附錄(三)：

DNV-GL KEMA 電力測試實驗室簡介

Taking a broader view

A brief introduction to DNV GL

Welcome to DNV GL – KEMA Laboratories

- Agenda for today

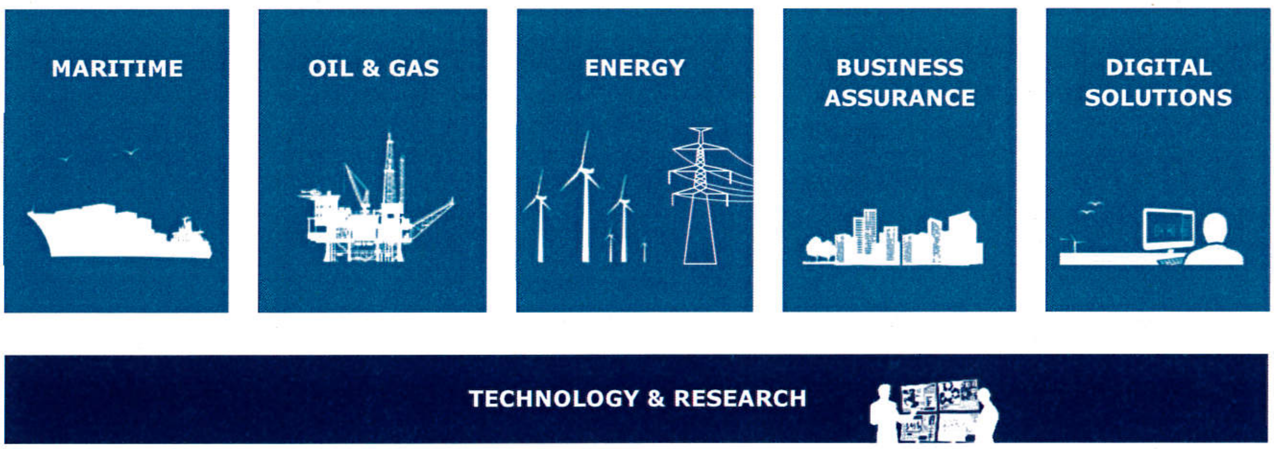
Time	Description
9:00 - 9:15 a.m.	Welcome and exchange business cards
9:15 - 9:45 a.m.	Presentation TERTEC (BSMI)
9:45 - 10:45 a.m.	Presentation DNV GL - KEMA Laboratories
11:00 - 11:30 a.m.	Discussion on ambition and expectations, discussing topics related to testing, inspection and certification.
11:30 - 11:40 a.m.	Signing Ceremony of MoU.
11:40 - 12:30 a.m.	Guide tour KEMA Laboratories
12:30 - 13:00 p.m.	Lunch at KEMA Laboratories, building R32
13:00	Adjournment

A global quality assurance and risk management company

OUR PURPOSE

TO SAFEGUARD LIFE, PROPERTY AND THE ENVIRONMENT

Our vision: global impact for a safe and sustainable future

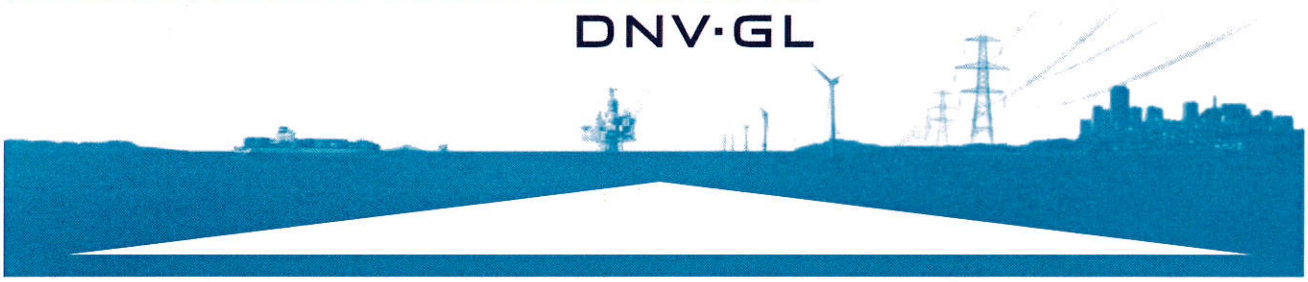


Global reach – local competence

150+ years	**100+** countries	**100,000+** customers	**12,500** employees

Industry consolidation

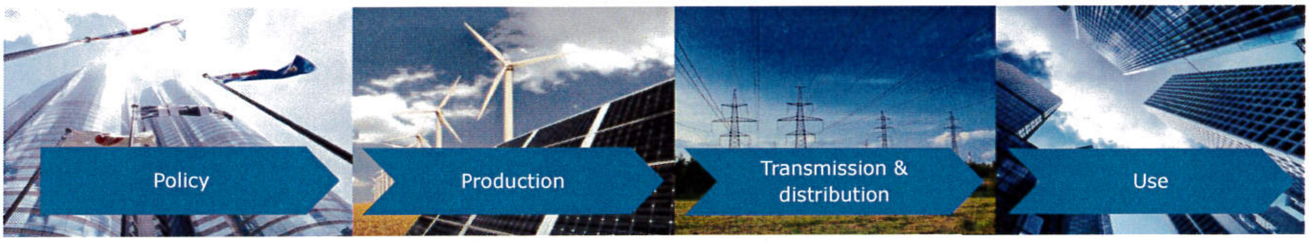
DNV·GL



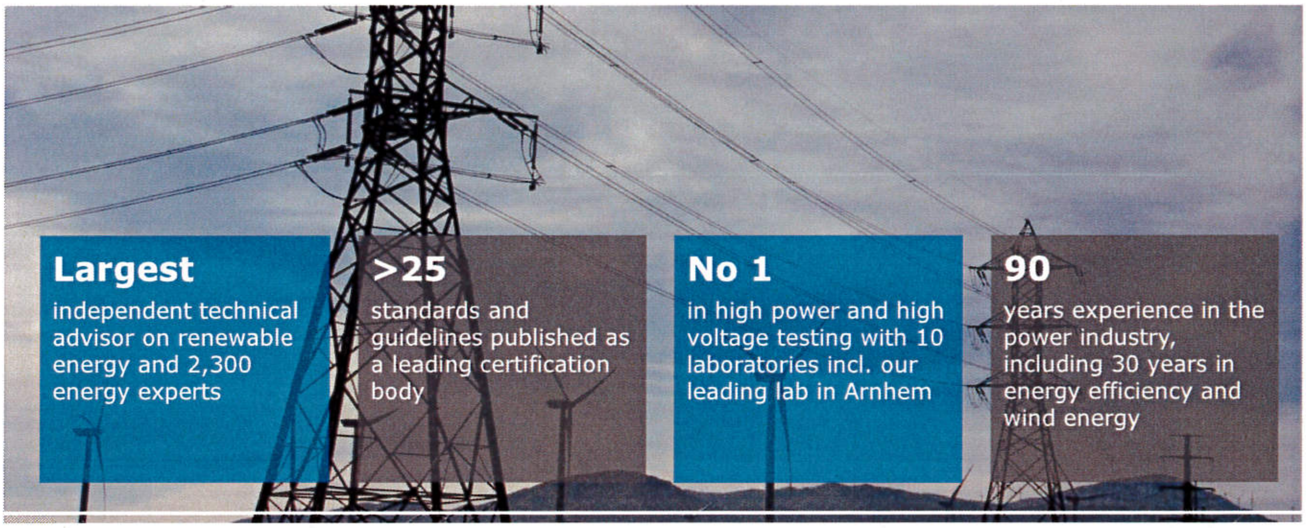
DNV | GL Group | KEMA | NOBLE DENTON | GARRAD HASSAN | ADVANTICA

Global services to the renewables and power sector

- Power testing, inspections and certification
- Renewables advisory services
- Renewables certification
- Electricity transmission and distribution
- Smart grids and smart cities
- Energy market and policy design
- Energy management and operations services
- Energy efficiency services
- Software



An energy technology power house



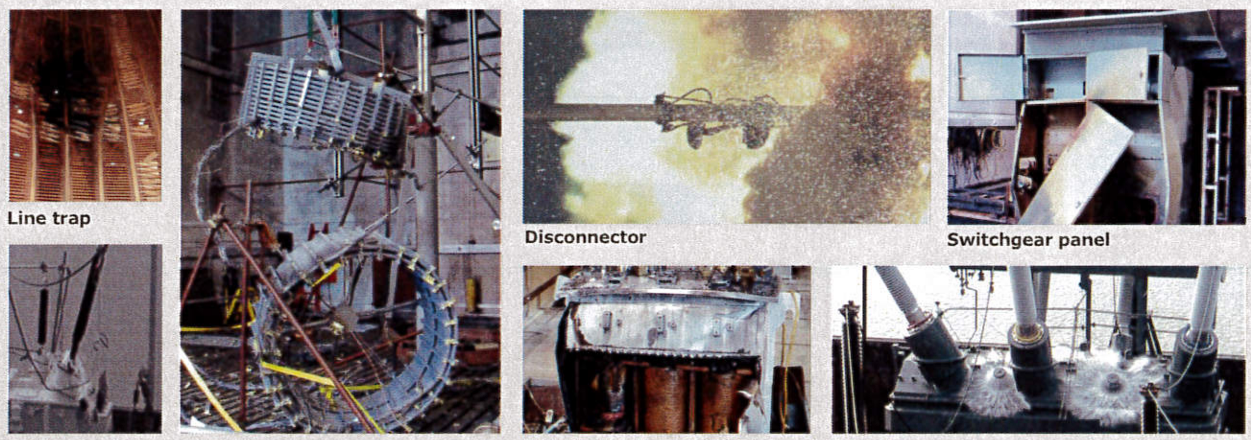
KEMA Laboratories

KEMA Laboratories

KEMA Laboratories

Experience with Type Testing at KEMA Laboratories

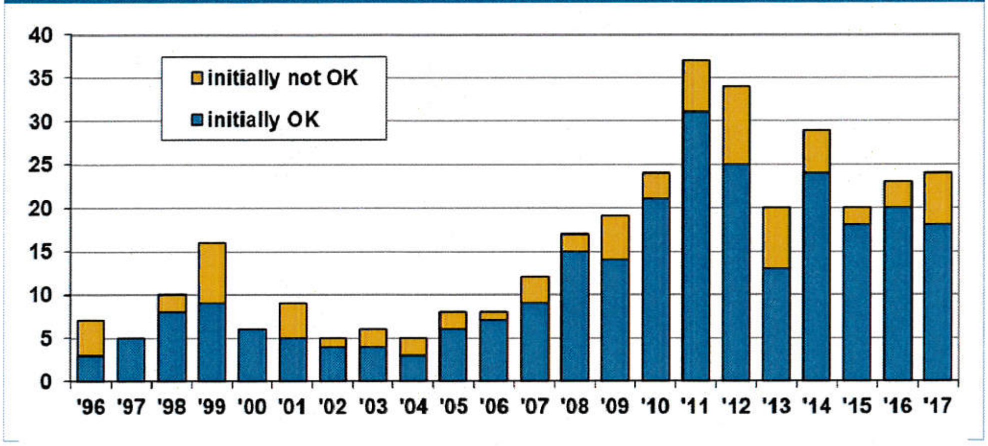
Around 25% of test-objects initially fail to pass type-tests



Line trap
Broken bushing
Line trap
Disconnector
Switchgear panel
Distribution transformer
Oil spill

Initial failure rate large power transformers

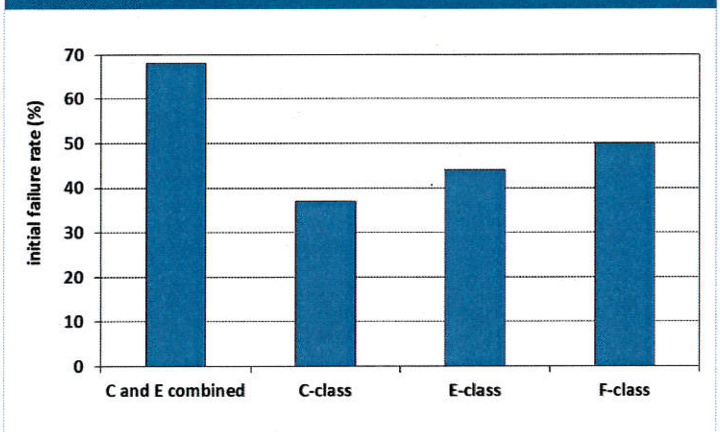
Number of large power transformers tested over the years (KEMA Laboratories) n=344



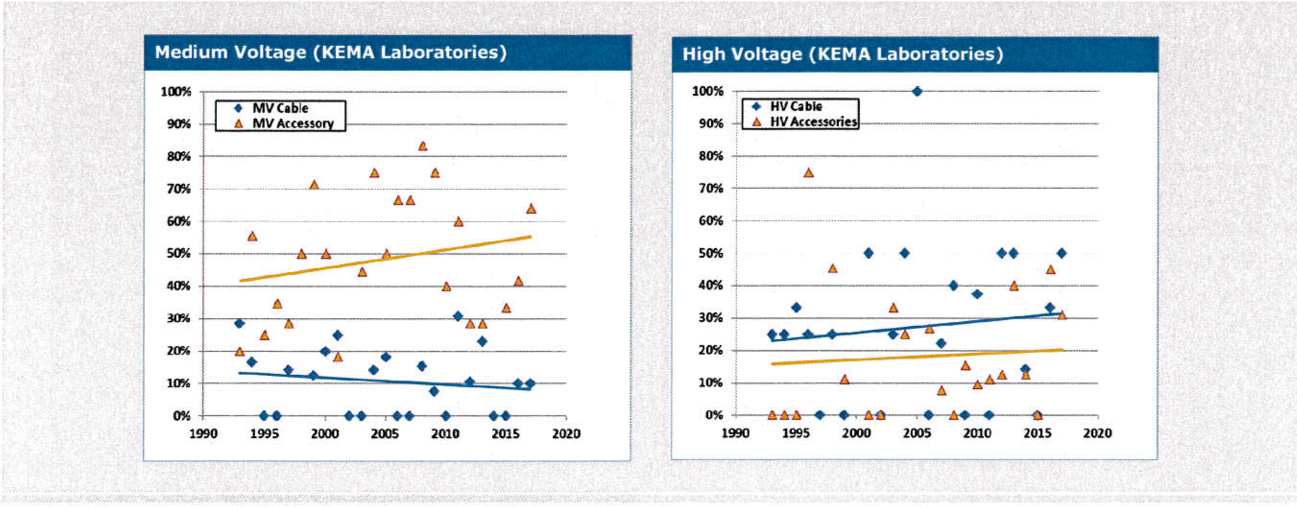
Average 22%

Initial failure rate cast resin transformers

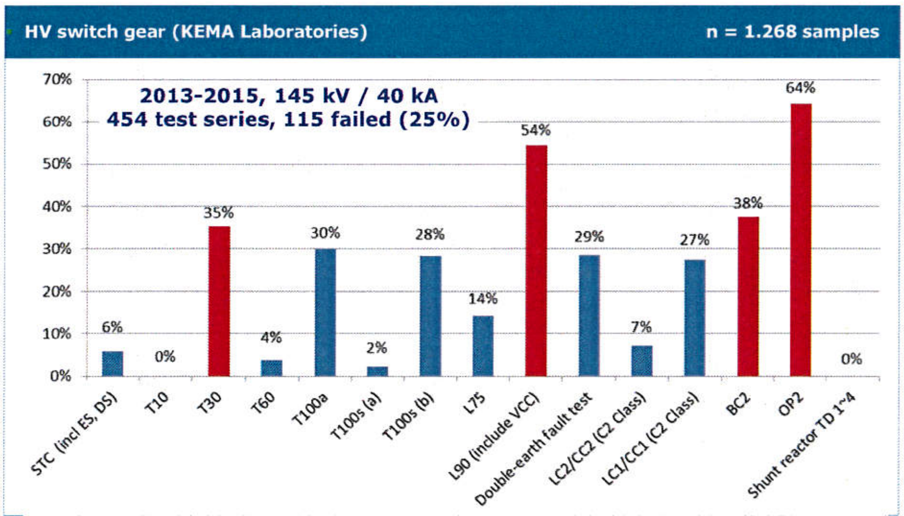
Cast resin transformers (KEMA Laboratories)



Initial failure rate cables and accessories



Initial failure rate circuit breakers – PRELIMANARY RESULTS



- Failure rate (72.5 – 800 kV) is 28%
- Issues: population size, few poor designs shall not dominate, ..
- More work is needed

DNV GL -Renewable Certification

We work with the best

DNV GL is proud to be working with the best in the industry. And when it comes to breaking new ground and ensuring lifetime performance - **experience matters.**

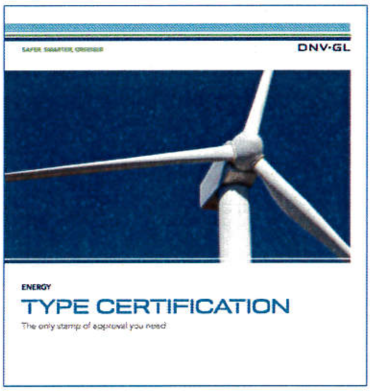
- More than **30 years of experience in wind energy**
- Active in **developing standards, guidelines and specifications** for wind turbine structures and components
- Leading role in developing and revising **international standards** through active involvement in International Electrotechnical Commission (IEC) committees and European and national standards bodies
- **Accredited by** global accreditation body DAkkS to provide certification services

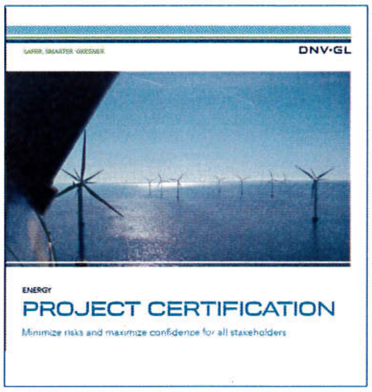
Component manufactures
tpi composites, Romax Technology, LM Wind Power, EUROS, winergy, AVIC Huiteng Windpower Equipment Co., Ltd., ABB, sinoma, Ingeteam, Sinoi

