Department of Wind Energy. Annual Report 2012

Larsen, Berit Carius; Kristiansen, Mette Bischoff

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Department of Wind Energy

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DTU Wind Energy
Technical University of Denmark
DTU Risø Campus
Building 118
Frederiksborgvej 399
DK-4000 Roskilde
www.vindenergi.dtu.dk

Editor in Chief
Berit C. Larsen

Editing:
Berit C. Larsen, Mette Bischoff Kristiansen

Layout:
Niels Larsen, SvendborgTryk

Photos:
Joachim Ladefoged
Troels Friis Pedersen
Siemens Press Picture
Joachim Ladefoged
Gregor Giebel
VibekeHempler DTU
Berit C. Larsen
etc.

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FROM THE HEAD OF DEPARTMENT

A STRONG BEGINNING FOR THE DEPARTMENT OF WIND ENERGY

DTU Wind Energy is a new department at the Technical University of Denmark with a specific focus on wind energy and a globally unique combination of research, education, innovation and public sector consultancy. The department was established January 1 2012 based on DTU's primary groups involved in wind energy, i.e. two groups from DTU Mechanical Engineering whose core activities are fluid dynamics and composite mechanics, two groups from the Risø DTU Materials Research Division, where the research is focussed on composite materials and metals and finally the former Wind Energy Division at Risø DTU.

Peter Hauge, Head of Department

Vision:
- DTU Wind Energy is a globally leading department for wind energy with technical-scientific competences in the international front and with a unique integration of research, education, innovation and public/private sector consulting
- DTU Wind Energy is a key contributor to the realization of the vision of Denmark as a "Wind Power Hub" and the activities support and develop the global wind energy sector with a special effort on national industrial development and innovation

Mission:
- To develop new opportunities and technology for global and Danish exploitation of wind energy and improve the competitiveness compared to other energy sources
- To develop technical-scientific knowledge and competencies in key fields, which are central for the development and use of wind energy and provide the basis for advanced education at DTU
- To facilitate the implementation and exploitation of research results through research-based consultancy and services to industry and the public sector, innovation and education comprising training courses at DTU

2012 was the beginning of new history writing for wind energy at DTU, having merged the key wind energy activities into the new department for DTU Wind Energy. The year has been a challenging year with new internal processes and responsibilities, but also an exciting and successful year with far reaching research results, a new educational programme, decisions on and inauguration of new technical facilities etc.

The creation of DTU Wind Energy shall be seen in the context of the global trends and European and national goals for a sustainable and secure energy conversion from carbon-rich towards green energy technologies. In Europe and globally ambitious energy policy targets have been set up, requiring wind energy to cover a large part of the electricity supply in the future energy system. For example, in the Danish Energy Agreement of March 2012 formed by the Danish Parliament, ambitious targets for a green conversion of the Danish society have been set up, namely 35 % renewable energy in 2020 and a 50 % share of the electricity consumptions supplied by wind energy. The ultimate target is to convert the total energy supply (electricity, heat, industry and transport) to renewable energy by 2050. On a global scale the energy and industrial policy objectives provide significant challenges for wind energy such as a reduction of the cost-of-energy, locating sites for a large number of wind farms, including the physical and the societal issues on-land and offshore as well as the integration into the Danish and European power system. These international and Danish targets for wind energy and the aim expressed in the MegaVind strategy for the public-private partnership to maintain and develop Denmark as a leading research and development center for wind energy provide the basis for the strategy of DTU Wind Energy.

Foto: Siemens press picture

The vision behind the creation of DTU Wind Energy is a mission-oriented DTU department with a globally unique combination of research, education, innovation and public sector consultancy. The overall objectives are to maintain and further develop Denmark as a leading knowledge and development center for wind energy and to support and develop the global wind energy sector. The department will with its close and well-established relations to all parts of the value chain in wind energy contribute significantly to DTU's mission in the energy area.

