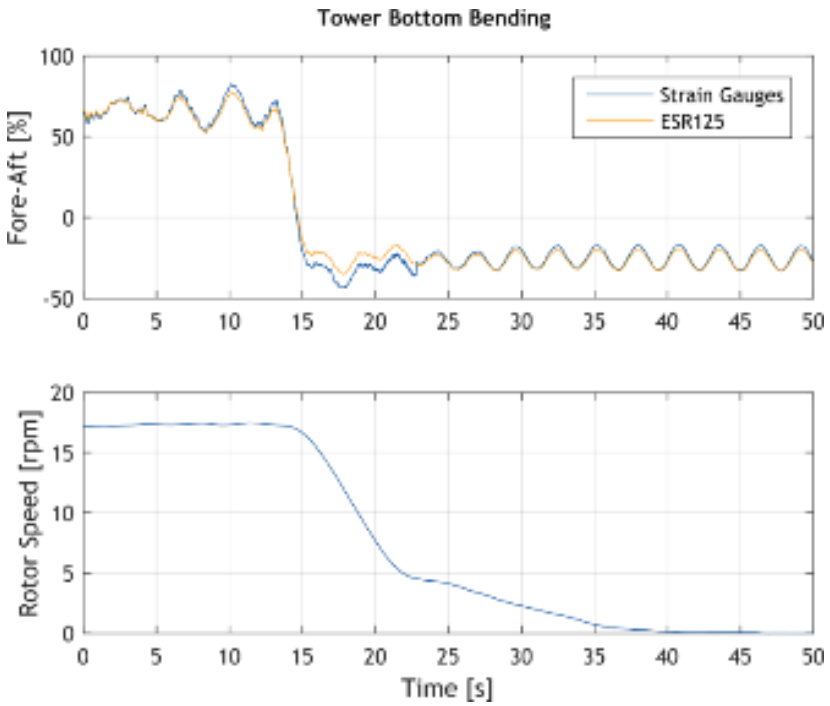
- Various measurement campaigns on wind turbines in rotor blades and towers

Field test

Measurement in tower bottom of a turbine

Comparison to strain gauge signals

- Good match between strain gauge and ESR
- No offset-drift at high deformation levels
- Better signal-to-noise ratio through larger measuring distance