Turbine manufactures
Siemens Gamesa Renewable Energy, Mingyang Wind Power 明阳风电, HZ windpower, Suzlon, Vestas, Goldwind, Envision, Adwen

Project developers
wpd, EnBW, e·on, Statoil, DONG energy, Iberdrola Renewables, Vattenfall

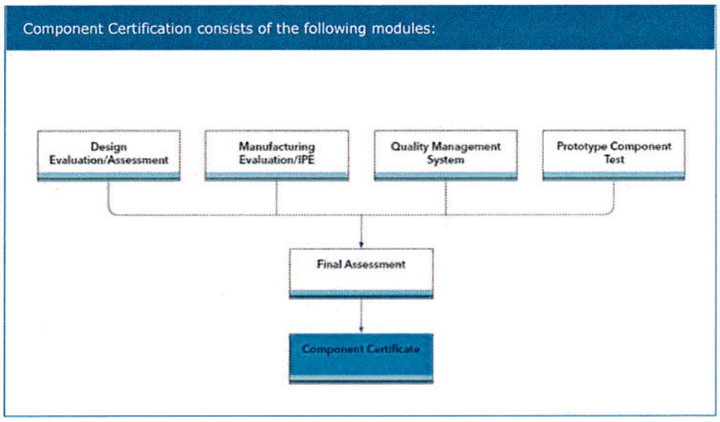
Within DNV GL Renewables Certification we have three main Service Lines



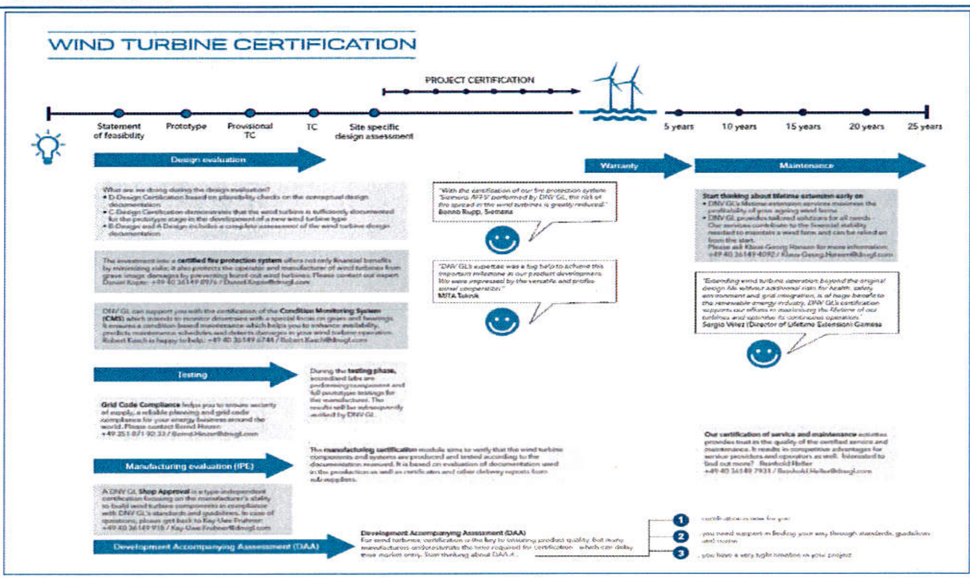


Component certification

- A DNV GL Component Certificate is your confirmation that a wind turbine component is designed, documented and manufactured in accordance to design assumptions, specific standards and technical requirements.
- We provide tailored solutions for wind turbine manufacturers, as well as sub-suppliers of components. Following successful evaluation, you receive a hallmark showing that your component meets international standards and customers' needs.
- Authorities in countries throughout the world recognize these systems. In addition, we are accredited by the accreditation body DAkkS.



Type certification



Project Certification

Project Certification is a well-proven system for third party review and approval of wind turbines, substation with their support structures, power cables and control station at a specific location.

Our Project Certification covers all the critical phases of a wind plant project, from development over construction to operation, and is offered according to the following standards:

- DNVGL-SE-0073 Project certification of wind farms according to IEC 61400-22
- DNVGL-SE-0190 Project certification of wind power plants

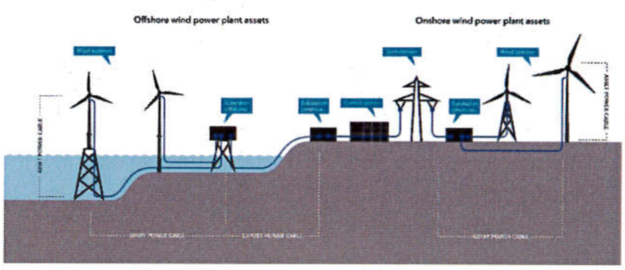

ENERGY
PROJECT CERTIFICATION
Minimize risks and maximize confidence for all stakeholders

Why Project Certification?

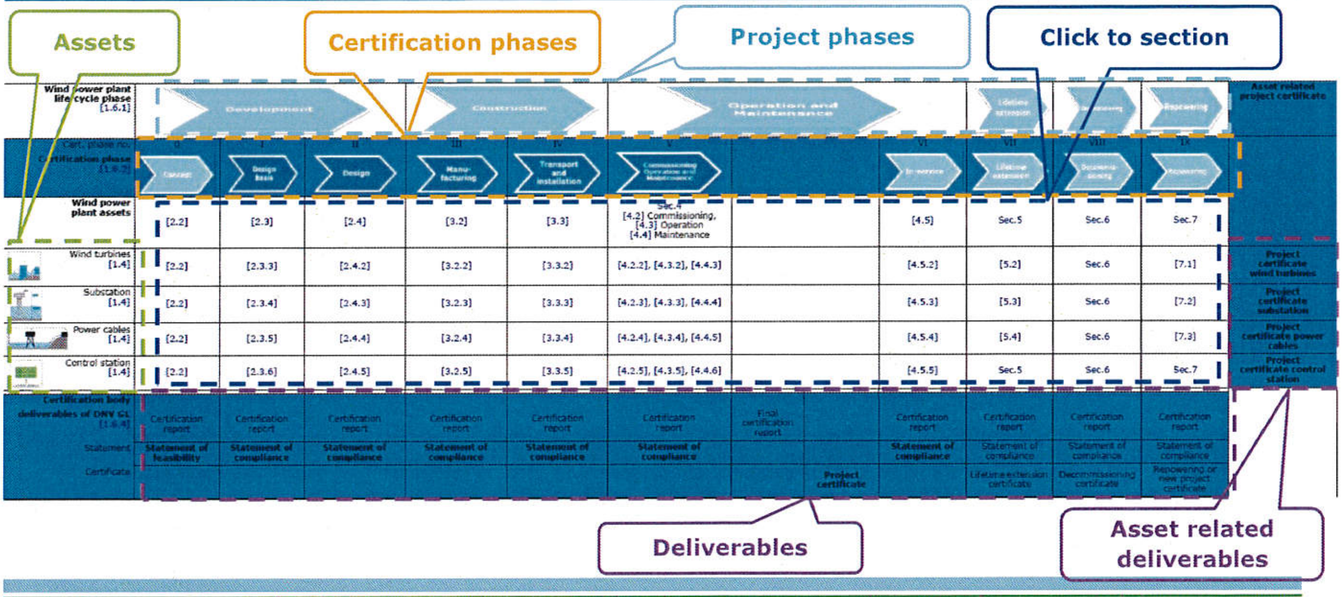
- Project Certification will help to provide reliable quality, stable operation and proper risk management to produce sustainable power in a competitive energy sector. In addition, the soil conditions of a wind farm may be extremely varying and complex.

- By subjecting the project to certification, the owner can demonstrate an awareness of the risk involved and a willingness to address the challenges such as the soil conditions head on.

- Although suitable for both onshore and offshore wind projects, Project Certification is significantly adding value for offshore wind installations, due to their inherently higher risks and more complex wind and wave loading conditions.

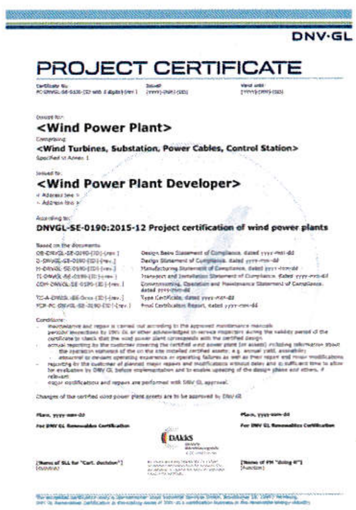


Project certification scheme DNVGL-SE-0190



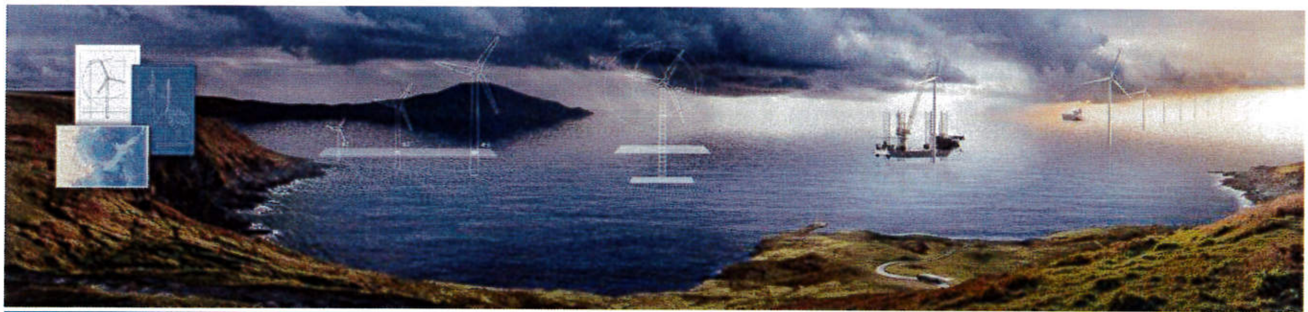
The added value of Project Certification

- Issued by an accredited certification body, the certificate gives all parties involved the confidence that a wind farm project has been assessed against industry best practice and that the documentation is in order.
- A complete life-cycle approach to projects can be applied to reduce the total risk and avoid costly and technically challenging field modifications to the assets during the project's in-service phase. This contributes to the reduction in costs over the life-time.
- The project certificate is a "ticket to trade" when financing or selling the project.



DNV GL – Advisory

Broad and deep expertise in offshore wind projects



FEASIBILITY
- Market intelligence
- Strategic advice
- Technology evaluation/Technology qualification
- Certification of wind turbines, offshore substation and cables

DEVELOPMENT
- Concept selection
- Measurements
- Resource and energy optimization
- Technical due diligence
- Pre-construction energy assessment
- Certification of wind turbines, offshore substation and cables

ENGINEERING
- Project engineering optimization
- Operation and maintenance planning
- Turbine and support structures consulting
- Interconnection review
- Certification of wind turbines, offshore substation and cables

CONSTRUCTION
- Construction optimization
- Monitoring and marine warranty
- Project management
- Construction monitoring
- Banks' engineer
- Certification of wind turbines, offshore substation and cables

OPERATION
- Asset management optimization
- Operation and maintenance optimization
- Performance and condition monitoring
- Inspections and audits
- Operational energy assessments
- Project portfolio due diligence
- Certification of wind turbines, offshore substation and cables
- Condition monitoring systems

*Our testing, certification and advisory services are independent from each other

Broad and deep expertise in T&D projects

FEASIBILITY	DEVELOPMENT	ENGINEERING	CONSTRUCTION	OPERATION
› Vision and strategy › Roadmap development › Compliance checks › Power system analysis › Generation interconnection studies	› Comprehensive project planning › Power system planning › Energy market design › Project risk management › Stakeholder communication strategy	› Basic design support/review › Functional description and specification based on relevant standards › Manufacturer assessment and selection › Tender support › Verification and acceptance plans	› Accredited testing and certification of equipment › Accredited communication protocol and cyber security testing › Verification of power systems › Validation of project conformity › Owner's engineer › Quality assurance and quality checking	› Diagnostics and performance measurement › Power failure investigations › Asset management processes review and optimization › Asset condition and remaining lifetime assessment › Smart energy services › Digital system operation support › Training of operating and maintenance staff

We close the loop and develop best practices + first time right projects for you

DNV GL delivers a full service portfolio covering the asset life cycle of power transmission systems

- Strategy, risk management and feasibility studies
- System studies, basic design and quality assurance
- Technical tender evaluation
- Quality control at production or testing at DNV GL
- Quality control at installation & commissioning
- Operation & maintenance
- Diagnostics
- Root Cause Failure analysis
- Repair, retrofit or decommissioning

DNV GL with its in depth experience in the asset life cycle knows where the risks are and closes the loop to have maximum impact on mitigation of risks

Project Management & Technical Services – qualifications

Expertise	Experience in supporting power generation, transmission and distribution projects with engineering services for the deployment of grid assets with risk mitigation and advanced technical services.
Service offerings	Owners engineer services from basic design, system specifications, procurement support, contract development, asset testing and diagnosis, quality assurance & implementation. Unique technical services deploying implementation of best practices with a view to addressing project, technical and operational risks.
Innovation	Innovative high voltage tower designs, AC to DC conversion, EMC verification standard for platforms, subsea cable verification. Optimization of asset operation, maintenance and monitoring. Support for strategic grid development. Smart solutions for grid connection of conventional and renewable power generation units.
Tools & methodologies	Risk management (Easy Risk Manager), quality assurance & control programs, electrical calculation tools for asset planning, design and system optimization (ADAPT Power, PLS CAD in combination with in-house software, Ansys, Autocad, Inventor, CDEGS, EFC-400, ATP-EMTP, Red Book applets), EMC tools, lectrical measurement and asset diagnostic tools, failure assessment and investigations tools.
Key projects	World's largest HVDC interconnector and bulk transmission projects, large wind farm grid integration projects, substation and line projects at EHV, HV and MV levels, asset diagnostics and electrical measurement activities, due diligence, grid assessment and security of supply studies.

Discussion

Guided Tour in KEMA Laboratories

Guided Tour

- Split in two groups
  - Tour guide for Group 1 is Bas Verhoeven
  - Tour guide for Group 2 is Frank Jansen

- Hard hats are required
- Stay close in the group
- No photography

Signing of the MoU

Memorandum of Understanding

between

Taiwan Electronic Research and Testing Center (TERTEC)

and

DNV GL Netherlands B.V. – KEMA Laboratories

Witnessed by Bureau of Standards, Metrology and Inspection (BSMI), Ministry of Economic Affairs

for cooperation in the offshore wind energy testing, inspections and certification technologies.

18 July 2018

KEMA Laboratories

SAFER, SMARTER, GREENER

Global impact for a safe and sustainable future

www.dnvgl.com

SAFER, SMARTER, GREENER

附錄(四)：

丹麥科技大學 DTU 簡介

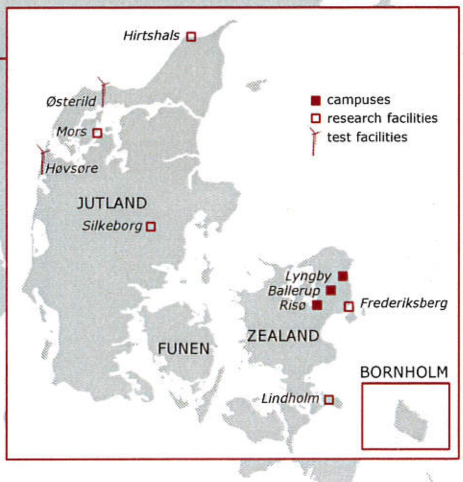
Visit by *delegation from MIRDC, Metal Industries Research Development Centre* - 19 July 2018

Peter Hauge Madsen
Head of Dept.