Hence the mission to develop new opportunities and technology for global and Danish exploitation of wind energy and improve the competitiveness compared to other energy sources, in the process to develop technical-scientific knowledge and competencies in key fields, which are central for the development and use of wind energy and provide the basis for advanced education at DTU and finally facilitate the implementation and exploitation of research results through research-based consultancy and services to industry and the public sector, innovation and education comprising training courses at DTU.

The research is cross-disciplinary and is organized in strategic research programmes and performed in cooperation between sections with Danish and international universities, research institutes and organizations as well as with the industry and users of the wind energy technology. The research takes its lead in critical challenges and needs for development and application of the technology, rather than in possible applications of more generic technical-scientific disciplines.

Furthermore, DTU Wind Energy is in charge of training and education in most wind energy related disciplines, comprising as different topics as aerodynamics, atmospheric physics and meteorology, aero-elasticity, aero-acoustics, composite materials, grid integration, offshore wind energy, dynamics of machinery, measurement techniques, and planning.

The cooperative and multi-disciplinary approach is evident in many of the research results and projects of the department, e.g. the Light Rotor project, which is a light-house project for the development of light very large wind turbine rotors, the combination of wind resource assessment and CFD modeling in WAsP CFD, the results on wake effects in wind farms of relevance for performance and loads on various time scales, the modelling of the electrical-mechanical dynamic interaction between grid and wind turbine and the integration of material research in the development of wind turbine blade technology with hybrid composites.

The international recognition and profile of the department is illustrated by the department being coordinator of several new EU FP7 projects in 2012 and the department's role in international R&D projects such as the Wind Atlas in South Africa.

Also the close research and innovation cooperation with the industry is witnessed by the inauguration of the Østerild Test Centre for Large Wind Turbines in October, the sale of the spinner anemometer patent and subsequent development cooperation, leadership of standardization groups and various software licenses.

As the only institution in the world, DTU Wind Energy offers a complete 2 years master program in wind energy. During the fall of 2012 a new European wind energy education was launched, the Erasmus Mundus European Wind Energy Master (EWEM), which is a two year double degree program in cooperation with NTNU, University of Delft and University of Oldenburg.

The Department comprises more than 240 staff members, including 160 academic staff members and nearly 60 PhD students, and 8 sections.

In the following pages you can read about some of the key activities, cooperation and achievements that have taken place during last year.

HIGHLIGHTS 2012

4 January 2012

New Year's reception at DTU Wind Energy

Head of Department Peter Hauge Madsen reported on the creation of the new Department of Wind Energy.

"We have gone through a rapid process in which the new department has been developed. The department now includes the following eight sections:

Composites and Materials Mechanics, Materials Science and Characterisation, Fluid Mechanics, Test and Measurements, Wind Turbine Structures, Aeroelastic Design, Meteorology, Wind Energy Systems.

We start from scratch building up a new department. It is a unique opportunity to build up a new and strong and globally very competitive wind energy research organization and despite the financial crisis, the outlook for the coming year is promising and we expect increased cooperation with bot industry, universities and other countries.

27 January

Wind Energy Department day at DTU Lyngby

All employees were invited to participate in the first seminar where an overview of all scientific activities in the new department was presented. Another purpose was to get to know each other in the new department.

The head of sections presented their activities and plans.

27 January 2012

Inaugural Lecture by prof. Torben Mikkelsen

On the 1st of May 2011 Torben Mikkelsen started as Professor of Remote Measurement of Wind. 27 January 2012 he held his inauguration lecture entitled "Atmospheric Boundary-Layer Research - from Nuclear Safety two Wind Energy - in a Remote Sense. The lecture was followed by a reception.

21 February

A spinner anemometer patent was sold

Department of Wind Energy has sold the patent for the Spinner anemometer technology to the company ROMO Wind. The technology can do yaw control more accurately and will improve production and give a higher return for wind turbine owners.