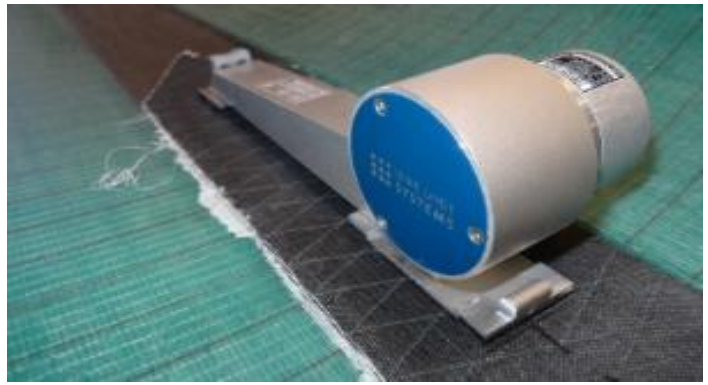


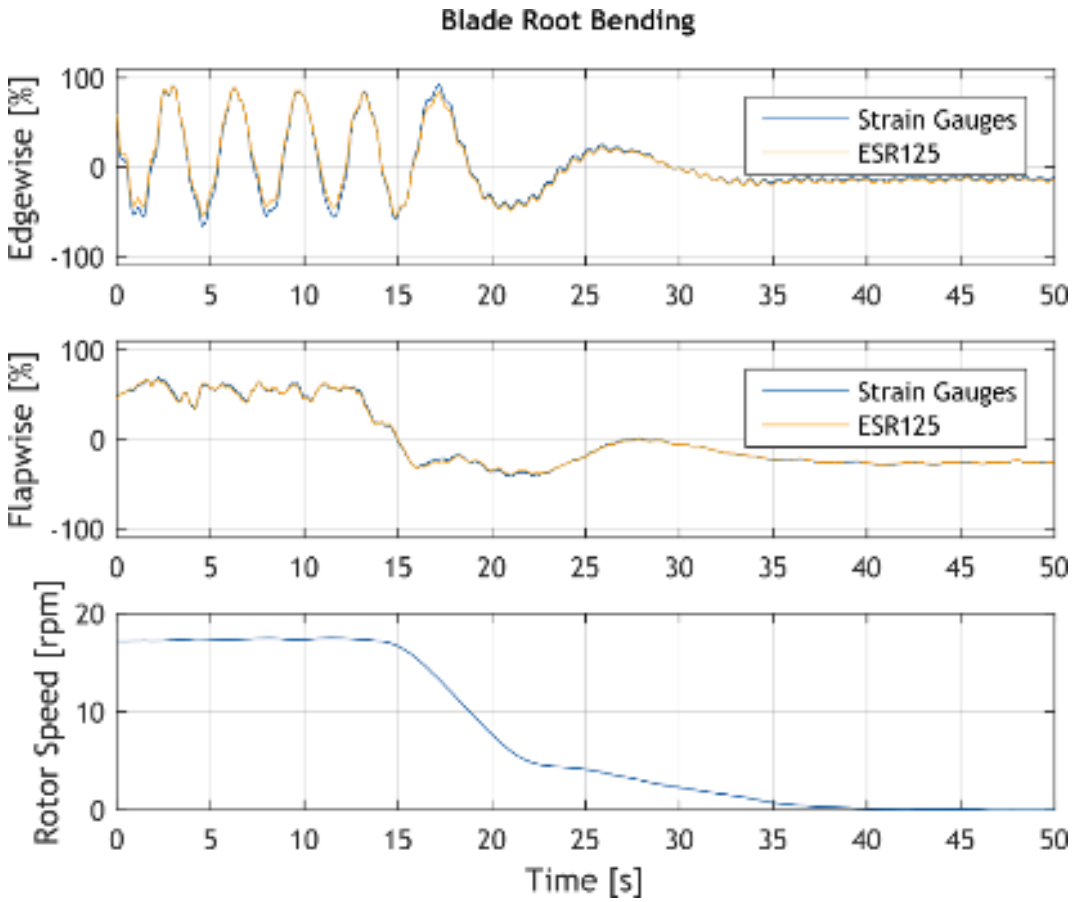
Field test

Measurement in blade root of a turbine

Comparison to strain gauge signals