DTU Wind Energy
Department of Wind Energy

Time	Subject
09:00 – 09:15	Exchange Business Cards and brief introductions
09:15 – 09:30	Welcome to DTU by Peter Hauge Madsen, Head of Department
09:30 – 09:55	Introduction of MIRDC by Ming-Jong Liou, Director Generel
09:55 – 10:00	Transport to Building 331
10:00 – 11:00	Site tour to the Poul La Cour Wind tunnel by Christian Bak, Senior researcher
11:00 – 11:05	Walk to Building 332
11:05 – 12:00	Site tour to the Large Scale Facility by Marcin Luczak, Senior researcher
12:00 – 12:05	Transport to the canteen, Building 116
12:05 – 13:15	Lunch
13:15 – 15:00	Presentations, discussions and signing of MOU Building 112 (H.H. Koch) - The Danish Certification system by Peggy Friis, DEA - Blade testing and standards by Marcin Luczak, Senior researcher and Xiao Chen, researcher - Prototype testing by Paula Gómez Arranz, Senior development engineer
15:00	End of meeting

Technical University of Denmark
- founded in 1829 by Hans Christian Ørsted



Key figures

Student body
11,200
- including PhD 1,300
- and int. MSc 1,600

Research publications
5,500

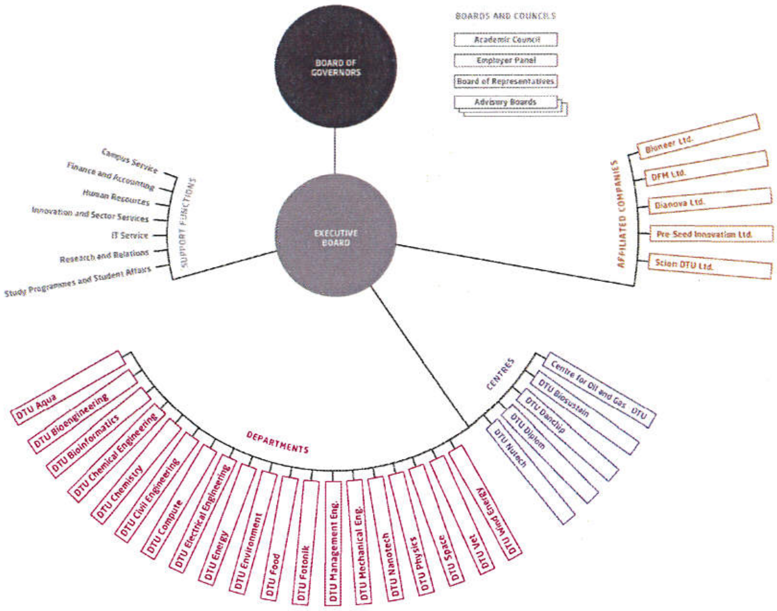
Ranking

Leiden Ranking 2017:

No 1 in the Nordic region

No 41 in Europa

Organization

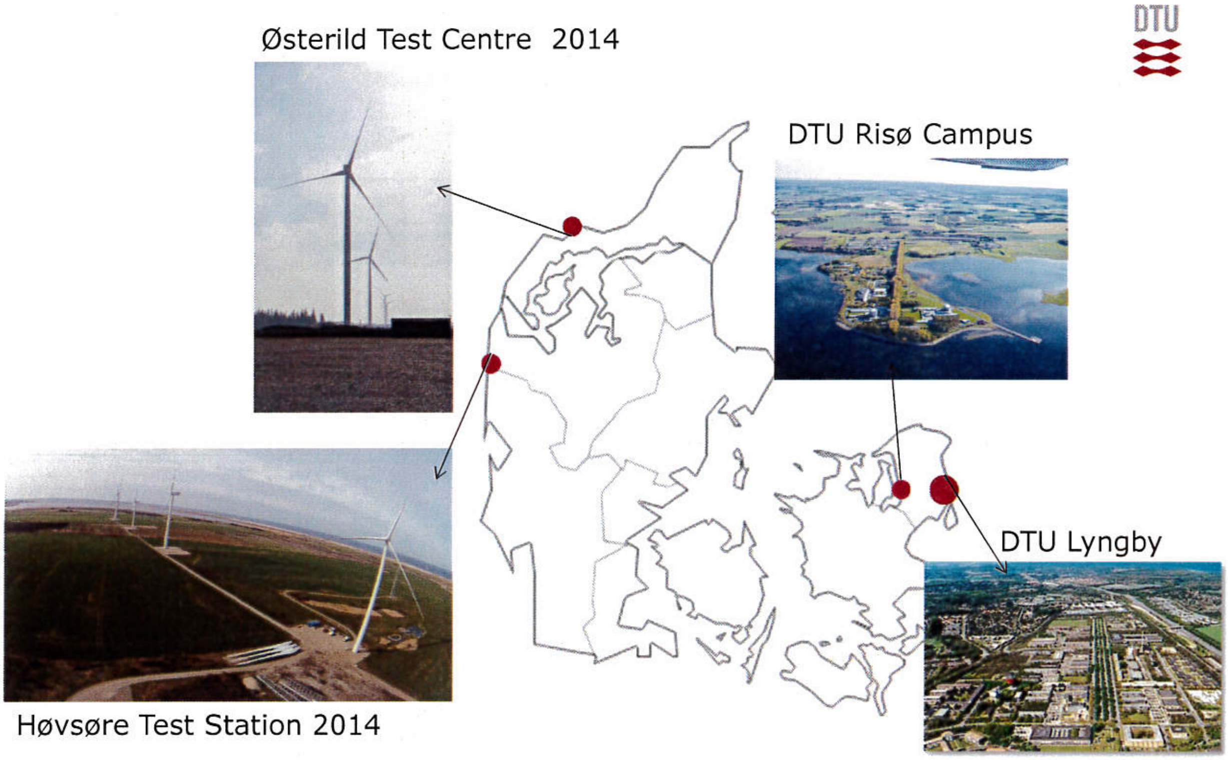


Raison d'etre

Purpose: To develop wind energy to meet essential societal challenges on climate, job creation and growth.

Mission: DTU Wind Energy must develop and create value from natural and technical science for the benefit of the society with focus on the wind energy sector.

Vision: DTU Wind Energy is the preferred university partner within wind energy.



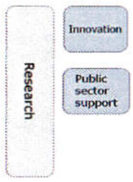
Technology development: Science (DTU) – industry

Concept development

- Demonstration
- Proof of concept

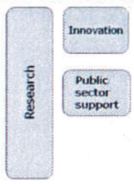
Documentation

- System test
- Design basis
- Basic design requirements
- System approval



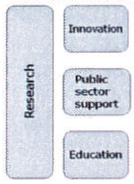
Development

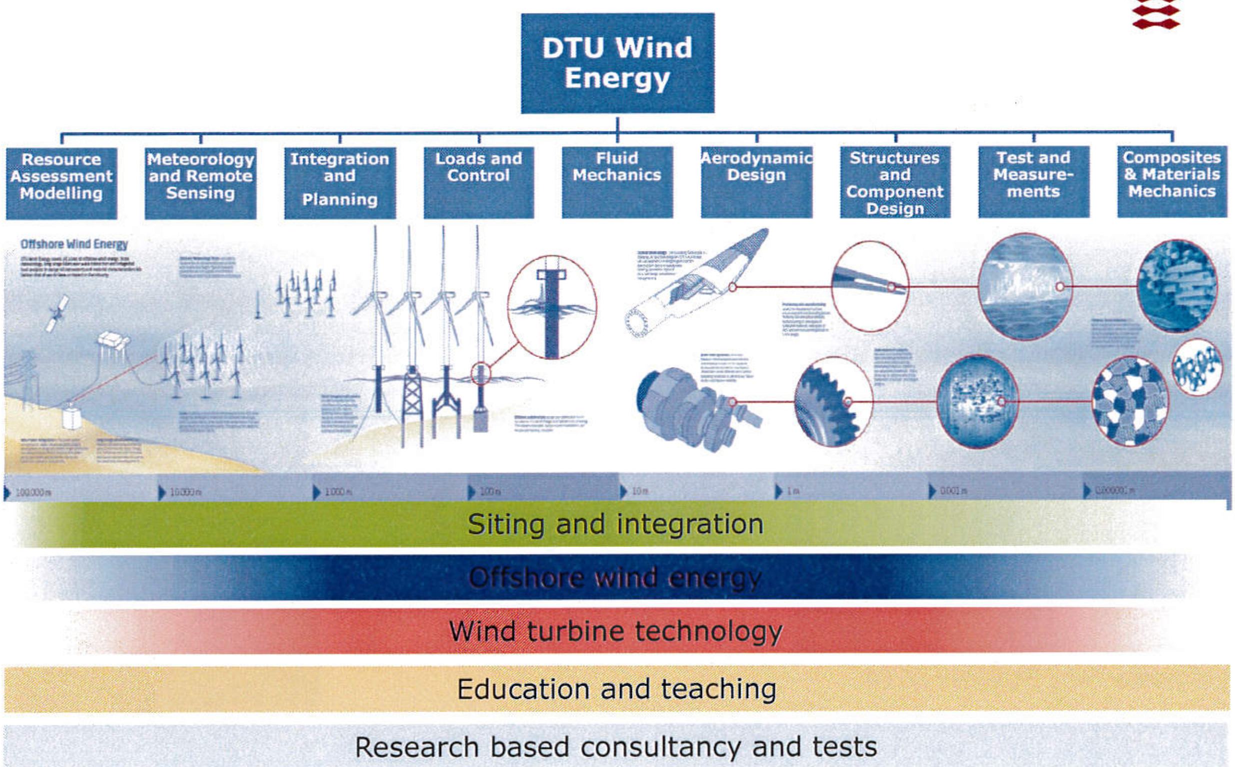
- Applied research, design tools, resource mapping
- Int. standardization



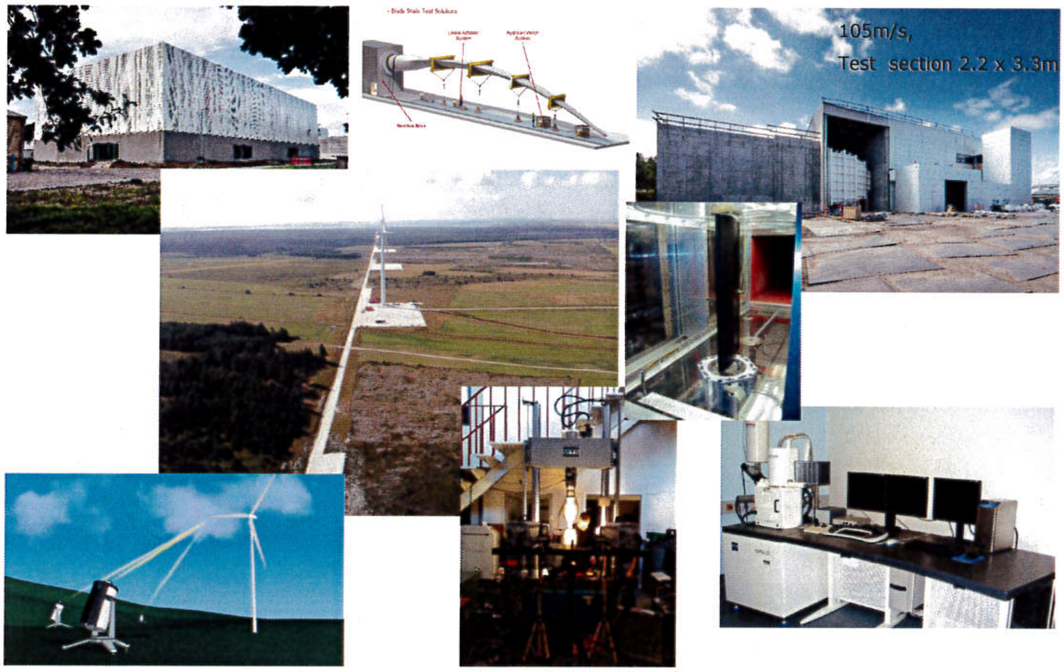
Industrialization

- Basic strategic research
- Integrated tools
- Validation
- Patents and education





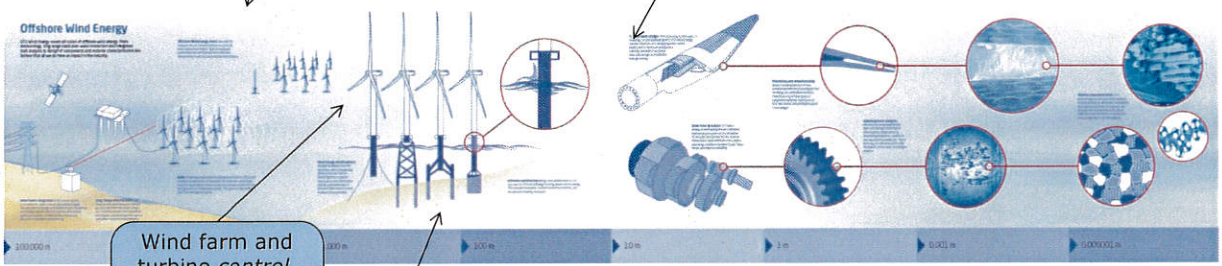
Test and research facilities



Siting and Integration focus fields

Atmospheric modelling from climate to energy production

Prediction of site-specific loads and performance



Wind farm and turbine *control, layout optimization and system services*

Variability and integration of wind power in the power system

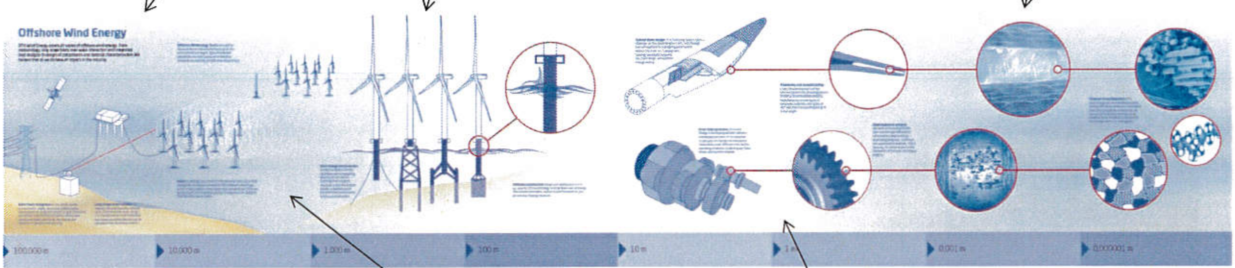
Planning and public perception, including acoustic effects

Offshore Wind Energy focus fields

Offshore **external conditions,** including met-ocean and uncertainty quantification

Offshore WT **system design complex,** including design for full life cycle

Structural **component design,** as well as optimizations methods, new concepts, materials selection and surface engineering for offshore structures



Offshore **WT and farm control,** internal grid and transmission and forecasting

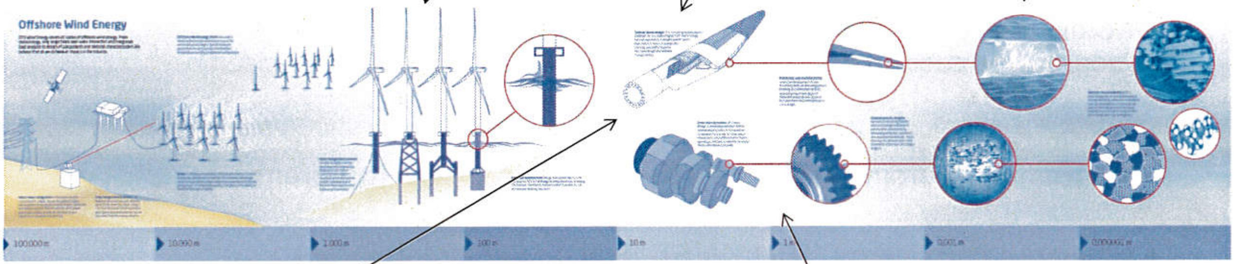
O&M and repair for offshore installations, including design for this and failure analysis. Logistical methods for O&M and installation

Wind Turbine Technology focus fields

Rotor design model complex, including uncertainty quantification

Test and validation of turbines and components

Existing and new **materials** including materials design, processing and performance as well as implementation in design



New **concepts, components** and their design fundamentals

Design for **O&M**, lifetime prediction and **extension, repair** and design **upgrade**

Research based consultancy and tests

Wind measurements

Calibration tests

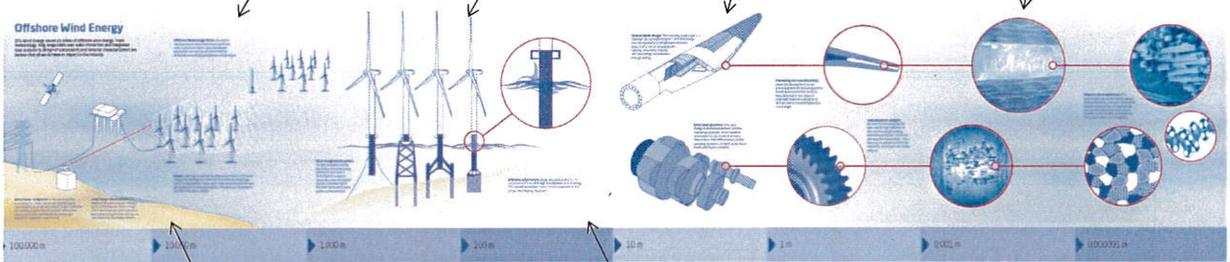
Accredited wind turbine testing

R&D measurements

Development of experimental verification of rotor blade design methods

Experimental development of verification methods of existing and new **materials** and structures

Accredited testing of materials



Research based consultancy to authorities and industries

National and international

Standardization

MSc Programmes in Wind Energy at DTU

- MSc in Wind Energy
  Programme coordinator: Martin O.L. Hansen (and Joachim Holbøll)

- European Erasmus Mundus Wind Energy Master (EWEM)
  Programme coordinator: Taeseong Kim

- Nordic Master's programme in Innovative Sustainable Energy
  Programme coordinator: Lise-Lotte Pade (Wind: Jens N. Sørensen)

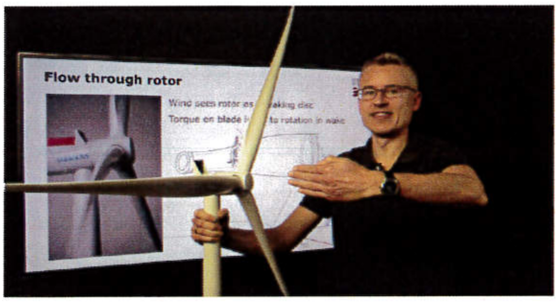
- MSc in Sustainable Energy
  Programme coordinator: Lise-Lotte Pade (Wind: Jens N. Sørensen)

- Offshore Wind Energy (DTU/KAIST dual degree programme)
  Programme coordinator: Taeseong Kim

- Online 1-year Master in Wind Energy
  Programme coordinator: Merete Badger

MOOC – Massive Open Online Course

- **Wind Energy** –*Coursera.org*



From video with Henrik Bredmose

- Link to course: https://www.coursera.org/learn/wind-energy
- Video teaser: https://youtu.be/he4UWTGHxrY
- Participants: ~30.000

Wind Energy Master

- Wind Energy Master programme launched
- First three master courses developed and executed

1. semester	2. semester	3. semester	4. semester
Wind Turbine Technology 5 ECTS	Economics, Environmental and Social Impact of Wind Turbines 5 ECTS	Numerical Tools in Wind Energy 5 ECTS	Final project 15 ECTS
Wind Resources 5 ECTS	Aerodynamics and Aeroelasticity 5 ECTS	Offshore Wind Energy 5 ECTS	
Materials for Wind Energy 5 ECTS	Grid Connection and Integration of Wind Power 5 ECTS	Measurement Techniques in Wind Energy 5 ECTS	

Wind Turbine Technology

In this course, you will learn about wind turbine technology covering aerodynamics, composite structure, structural dynamics, electrical systems, control.

Go to the course

Wind Resources

The focus of the course is to get familiar with tools and give an understanding of wind resources to perform wind energy resource assessment at various scales.

Go to the course

Materials for Wind Energy

In this course, you will learn about materials used in wind turbines and the loads they are subjected to. You will need to focus on composites and metals.