16-19 April

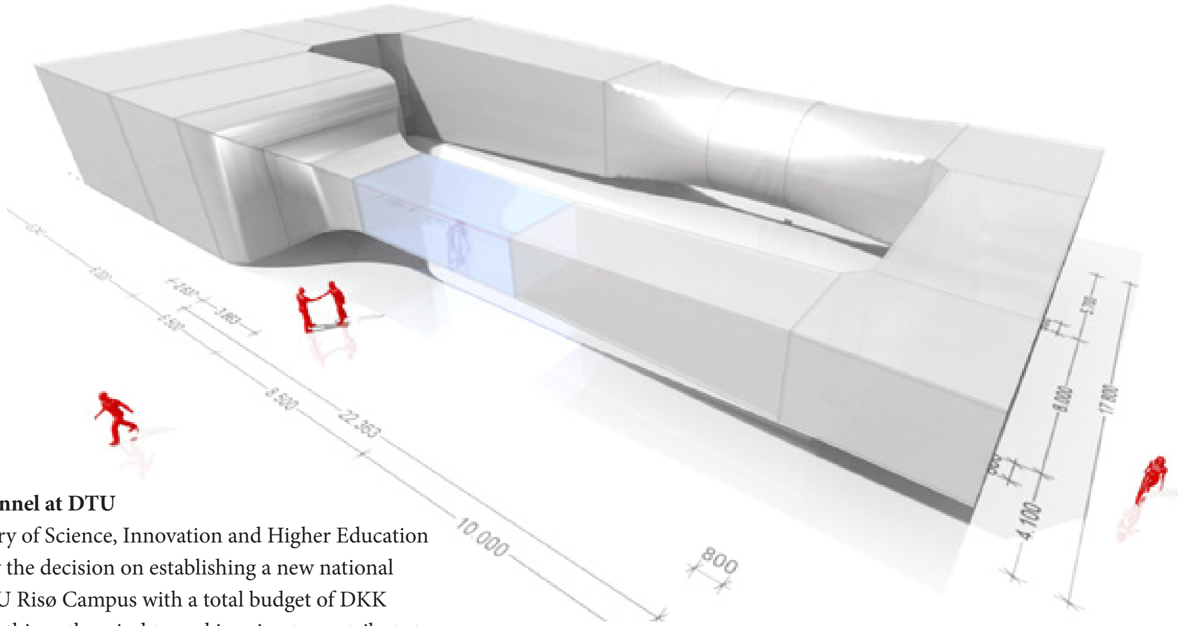
EWEA 2012 – in Bella Centret, DK

Europe's leading wind energy event, the annual EWEA conference, was this year held in Denmark at the Bella Center. Department of Wind Energy had a stand outside where the wind car and wind scanners attracted a lot of attention, as well as a large stand in the exhibition area.

Price given at the DTU Annual commemoration 27 April 2012 Best teacher of the year at DTU

Henrik Bredmose was awarded the price Teacher of the Year 2012 at DTU.

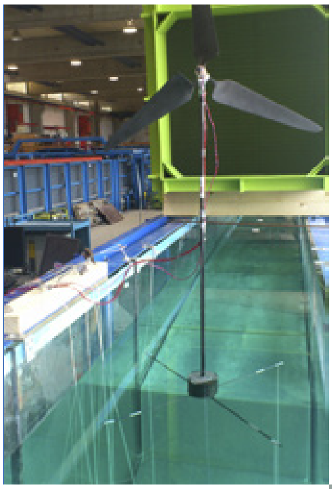
Henrik is Associate professor in Offshore Wind Energy at Department of Wind Energy.



May

National Wind Tunnel at DTU

The Danish Ministry of Science, Innovation and Higher Education announced 16 May the decision on establishing a new national wind tunnel at DTU Risø Campus with a total budget of DKK 74m. Among other things the wind tunnel is going to contribute to the development of the future generations of wind turbines.