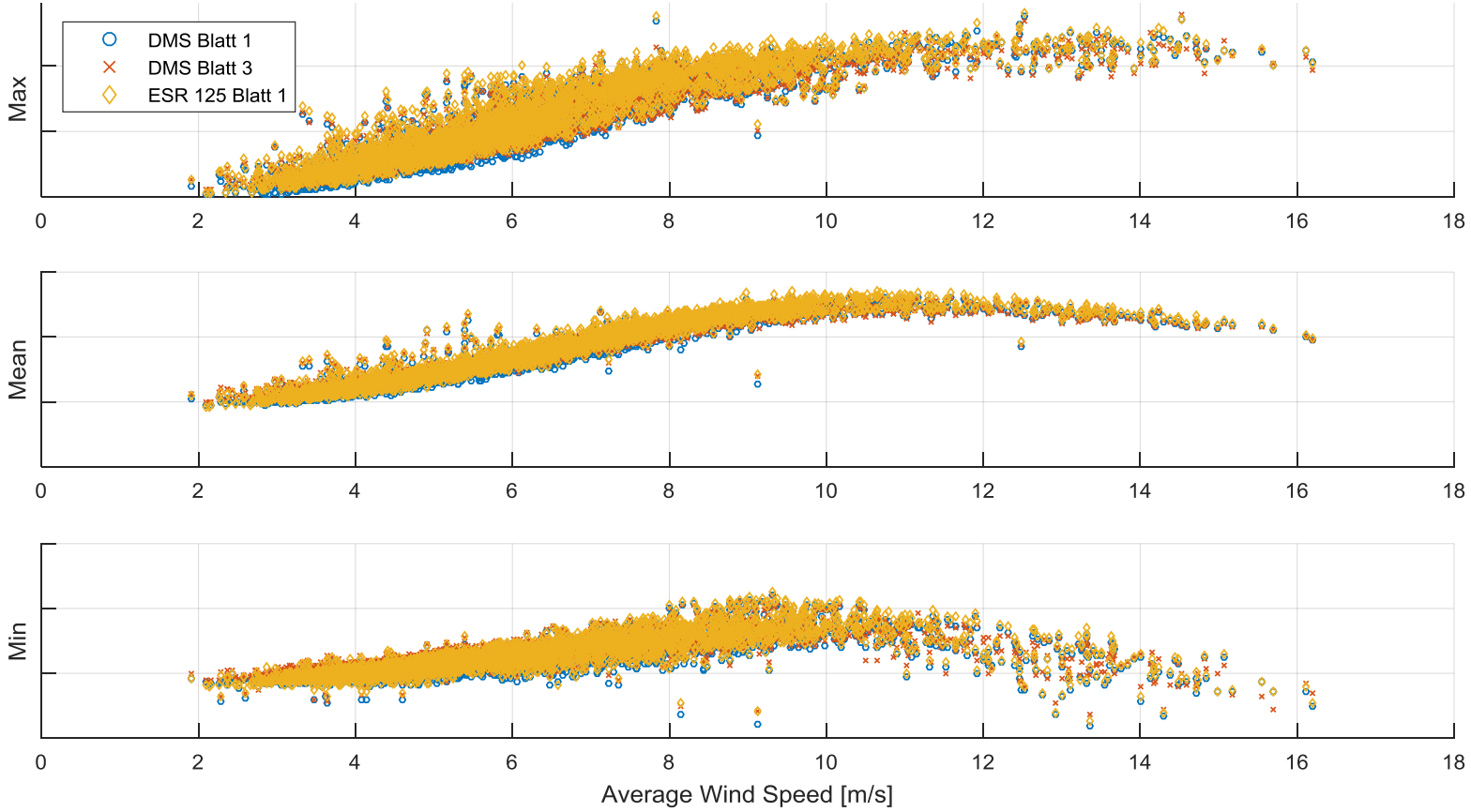
- Good match between strain gauge and ESR
- Better signal-to-noise ratio through larger measuring distance