Go to the course

Participants in the programme

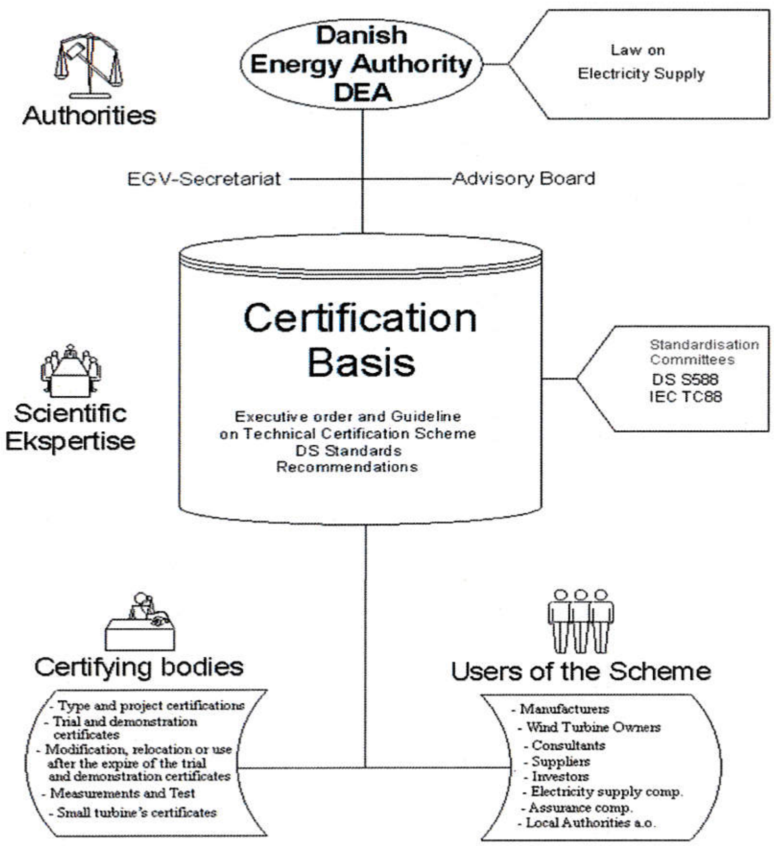
Autumn 2017 intake:

- 33 participants accepted from all over the world
- Distributed within a range of time zones
- Experienced or less experienced in the field of wind energy
- Extremely motivated, dedicated, and ambituous

The Danish Technical Certification Scheme Design, Manufacture and installation of Wind Turbines

History in brief:

- System Approval from 1980 -1991
- Type Approval scheme from 1991
  - Type approval of wind turbines
  - Quality assurance
  - Danish Standard DS 472 on Loads and Safety of Wind Turbine Constructions
- Certification Scheme based on IEC WT 01 and international standards (61400-serie) ultimo 2004
- Rules for Service 2008
- Supplementary rules for Small Wind Turbines under 200 m^2 2009/2010
- WT01 becomes 61400-22, 2010
- EGV moves from DTU Wind Energy to The Danish Energy Agency, 2017



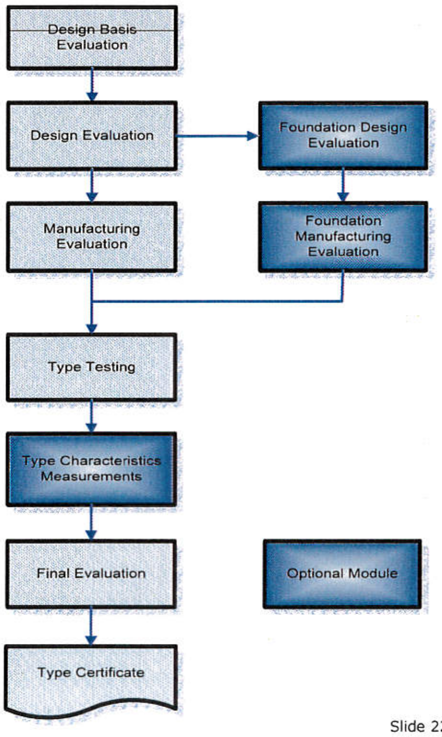
IEC TC88: IEC 61400 standards series

- IEC 61400-1 Design requirements
- IEC 61400-2 Small wind turbines
- IEC 61400-3 Design requirements for offshore wind turbines
- *IEC 61400-4 Gears for wind turbines*
- *IEC 61400-(5) Wind Turbine Rotor Blades*
- IEC 61400-11, Acoustic noise measurement techniques
- IEC 61400-12-1 Power performance measurements
- IEC 61400-13 Measurement of mechanical loads
- IEC 61400-14 Declaration of sound power level and tonality
- IEC 61400-21 Measurement of power quality characteristics
- *IEC 61400-22 Conformity Testing and Certification of wind turbines*
- IEC 61400-23 TR Full scale structural blade testing
- IEC 61400-24 TR Lightning protection
- IEC 61400-25-(1-6) Communication
- *IEC 61400-26 TS Availability*
- *IEC 61400-27 Electrical simulation models for wind power generation*

- *IEC 60076-16: Transformers for wind turbines applications*

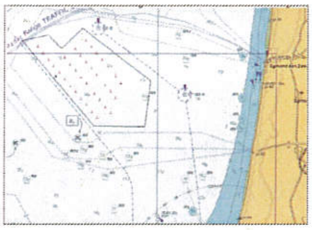
Type Certification
(IEC 61400-22)

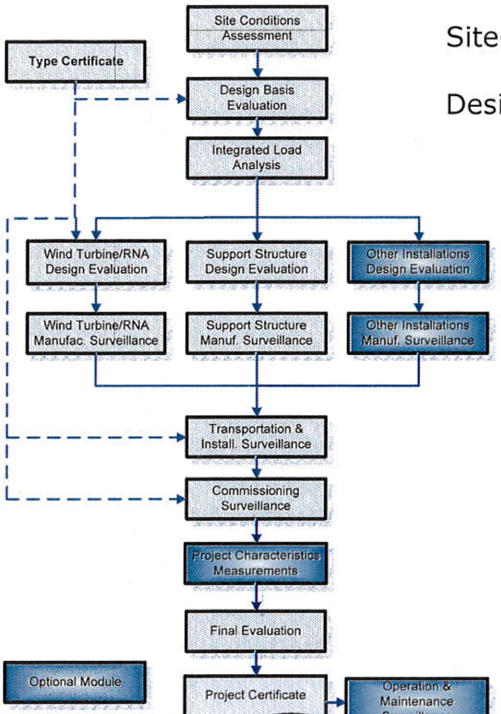
Verification of product compliance with standards



Project Certification
(IEC 61400-22)

"Fit-for-Purpose"





Site-specific conditions

Design conditions

Load and design analysis

Surveillance

Certificate

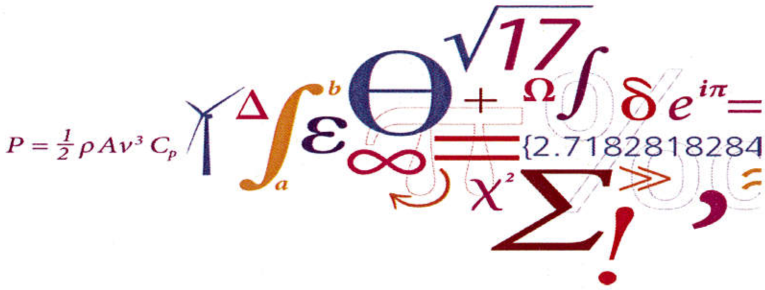
Thank you for your attention

附錄(五)：

DTU 風力機結構、組件設計及大尺度測試試驗室簡介

Large Scale Test Facility
Wind Turbine Structures and Component Design (SAC)

Marcin Luczak
Xiao Chen



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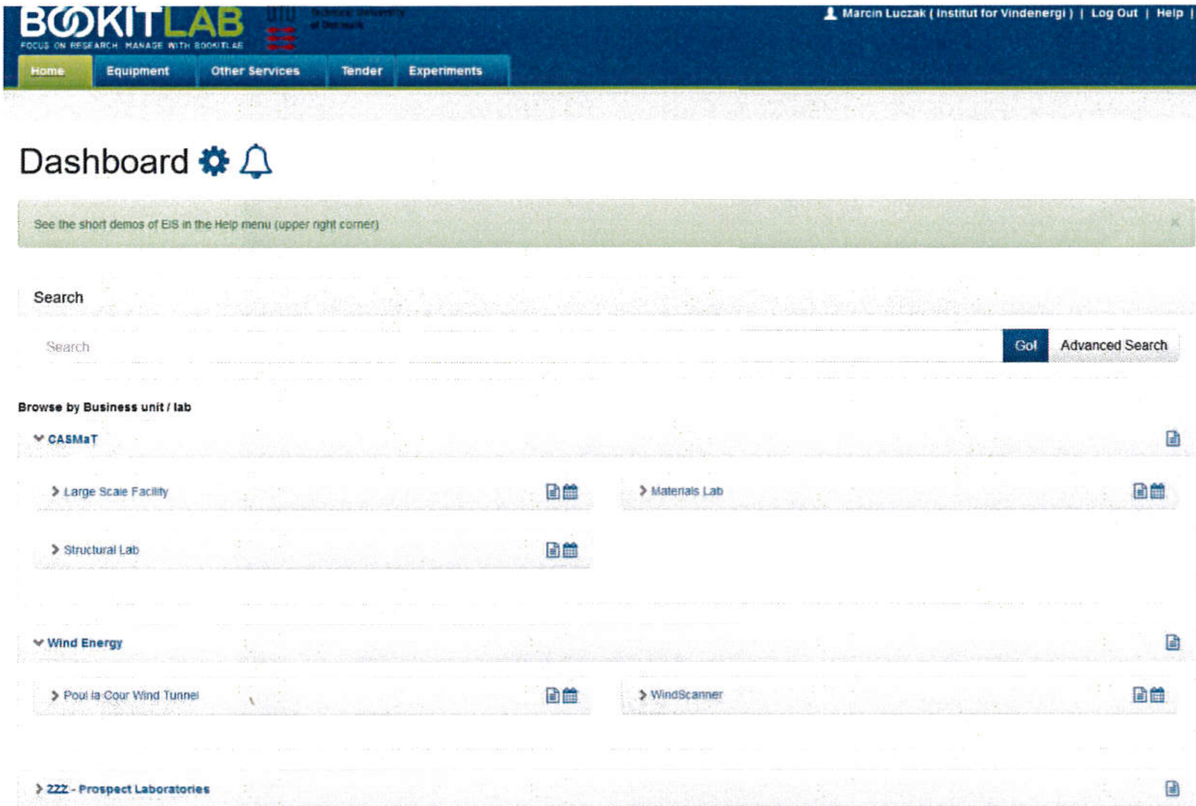
Agenda

- Large Scale Test Facility
- Ongoing projects
- Talk on the test standards (Xiao)
- Walk around

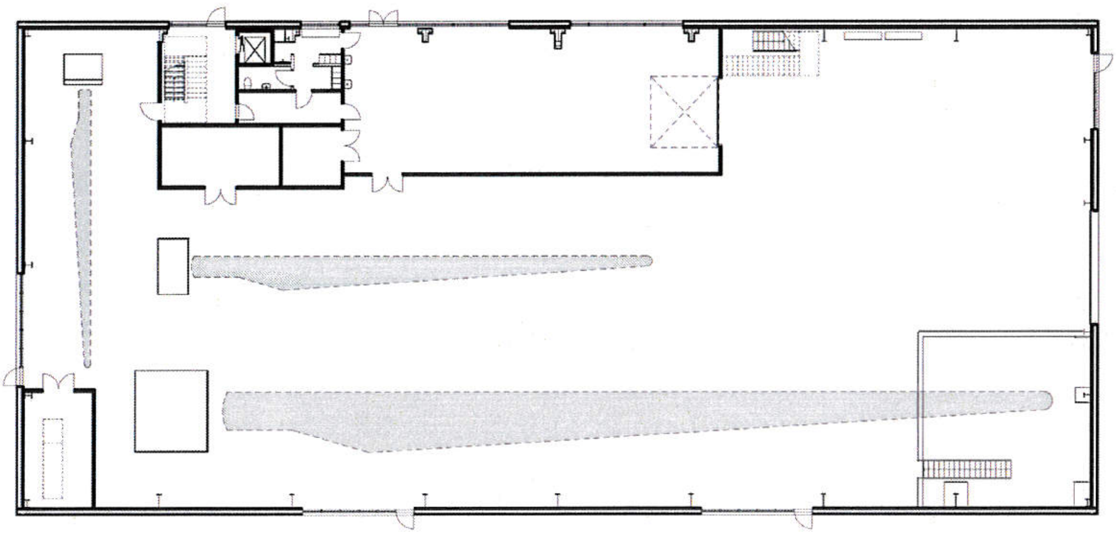
Villum
CASMaT
Center for Advanced Structural and Material Testing

- DKK 76 mill donation from the Villum Foundation
- Center Leader, Professor Henrik Stang, DTU Civil Engineering
- DTU Civil Engineering, DTU Mechanical Engineering and DTU Wind Energy
- Experimental research facilities for advanced mechanical testing of structures and materials
- http://www.casmat.dtu.dk/english
- http://www.dtu.dk/english/news/2013/10/villum-center-for-advanced-structural-and-material-testing?id=b0b39c96-0803-499e-8d9b-1865a82fe0e2

5



Large Scale Test Facility
Coordinator: Kim Branner



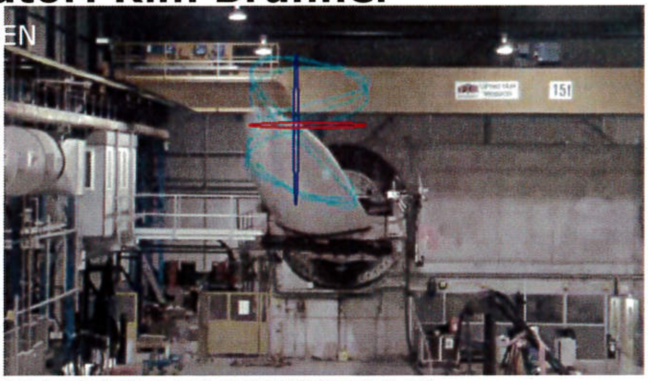
Static testing

DTU Wind Energy

	45 m test stand	25 m test stand	15 m test stand	
Maximum bending moments on test stands				
Static	20.0	3.5	1.0	MNm
Dynamic, amplitude	6.0	1.0	0.4	MNm
Maximum deformations during test				
Static tip deflection	13.5	10.0	5.0	m
Dynamic tip-to-tip	11.0	6.0	4.0	m

BLATIGUE - Fast and efficient fatigue test of large wind turbine blades Coordinator: Kim Branner

A project supported by EUDP and VILLUM FONDEN



Dual-axis fatigue test at ORE Catapult in UK

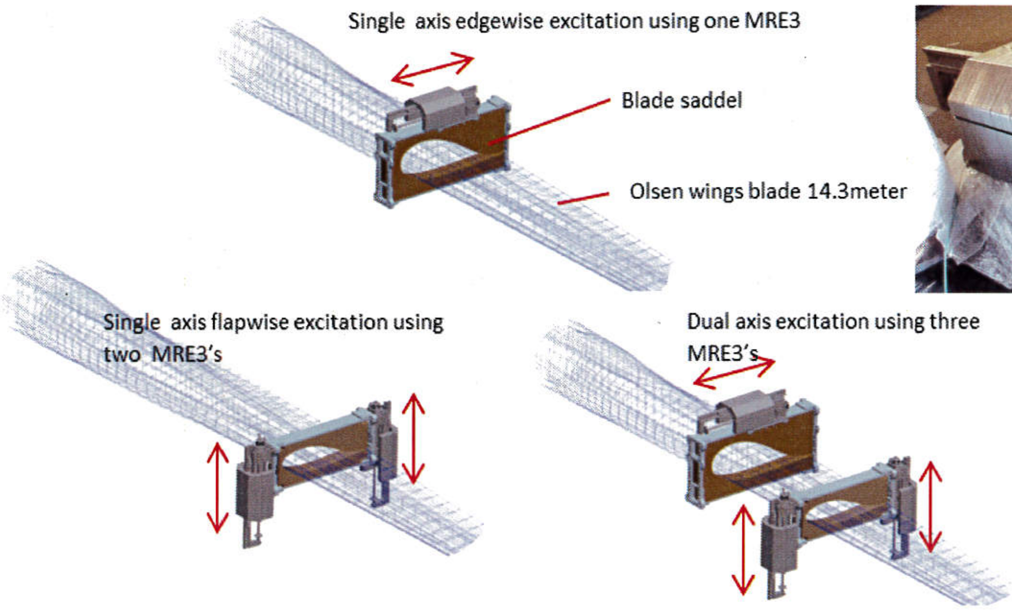
Project partners:

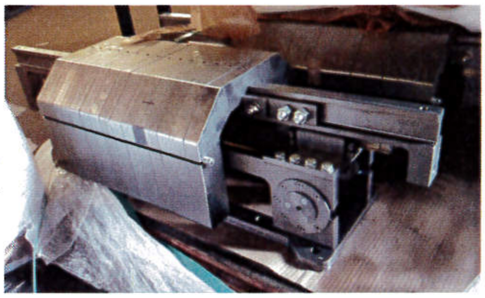
- DTU Wind Energy
- Siemens Wind Power A/S
- R&D A/S
- Blade Test Centre A/S (BLAEST)
- Olsen Wings A/S
- DNV GL
- Zebicon A/S
- DONG Energy Wind Power A/S

The objective of BLATIGUE is to develop **fast and efficient fatigue test methods** for large wind turbine blades and to develop **equipment to excite the blades** under such tests.

- Period: Dec. 2016 – May 2020
- Total hours: 30730 h

Dual-axis testing

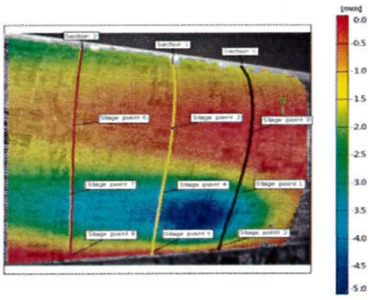


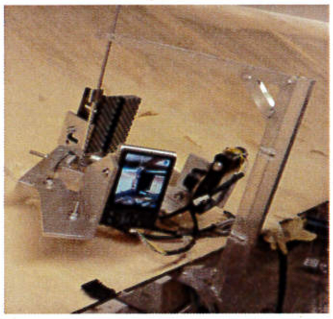


Measuring equipment

The facility has many possibilities to do advanced measurements and data acquisition.

- 3D full field displacements with digital image correlation systems
- Strain gauges (quarter, half and full bridge) and Fiber Bragg Grating sensors
- Displacements with LVDT and ASM
- Scanning laser Doppler vibrometer for vibrations and modal analysis
- High speed cameras, video and thermal imaging camera
- Failure and cracks can be studied with Acoustic Emission, ultrasound and X-ray imaging

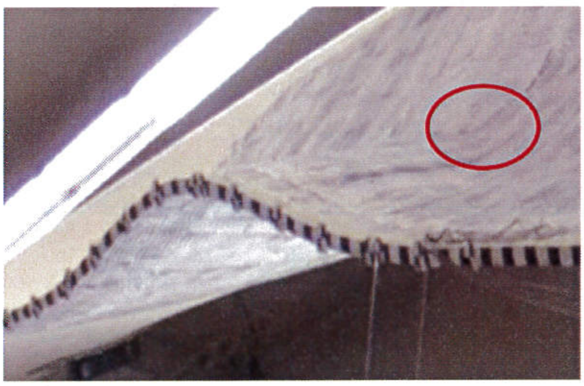


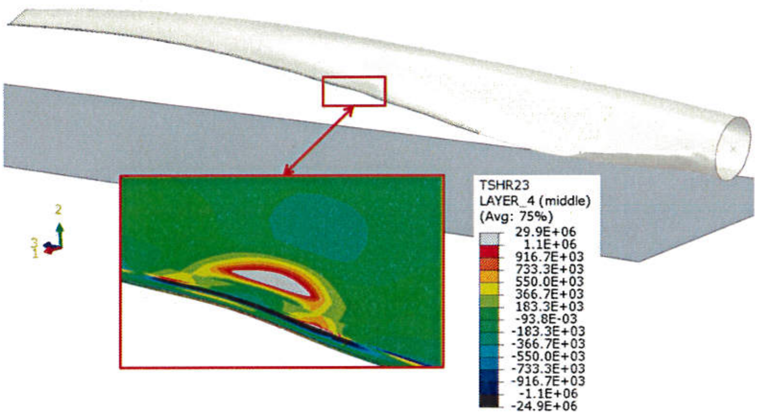


2nd bending

Applied fracture and damage mechanics

Philipp U. Haselbach





Sharp bend in the sandwich structure of the blade

Progressive damage analysis

DARWIN - Drone Application for pioneering Reporting in Wind turbine blade Inspections

A project supported by Innovationsfonden

Project partners:

- EasyInspect ApS
- DanDrone Erhverv ApS
- DTU Wind Energy
- DTU Compute
- Aalborg University
- E-on
- Vattenfall
- Recover Nordic ApS
- ...

Innovationsfonden

- Period: Jan. 2017 – Dec. 2019
- Total budget:25.84 MDKK

The overall aim is the development and commercialization of a **drone based intelligent and innovative** NDT (Non Destructive Test) **inspection tool** for the Wind Power Industry with highly export potential and a commercial potential also for multiple inspection tasks.

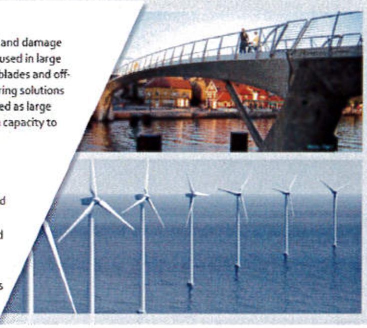
Don't fear - control!

DACOMAT

DACOMAT
Damage Controlled Composite Materials

Objective & Impact

The objective of DACOMAT is to develop more damage tolerant and damage predictable low cost composite materials in particular aimed for used in large load carrying constructions like bridges, buildings, wind-turbine blades and off-shore structures. The developed materials and condition monitoring solutions will enable composite structures to be designed and manufactured as large parts with more and larger manufacturing imperfection and high capacity to sustain damages.



Outcomes

- Composite materials and structures with significantly improved durability and damage tolerance
- Guidelines and modeling tools for reliable design of critical load carrying composite structures
- Guidelines for materials qualification
- Structural health monitoring and damage assessment solutions
- LCCA & LCA methodology for large composite constructions

Consortium

Coordinator SINTEF

Duration: January 2018 to December 2021
Budget: 5.9 M€
Contact: jens.k.jorgensen@sintef.no
Twitter: DACOMAT @DACOMAT_EU
www.dacomat.eu

The DACOMAT project has received funding from the European Union's Horizon 2020 research and innovation programme under GA No. 761072

- WP1 Concept Modelling
- WP2 Materials development
- WP3 Materials Testing
- WP4 Composites manufacturing and demonstration
- WP5 Structural Health Monitoring
- WP6 Guidelines, Standardisation and Sustainability
- WP7 Exploitation, Dissemination and Communication
- WP8 Project Management

Demonstration cases

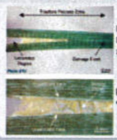
Bridges targeting 30 % improvement in durability and 30 % lifetime cost reduction	
Challenges	**DACOMAT solution**
High maintenance cost	High environmental resistance and mechanical durability
Severe traffic interruption in construction phase	Fast installation of prefabricated light weight elements
Large need for reinforcement of deteriorated old bridges	Reinforcement adding minimal additional weight preventing need for new fundamentation

Wind turbine blades targeting 30 % improvement in durability and 50 % reduction in blade related costs	
Challenges	**DACOMAT solution**
Low accessibility for inspection and maintenance	Remote damage detection and assessment
Revenue loss due to downtime	High damage tolerance preventing need for shutdown
High demands to upscaling at low costs	Higher tolerance for production imperfections and lower safety factors

(Additional applications: Marine structures, marine vessels, buildings, pipes, power transmission towers)

Technical developments

- Optimised systems of resins, fibres and fabrics to control and enhance fracture mechanical properties at micro and macro level
- Design to control initiation and arrest of cracks
- Combined fibre optics and acoustic damage detection tools
- Fracture mechanics based modelling tools for composite design



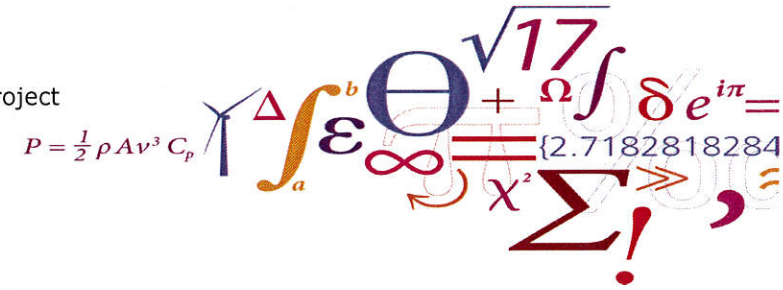
Example: Delamination of a glass fibre composite

Fracture process zone
- large-scale crack bridging in composites

Risk-based damage categorization and decision modelling

Nikolay Dimitrov

Work presented here is part of the DARWIN project



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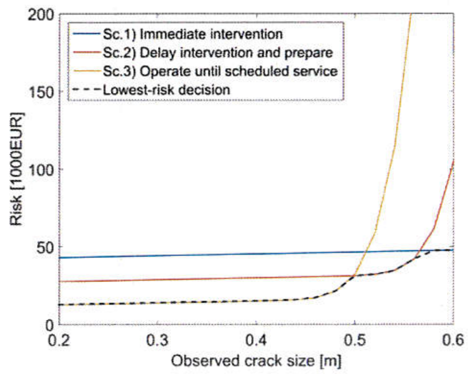
Department of Wind Energy

What can we improve?

Annual event rate							
$1 \cdot 10^{0}$							
$1 \cdot 10^{-1}$							0.6m
$1 \cdot 10^{-2}$							
$1 \cdot 10^{-3}$							
$1 \cdot 10^{-4}$							
$1 \cdot 10^{-5}$							
$1 \cdot 10^{-6}$							0.4m
Consequence	10^{0}	10^{1}	10^{2}	10^{3}	10^{4}	10^{5}	10^{6}

Risk: probability × consequence

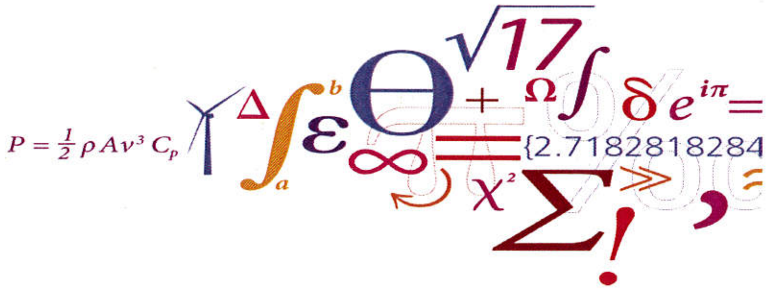
The risk-optimal decision



Estimated risk as function of trailing edge crack size for three mitigation scenarios. Dashed black line indicates optimal decision.

Lifetime Assessment and O&M

Anand Natarajan



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LifeWind Project Objectives

- The project focuses on quantifying the site specific design life of wind turbines and the process of life extension beyond 20 years.
- Put together clear requirements for life extension using interviews with TSOs, wind farm/turbine owners and certification bodies.
- Demonstrate procedures that
    1. quantify the risk of failure and the remaining structural reliability
    2. the maintenance costs upon extension of life
    3. Validates the process for life extension using data from wind turbine manufactures and wind farm owners
- Recommend procedures for a new IEC Technical Specification on wind turbine lifetime extension to the IEC advisory committee.

LifeWind Partners

DTU

ALL NRG a world of power

AALBORG UNIVERSITET

EUROPEAN ENERGY

SUZLON

Ørsted

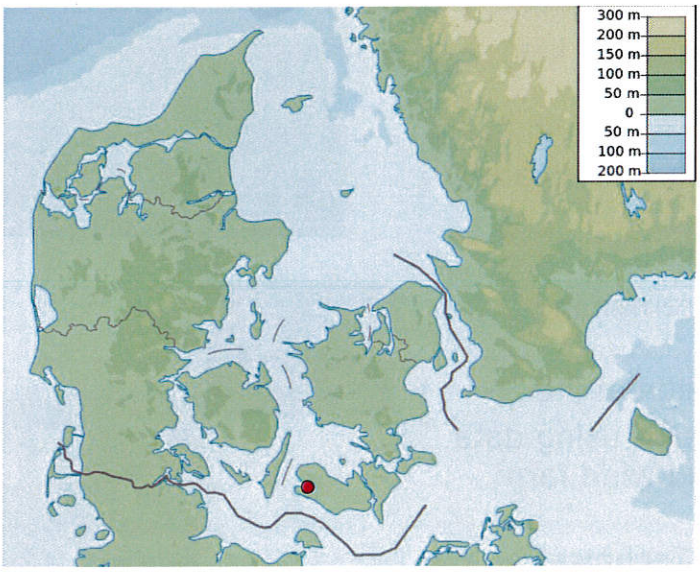
SIEMENS Gamesa RENEWABLE ENERGY

Energistyrelsen

DANMARKS VINDMØLLEFORENING

DNV·GL

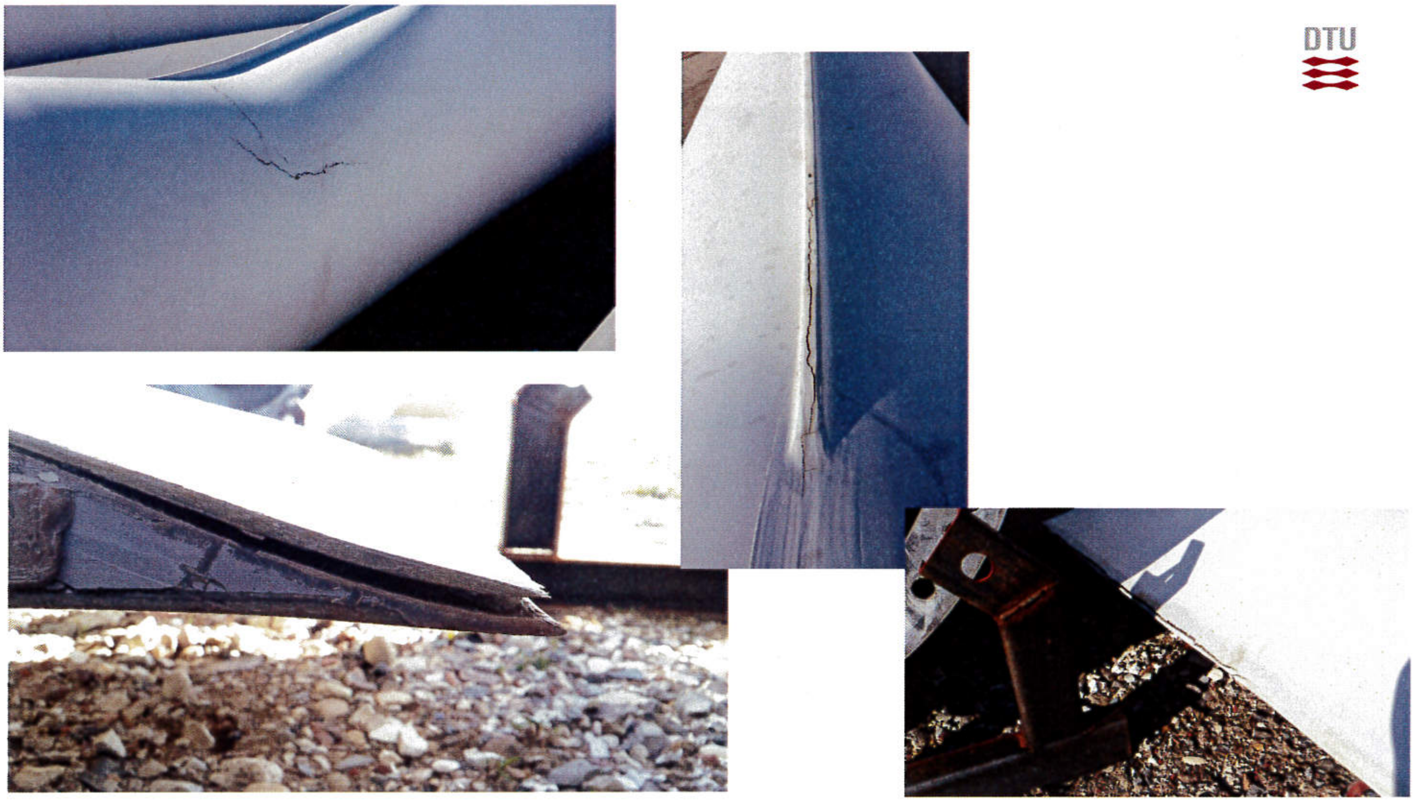
Vindeby Offshore Wind Farm
The first offshore wind farm in the world, made in 1991.



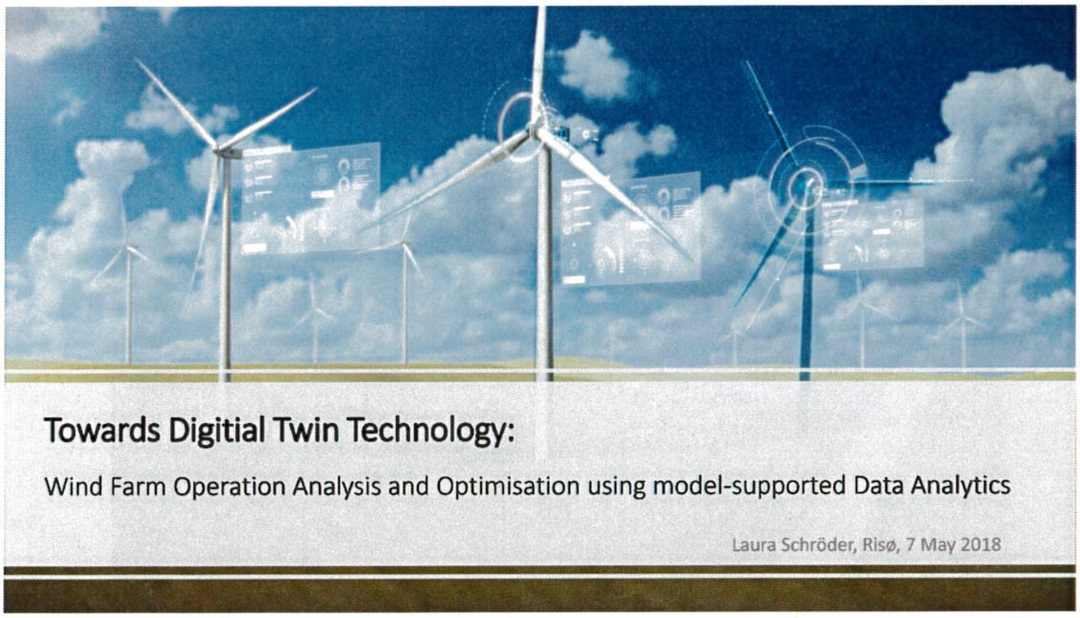
By Urutseg - Own work, CC0,
https://commons.wikimedia.org/w/index.php?curid=14617595

Country	Denmark
Coordinates	54°58′12″N 11°7′48″E
Status	Decommissioned
Commission date	1991
Decommission date	2017
Construction cost	75 million Danish kroner
Owner(s)	DONG Energy
Wind farm	
Max. water depth	4 m (13 ft)
Distance from shore	2 km (1 mi)
Hub height	35
Rotor diameter	35
Power generation	
Units operational	11 x 450 kW
Make and model	Bonus
Nameplate capacity	4.95 MW
Capacity factor	22.1%[1]
Annual net output	9.61 GW·h (lifetime average)

https://en.wikipedia.org/wiki/Vindeby_Offshore_Wind_Farm



predictive maintenance and advanced SCADA analytics



Laura Schröder • 2.
PhD Student bei DTU Wind Energy
Oldenburg, Lower Saxony, Germany

DTU

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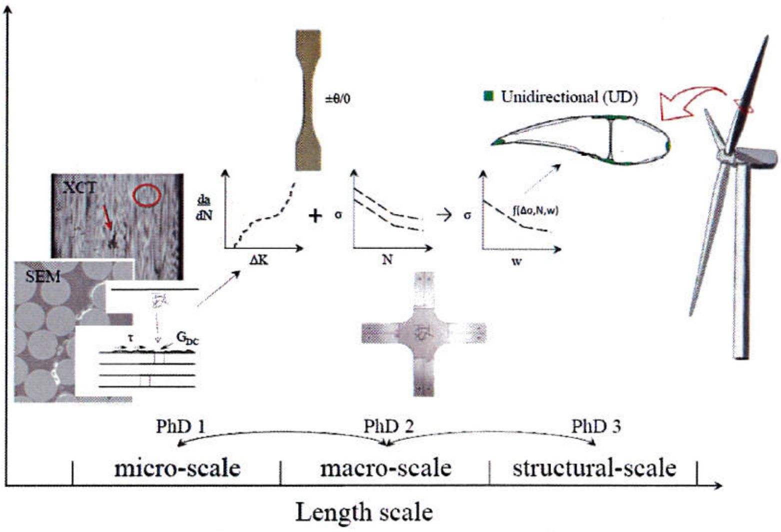
CASMaT Initiation Project overview

'Understanding fatigue through multi-scale testing and modelling'



gure 2: Overview of PhD studies and their synergy to investigate multi-scale and multi-axial fatigue damage mechanisms in wind turbine blades.