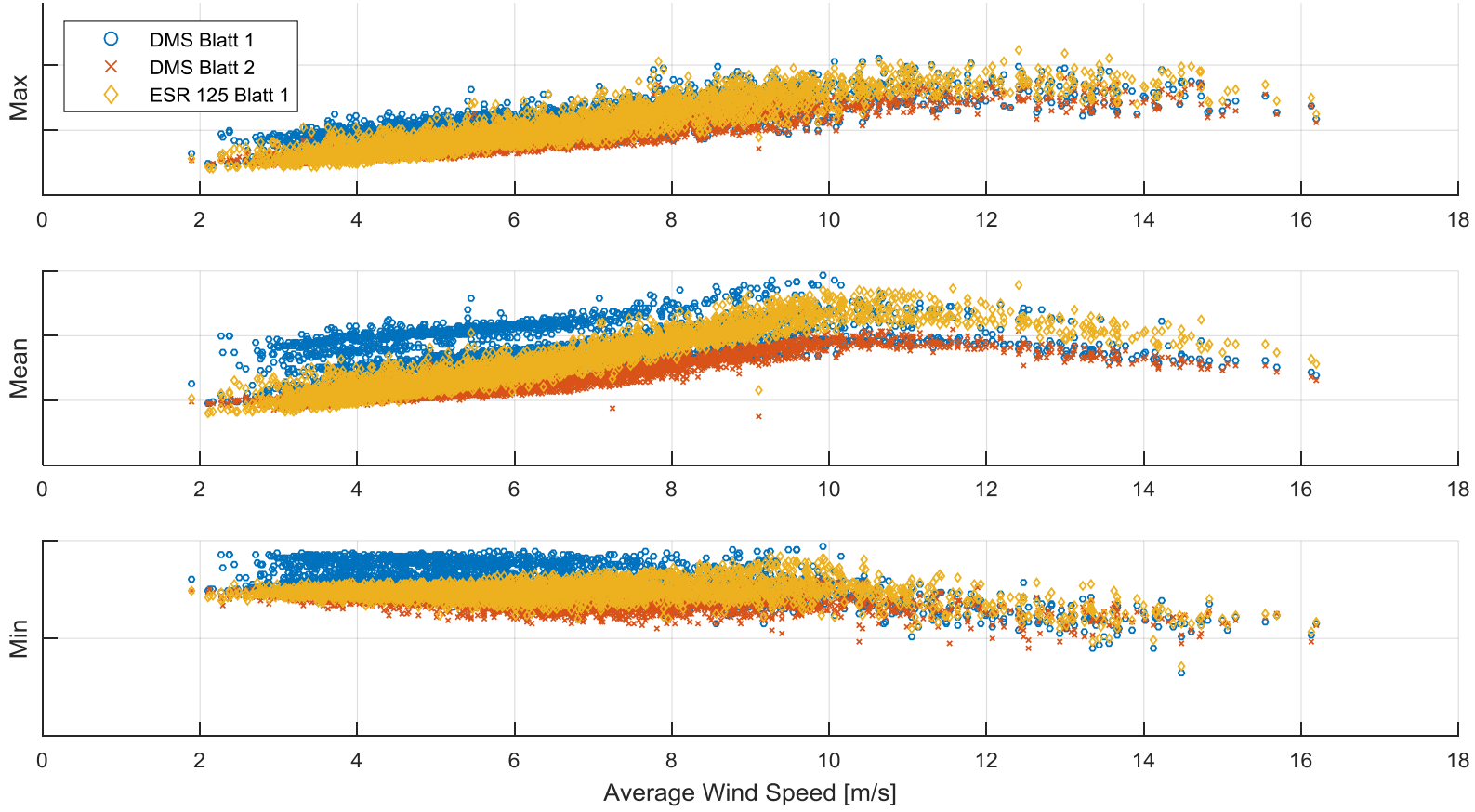
Field test

Rotor blade flapwise bending moments



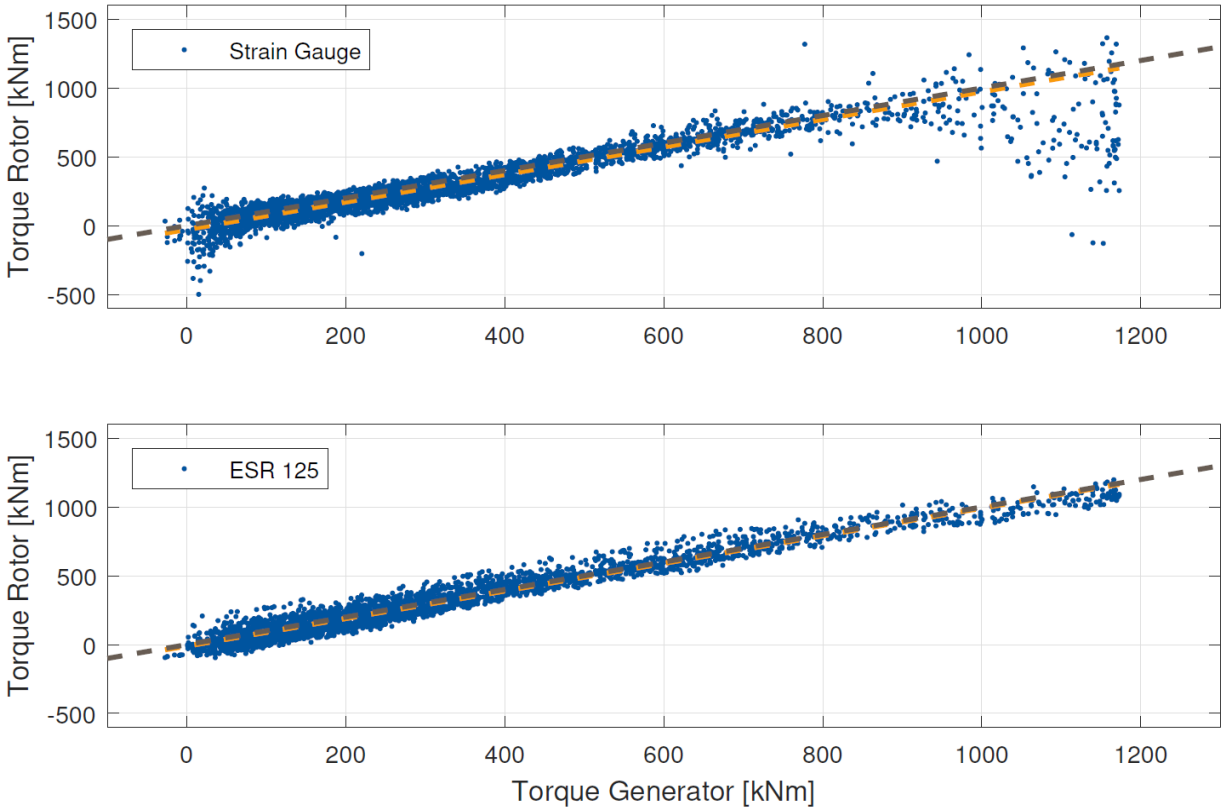
Field test

Rotor blade edgewise bending moments



Field test

Rotor torque versus generator torque



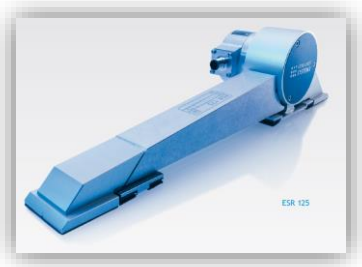
Field test

RESULTS

- Good match with strain gauge
- Higher reliability compared with strain gauges (several strain gauges failed during the test)
- No offset drift of the ESR
- Constant accuracy at high rotor speed (in comparison to the strain gauges)