Blade O&M

TECHNICAL UNIVERSITY OF DENMARK

Report from the internship in Technical Integrity Management Department - Blade Team in Ørsted

May 15, 2018

Authors:
Agata Skupien

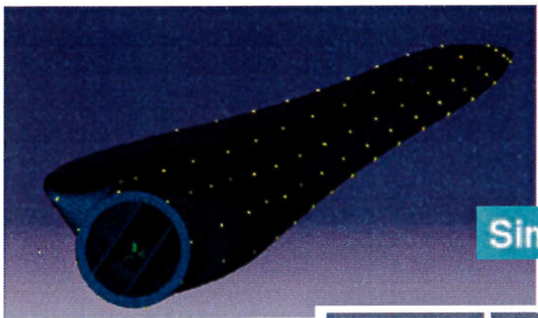
Student ID:
s146955

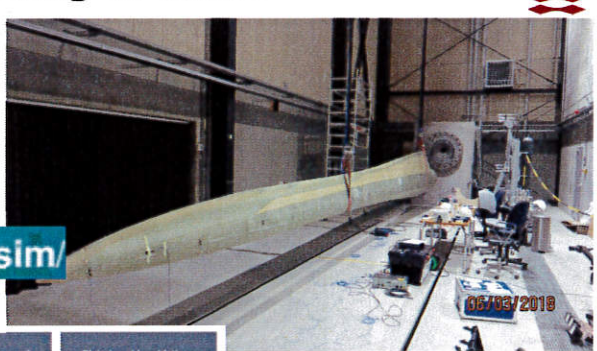
Supervisors:
Kim Branner
Marcin Luczak
Troels Rahbek Lindhard

- Performing damage evaluation for turbine blades as well as participating and performing failure investigation projects on turbine blades in collaboration with blade experts.
- Assisting the blade specialists on the team, with the work being focused on offshore wind turbine blades.
- Updating inspection and assessment tools together with the blade specialists as well as assisting in asset integrity communication and reporting.
-Ensuring correct data logging and database handling for turbine blade inspections.

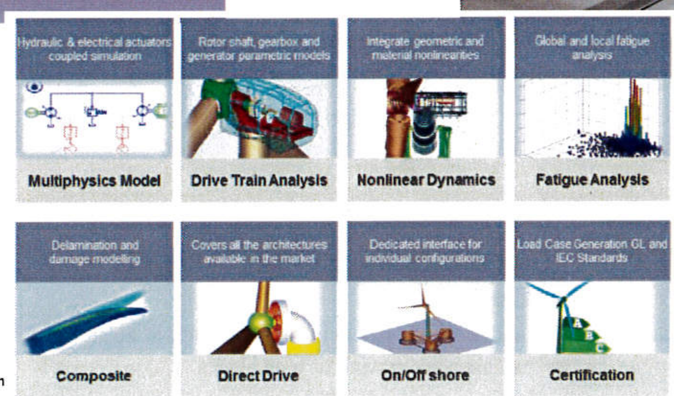
Agata Skupien • 1.
Mechanical Engineer devoted to Wind Energy / DTU Wind Energy Student
Kongens Lyngby, Capital Region, Denmark

Model Based Structural Testing of Blade



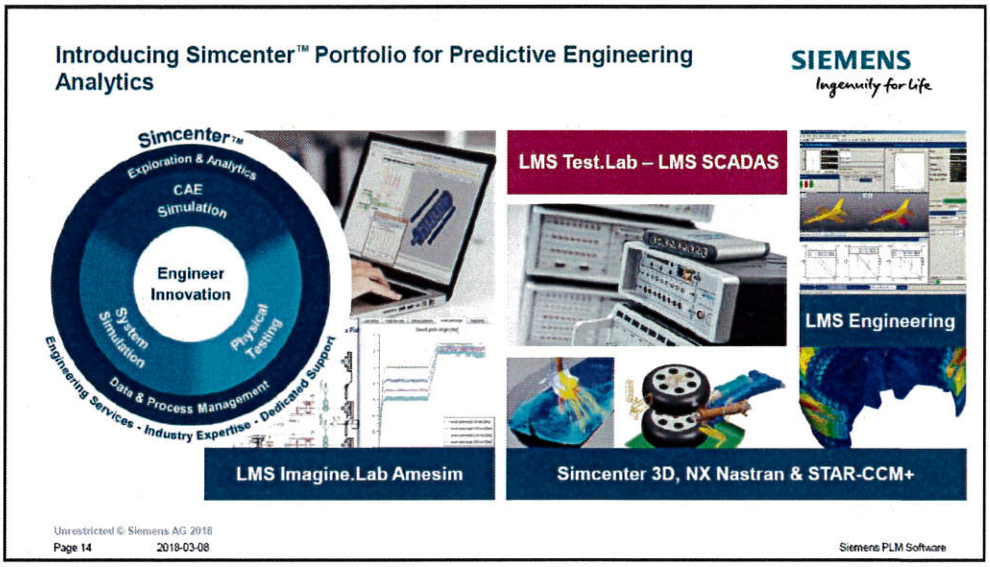


Simcenter Amesim/

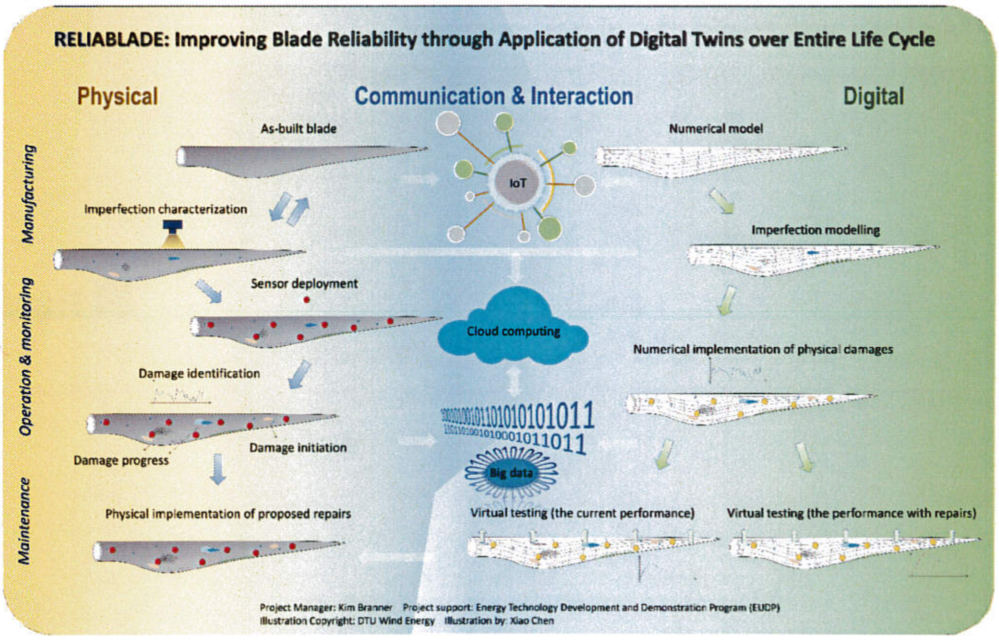


Olga Olkowicz • 1.
Student, Power Engineering, Warsaw University of Technology
Pow. warszawski zachodni, woj. mazowieckie, Polska

Research partnership with Siemens Industry Software



Reliablade EUDP - Project Concept
Coordinator: Kim Branner



Reliablade EUDP – Coordinator: Kim Branner

DTU

- WP 0: Project Management
- WP 1: Digitalization Platform
- WP 2: Blade Design
- WP 3: Blade and Component Manufacturing
- WP 4: Material Properties and Effects of Process-induced Defects
- WP 5: Subcomponent Testing
- WP 6: Full-scale Blade Testing
- WP 7: Dissemination/Commercialization

Track 1: Sensor Technologies

Track 2: Condition monitoring and Sensor technologies

Track 3: Multi-scale Modelling

Danish German cooperation programme and project

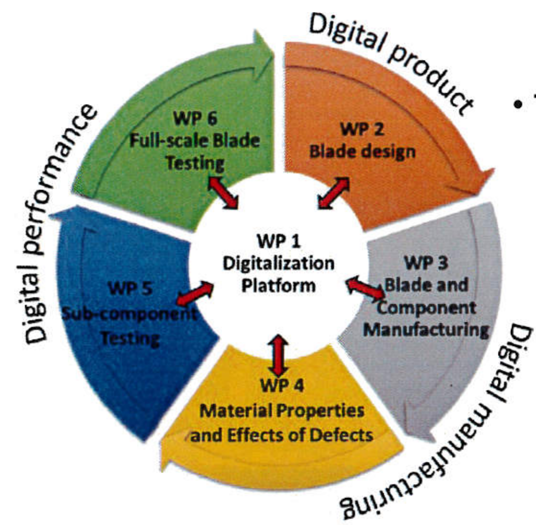
DTU

BladeMaker manufacturing center

Fraunhofer
IWES

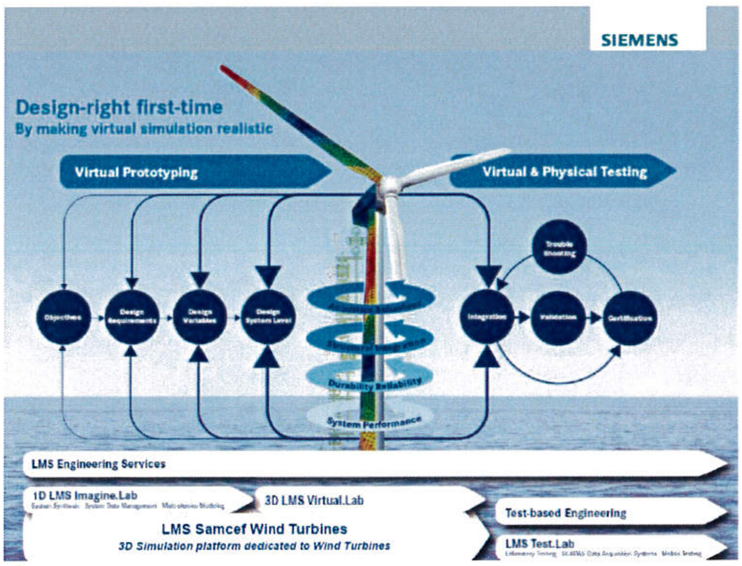
Fraunhofer Institute for Wind Energy Systems

Project Concept:
Digitalisation Platform for PLM (Siemens+IBM)



- **Two approaches to be combined:**
  - **Knowledge driven (Germany)**
  - **Data driven (Denmark)**

WT Blade Digital Twin



Project Partners

- **Vestas Wind Systems A/S**
- **LM Wind Power A/S**
- **IBM Danmark ApS**
- **FORCE Technology**
- **CEKO Sensors ApS**
- **Dantec Dynamics GmbH**
- **Siemens Industry Software NV**
- **DTU Compute**
- **Zebicon A/S**
- **Blade Test Centre A/S (BLAEST)**
- **Olsen Wings A/S**
- **DTU Wind Energy**

DTU

Thank you for your attention

附錄(六)：

DTU 結合動態測試及分析方法用於葉片創新設計之模型確效研究簡介

Integrated dynamic testing and analysis approach for model validation of an innovative wind turbine blade design

Siemens Industry Software:
Emilio Di Lorenzo, Simone Manzato, Bart Peeters

CEKO Sensors:
Kasper Reck-Nielsen

DTU Wind Energy:
Peter Berring, Marcin Luczak

DTU Wind Energy
Department of Wind Energy

Presentation outline

- Motivation and objectives
- Research team
- Object of investigation
- Test setup
- Results
- Conclusions
- Future outlook
- Acknowledgements

Motivation and objectives

IEC 61400-23:2014 © IEC 2014 – 25 –

10.4.2 Natural frequencies

As a minimum, the first and second flatwise and first edgewise frequencies shall be measured. The mass of the test instrumentation can influence the results of the natural frequency tests.

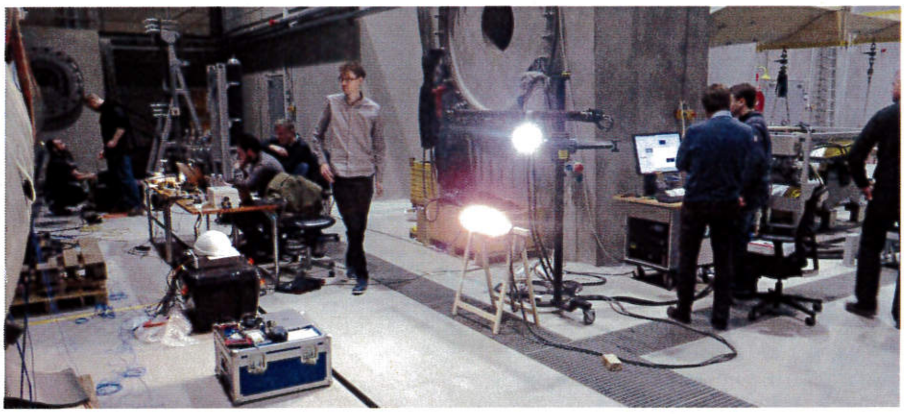
10.4.3 Optional blade property tests

Testing of other blade properties may be of interest. These may include (but are not limited to):

- damping;
- mode shapes;
- creep;
- mass distribution;
- stiffness distribution.

Research teams

- International, Intersectoral and Interdisciplinary



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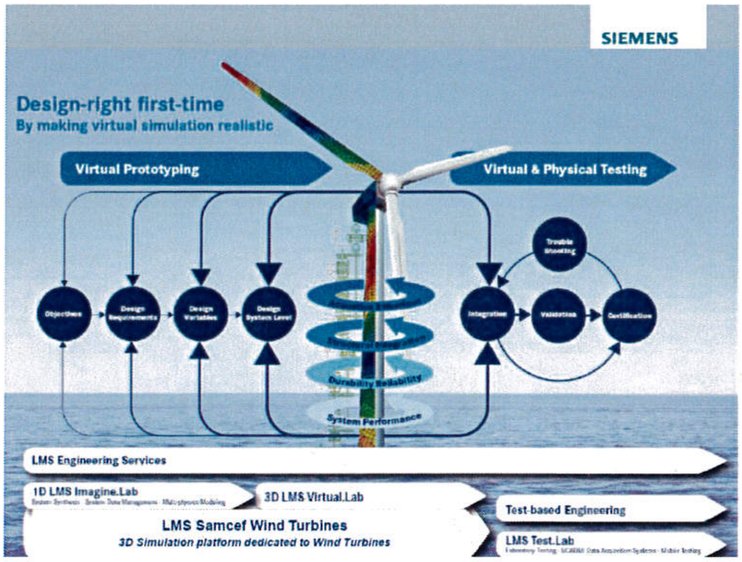
Department of Wind Energy

SIEMENS
Ingenuity for life

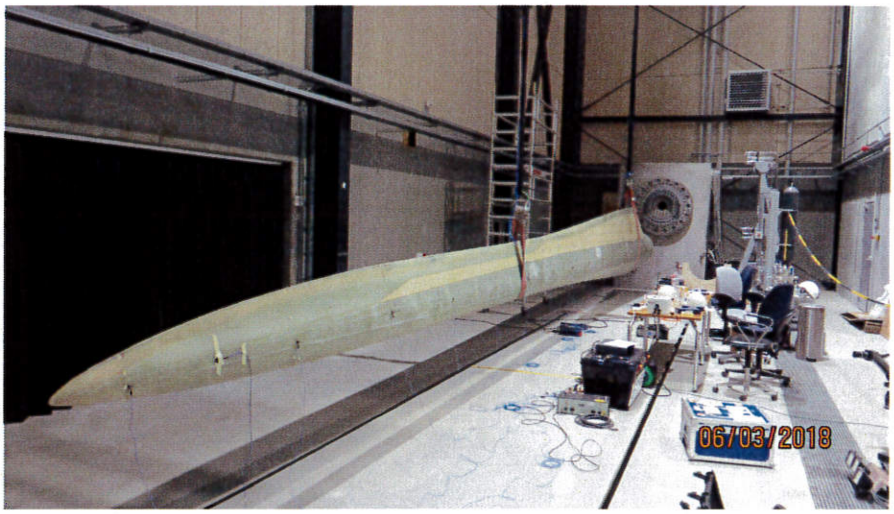
CEKO

Motivation – Digital Twin of the blade



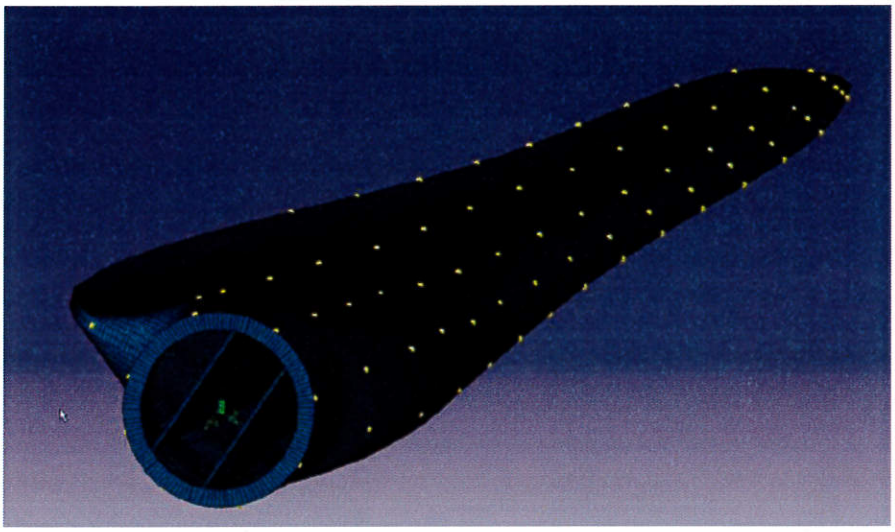
Object of investigation

- Object of investigation

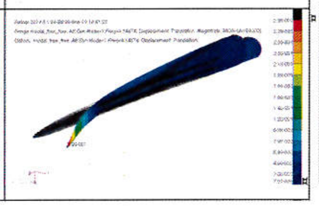
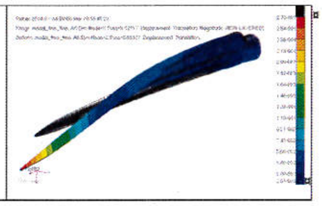
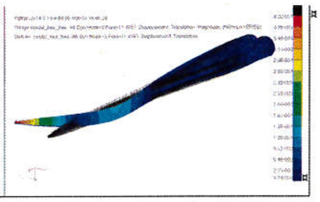


Object of investigation

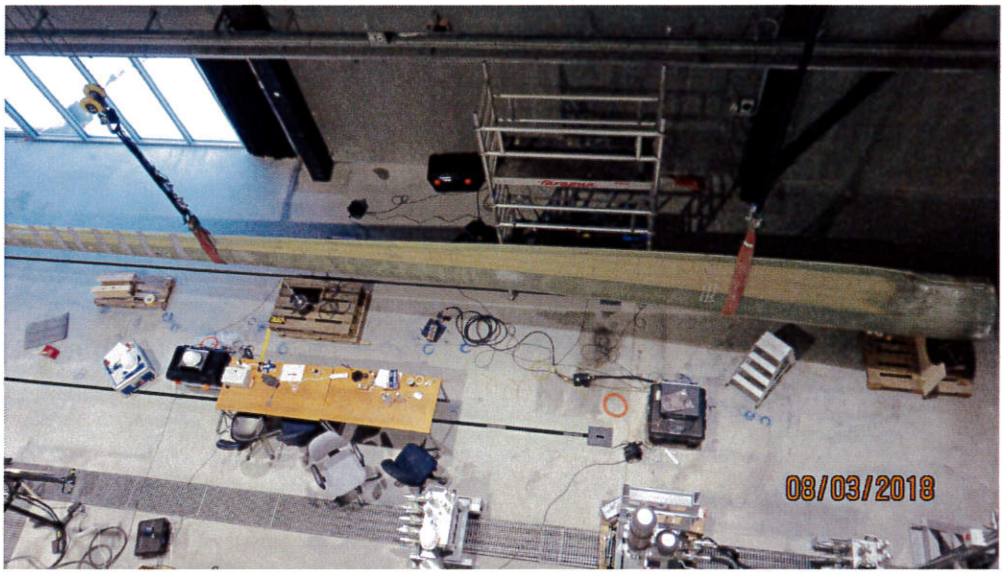
- FEM model of the blade with the measurement points



Modes from FEM model

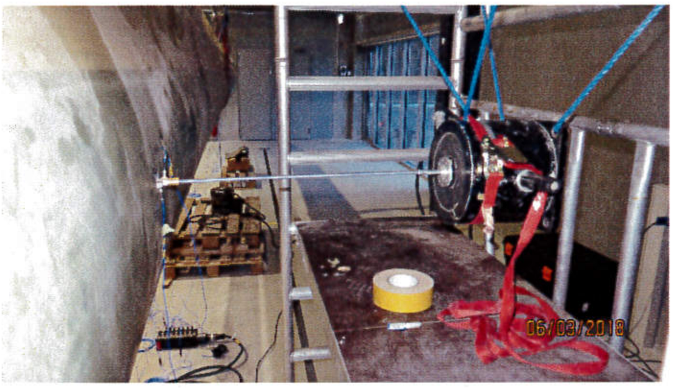
Mode [#]	Frequency [Hz]	Mode, numerical model
1, 1st flap mode	4.15	
2, 1st edge mode	9.82	
3, 2nd flap mode	11.42	
7, 1st torsion mode	36.26	