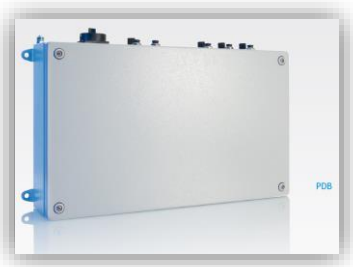
EMS

Overview of available components and systems

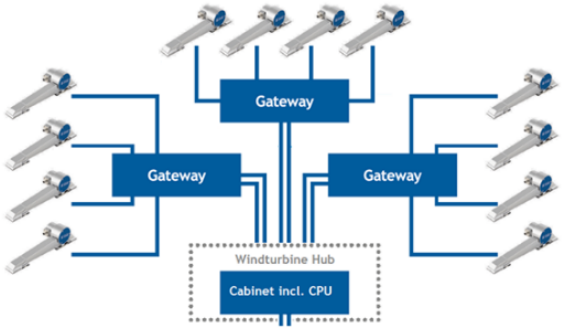


Strain sensor

Fieldbus gateway



Data processing unit



Fieldbus-Gateways

Variants

Technical data	VRG 4:1	CRG 1:1
Power supply	24 VDC	24 VDC
Current consumption (max.)	500 mA @ 24VDC	100 mA @ 24VDC
Protection class	IP 65	IP 65
Operating temperature	-25°C...+50°C	-40 °C...+60 °C
Sensor connection	8pM12	12pM23
Fieldbus connection	5pM12	5pM12
Electrical connection	Bis zu 4x EnDat 2.2	1x EnDat 2.2
Available fieldbusses	CANopen, POWERLINK	CANopen, PROFINET, PROFIBUS, Ethernet/IP
Accessible sensor informatione	Dehnung, Temperatur, Diagnose, Typenschild	Dehnung, Typenschild

Data processing unit

Variant

Technical data	PDB
Power supply	24 VDC
Current consumption (max.)	2000 mA @ 24VDC
Protection class	IP 65
Operating temperature	-25°C…+50°C
Gateway connection	3x M12, POWERLINK
Fieldbus connection	1x M12, CANopen
Ethernet connection	1x M12
Accessible information	Grafische Benutzeroberfläche mit Kalibrierung, Kurzzeit-Datenaufzeichnung, Benutzerrollen, Zustandsüberwachung, Diagnose

User Cases

Software supported user cases

CONFIGURATION

- Configuration of hardware setup
- Configuration of WTG specific parameters
- Plausibility check on configuration settings

COMMISSIONING

- Functional and fieldbus communication test
- Semi-automated calibration sequence (depends on availability of SCADA signals)

NORMAL OPERATION

- Continous measurement of elongation
- Conversion to fieldbus data
- Comparision of limit values and actual values

MAINTENANCE

- Staff training: only awareness, no special training needed
- Easy work with standard tool box
- Short delivery times for spare parts
- ESR electronic label for easy recognition of sensor parts
- Mobile, battery driven diagnostic tools for the ESR
- OEM memory space availbale (e.g. customer information)

MONITORING

- Condition monitoring
- Structural health monitoring
- Load monitoring (end limits)
- Recording of load spectrum
- Ice detection

LEINE LINDE SYSTEMS

Summary of benefits

EASY INSTALLTION

- Velcro fastening during installation
- Sensor installation up to 50% faster compared to conventional strain gauges
- Installation on different surfaces by 2K bonding
- Easy replacement with standard tools
- Sensors re-usable

INDUSTRIAL SCALE

- Robust and proven strain sensor technology
- Based on high-volume encoder technology
- Automated & scalable in-house production lines

RELIABILITY

- Redundant system designs allows further turbine operation and increased uptime
- 3-level plausibility checks secures safe operation within turbine design loads
- Subsequent electronics (computing) based on reliable standard PLC technology
- Algorithms based on standard C libraries

APPLICATIONS

Short-term measurments

Highly accurate strain measurement

High sampling rate (e.g. turbine dynamics, resonances, noise)

Load measurement (IEC 61400-13, DIBt, FGW)

Long-term measurments

Operation time extension (DNVGL-ST-0262)

Individual Pitch Control (IPC)

Turbine control optimization