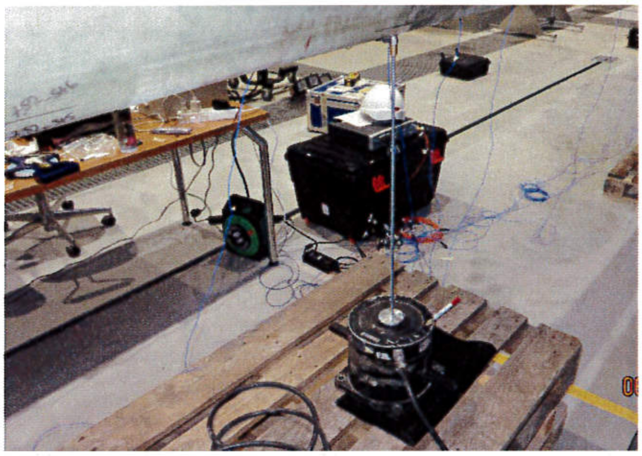
Test setup - overview



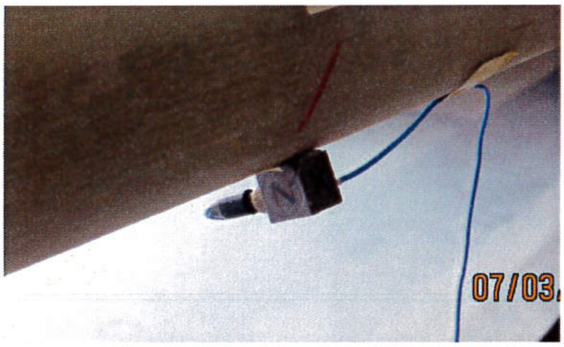
Test setup
free free support

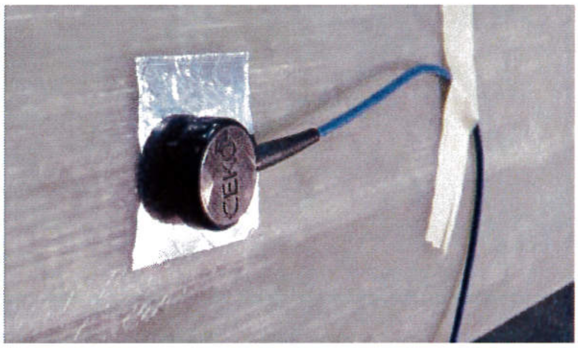
Test setup: Excitation

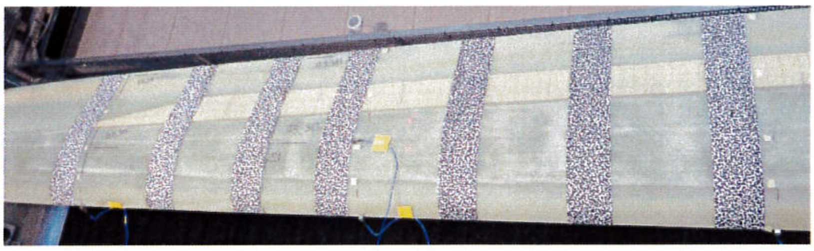




Test setup: Response

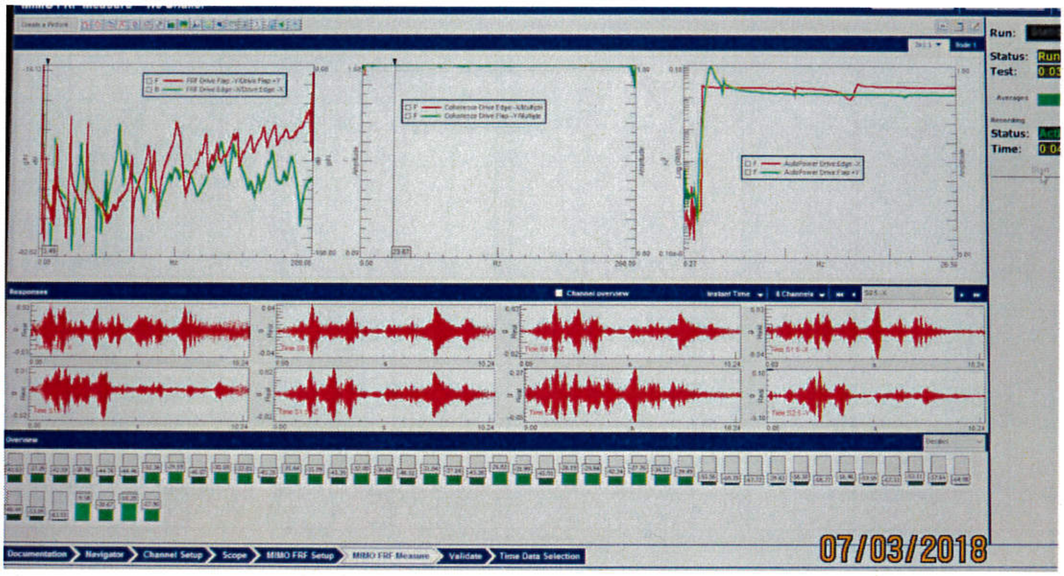






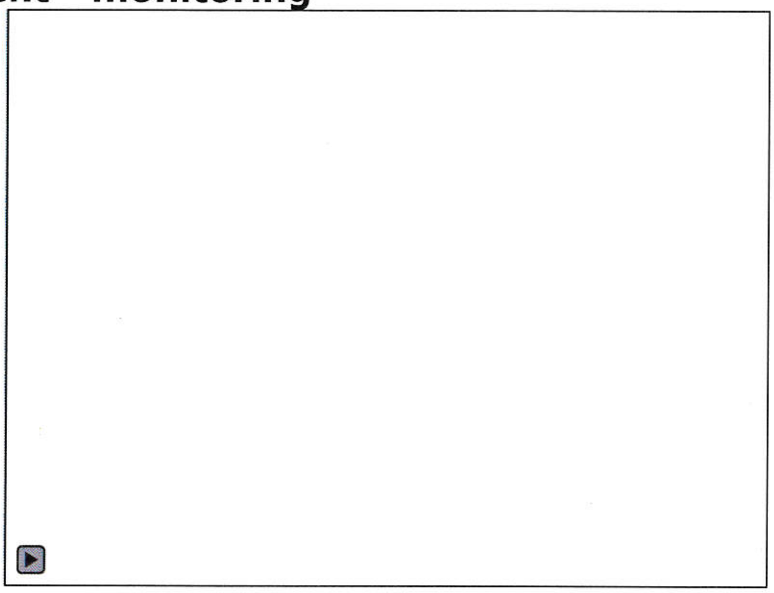
DTU

Measurement – software

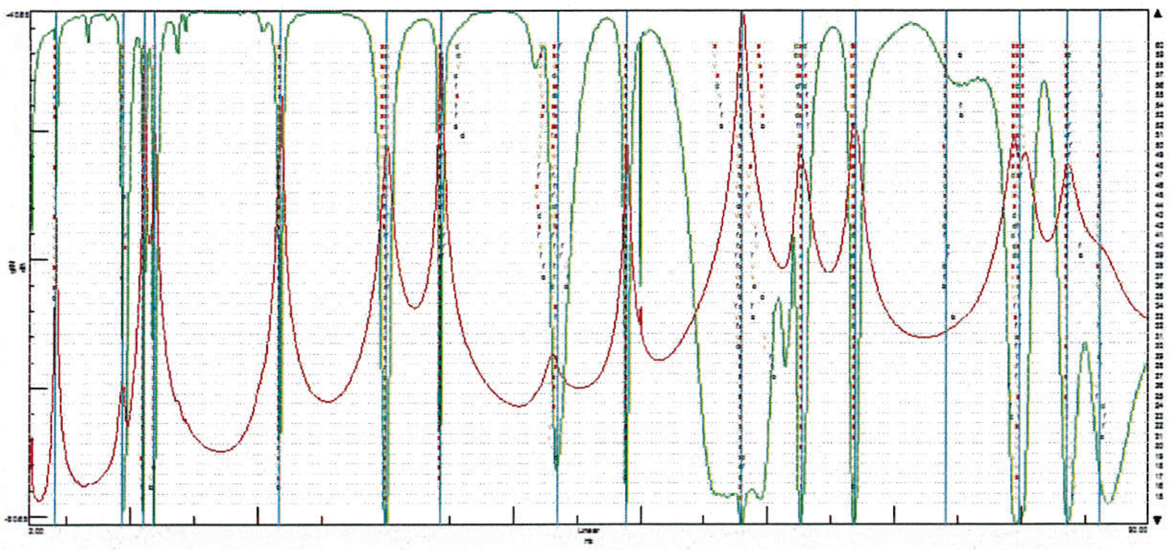


DTU

Measurement - monitoring

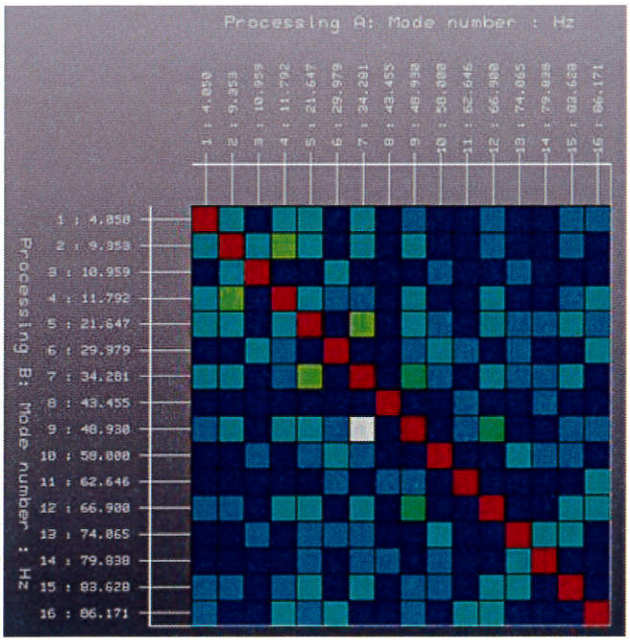


Stabilisation Diagram

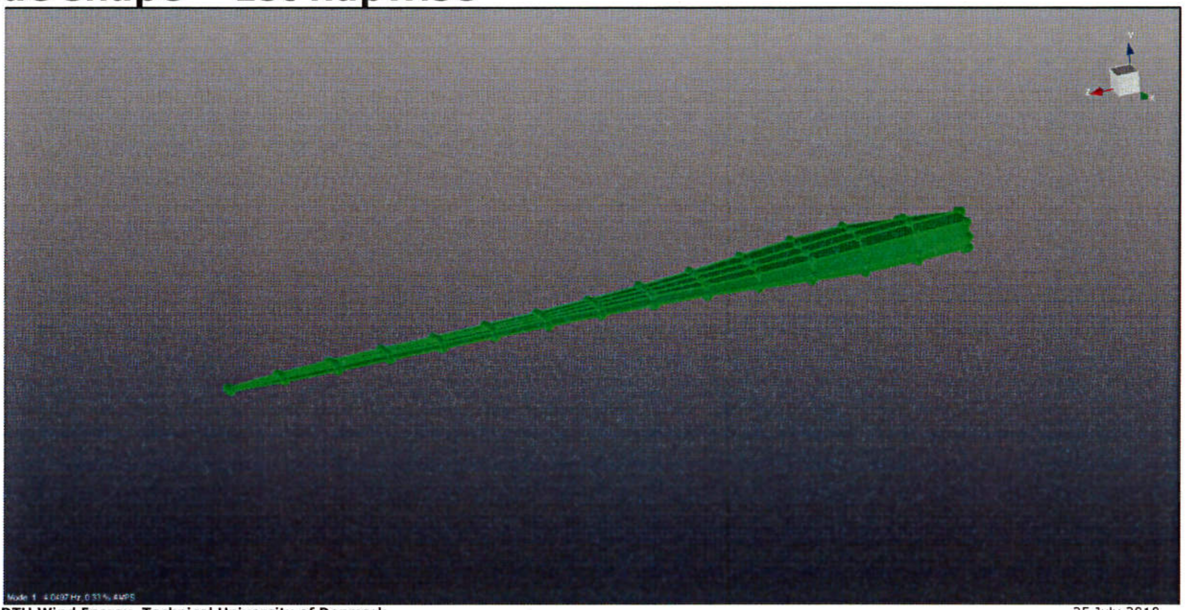


Mode frequencies, damping and Auto MAC

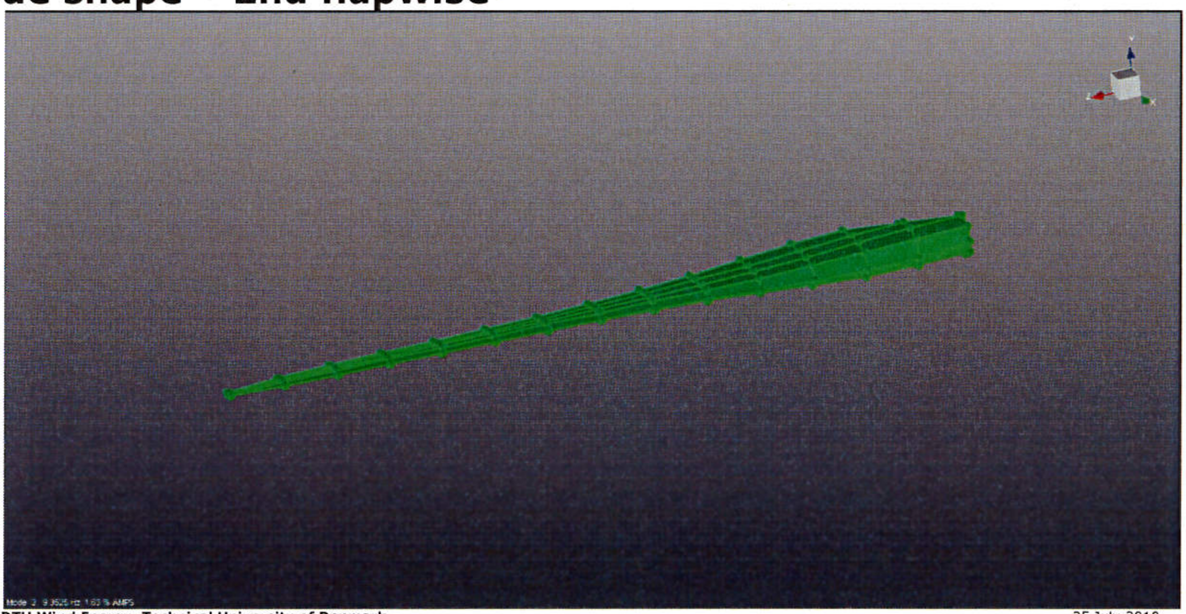
- Mode 1 : 4.050 Hz, 0.33 % AMPS
- Mode 2 : 9.353 Hz, 1.63 % AMPS
- Mode 3 : 10.959 Hz, 0.41 % AMPS
- Mode 4 : 11.792 Hz, 0.87 % AMPS
- Mode 5 : 21.647 Hz, 0.41 % AMPS
- Mode 6 : 29.979 Hz, 0.87 % AMPS
- Mode 7 : 34.281 Hz, 0.25 % AMPS
- Mode 8 : 43.455 Hz, 2.12 % AMPS
- Mode 9 : 48.930 Hz, 0.27 % AMPS



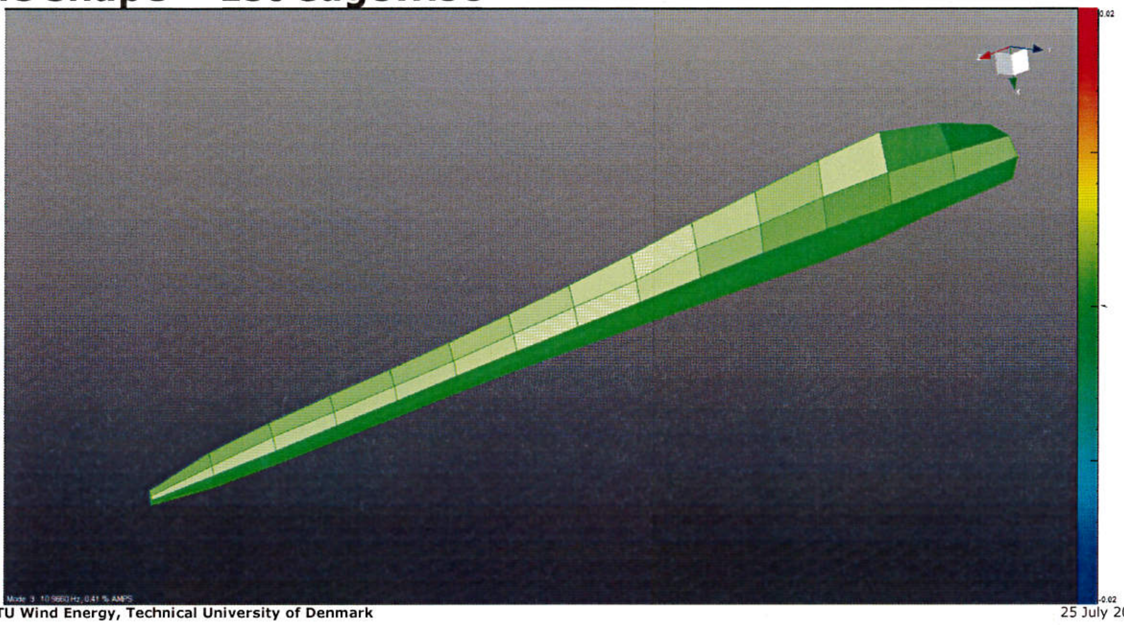
Mode shape – 1st flapwise



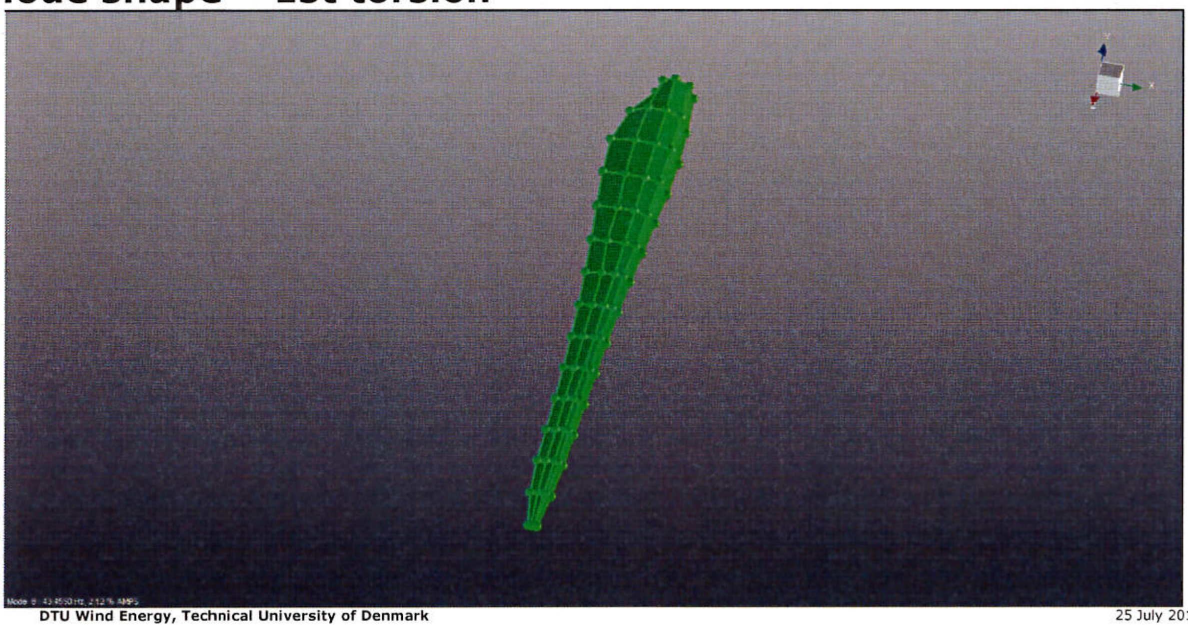
Mode shape – 2nd flapwise



Mode shape – 1st edgewise



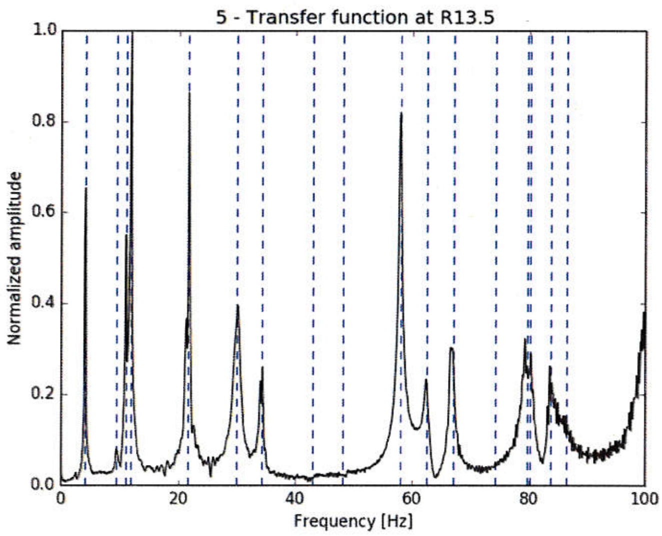
Mode shape – 1st torsion



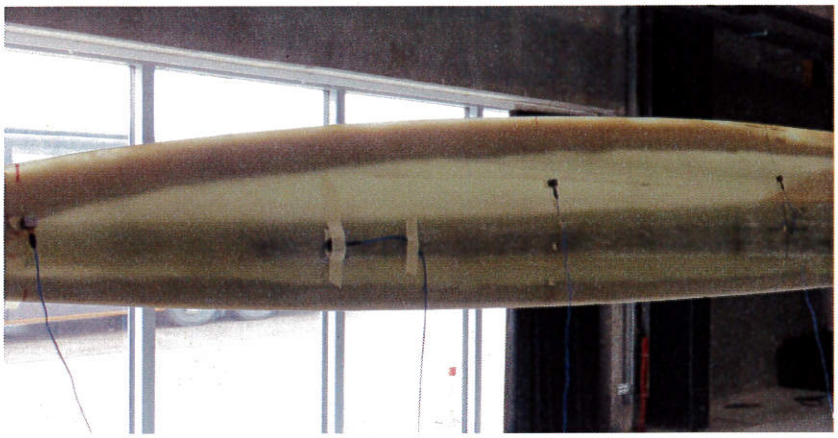
Results: comparison FE vs Experimental

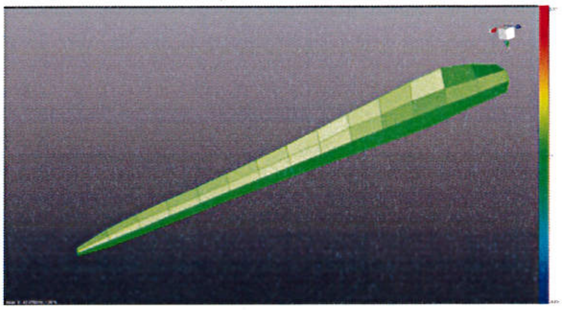
FE model	Experimental analysis	
Natural frequencies	Natural frequencies	Damping ratios
4.15 Hz	4.05 Hz	0.27%
9.82 Hz	10.97 Hz	0.41%
11.42 Hz	11.81 Hz	0.78%
36.26 Hz	43.08 Hz	1.39%

Results: CEKO optical accelerometer



Results: CEKO optical accelerometer





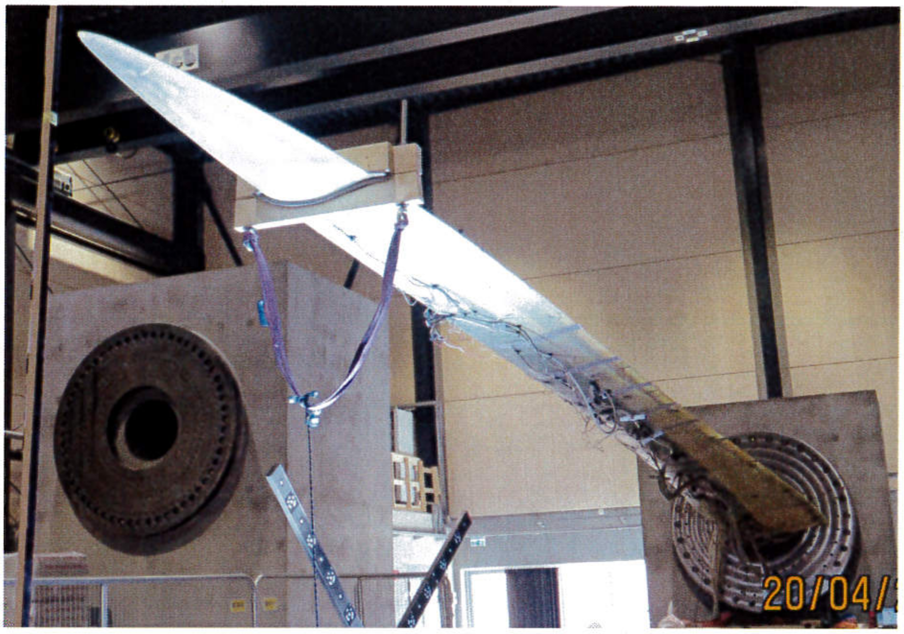
Conclusions:

- Different excitation techniques applied (impact, random, stepped)
- ICP and optical contact sensing principles used and assessed
- Modes are well separated
- All parameters of the modal model of the full scale blade estimated within 200 [Hz] bandwidth:
  - natural frequencies,
  - mode shapes
  - damping ratios
- Good consistency of the results from different methods and FE model

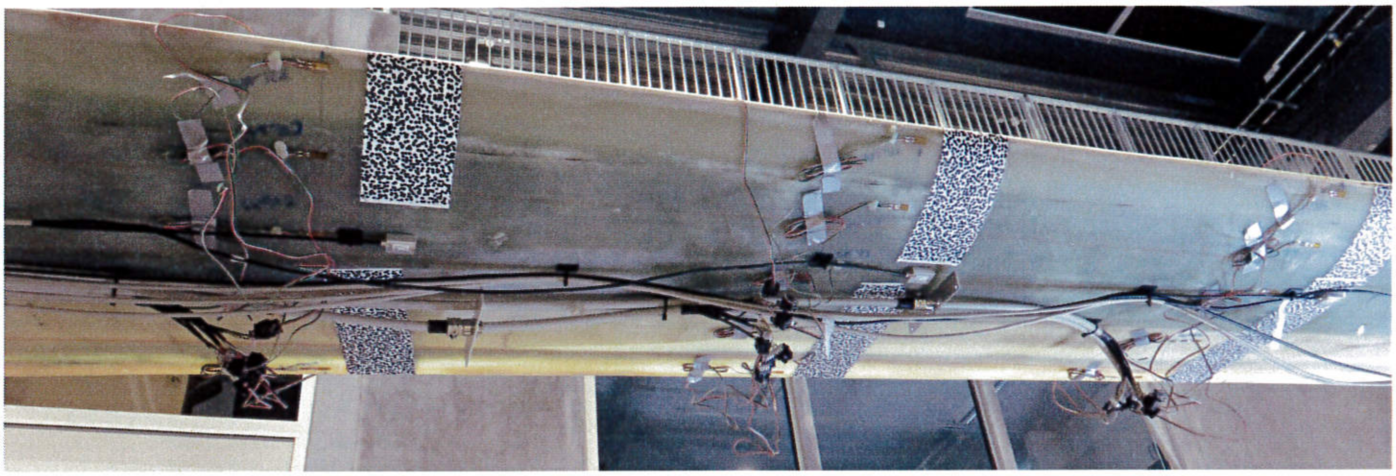
Future outlook:

- Investigate further the frequency difference for the Torsional mode
- Test-simulation correlation, model validation and updating,
- Uncertainty Quantification
- Test on the 2nd blade
- Pull and release, strain, output only modal analysis
- Dissemination:
  - ISMA, International Conference on Noise and Vibration Engineering
  - WindEurope Summit,
  - IMAC Conference & Exposition on Structural Dynamics.

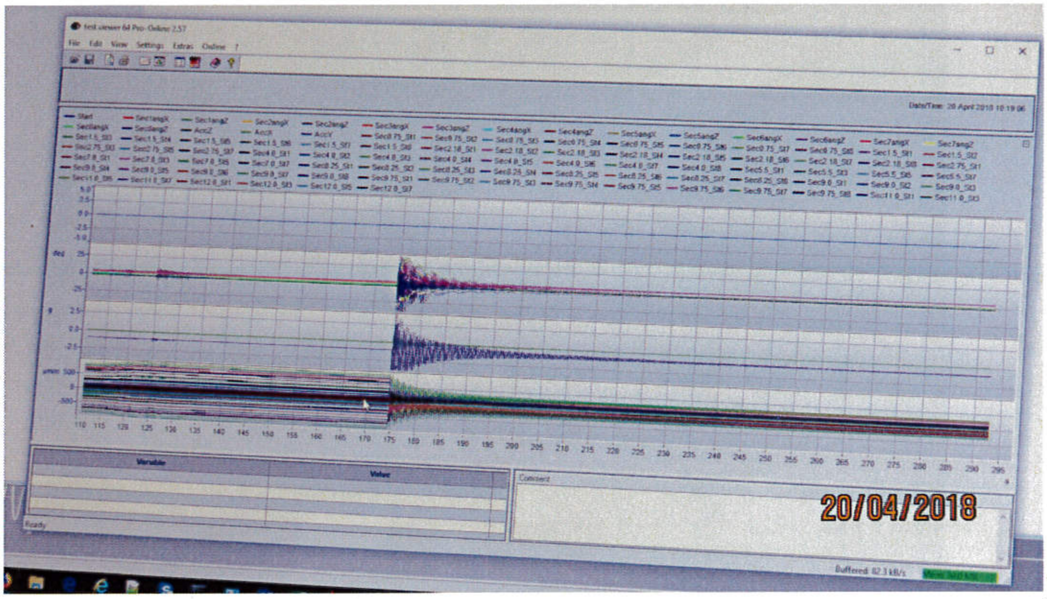
Pull and release free vibration test:



Pull and release test:



Pull and release test:



Pull and release test:

Differencies between the tests:

- Clamped – free support configuration
- Flapwise orientation
- Additional mass from cables and „saddle"
- Output only signals
- Stain gauges

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Thank you for your attention