June

Grøn Dyst Competition

In the spring of 2012 an experimental bachelor project with a floating wind turbine was carried out in the Coastal Engineering lab at DTU Mechanical Engineering. A model scale floating TLP (Tension Leg Platform) wind turbine was exposed to simultaneous wind and waves. The project addressed the structural dynamics from the combined loads and included the construction of the green open-jet wind tunnel shown on the picture. The two students Anders Mandrup Hansen and Robert Laugesen were awarded the Energinet.dk prize at the DTU Grøn Dyst competition for the project. Supervisors were Robert Mikkelsen and Henrik Bredmose, DTU Wind Energy.

September

New Erasmus Mundus

A new European Wind Energy education, the Erasmus Mundus European Wind Energy Master (EWEM), was initiated autumn 2012.

11 June

Wind Power Day

Monday 11 June DTU Wind Energy was hosting the Wind Power Day 2012 with the theme Optimising Reliability.

Around 120 participants did on the annual wind power day listen to many presentations giving an up to date status of the wind energy research fields and many interesting research results.

22-23 August

Staff Conference at L.O. Skolen

Around 180 staff members were gathered at the conference facility “LO skolen” in Elsinore at the wind energy department’s Staff Conference.

The purpose of the seminar was to develop the strengths and competencies and get a mutual understanding of the differences in the newly merged department.

We discussed and exchanged ideas on values and visions based on which DTU Wind Energy in the future should be developed.

22-25 August 2012

Wind Car Race

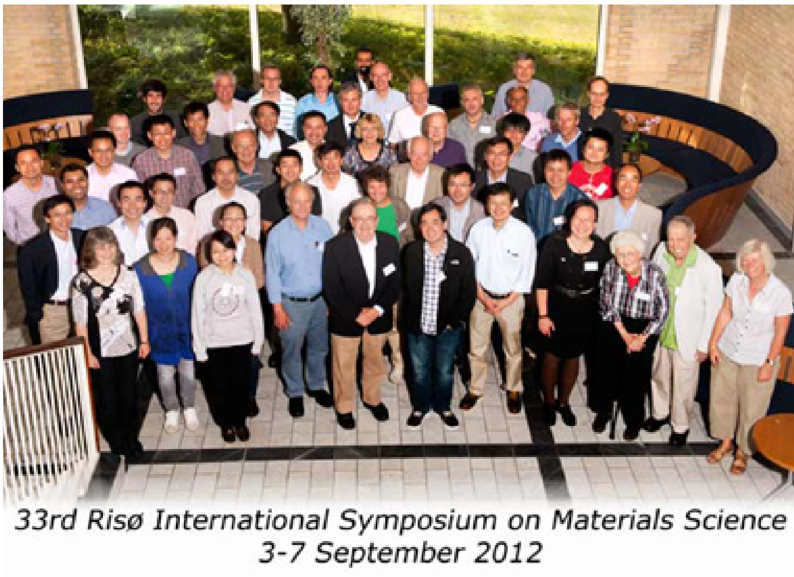
22-25 August DTU Wind Energy participated in the contest to become the fastest driver against a headwind in Den Helder, Netherlands. DTU Wind Energy took part in race along with 7 other teams with 10 specially-built cars. DTU brought 2 cars, last year’s winner car with mechanical transmission and this year’s new car built with an electrical transmission.

Canada ended up as number one and DTU at a second and fifth place.

6 October

Inauguration of Østerild

October 6 the Test Center Østerild opened and the event was indeed a public event. One of the aims of the event was to invite neighbours, industry etc. in order to present the center and tell what is going to do happen here in the future.



3-7 September

33rd Risø International Symposium on Materials Science: Nanometals - Status and perspective

At present, nanometals and nanotechnology is an important part of national and international programmes in USA, Europe, China and Japan, and the symposium included a series about nanometals and nanotechnology.

A holistic approach characterised the themes of the symposium encompassing synthesis, characterisation, modeling and performance also under extreme conditions.

24 September

Green Smiley from the Danish Working Environment Service

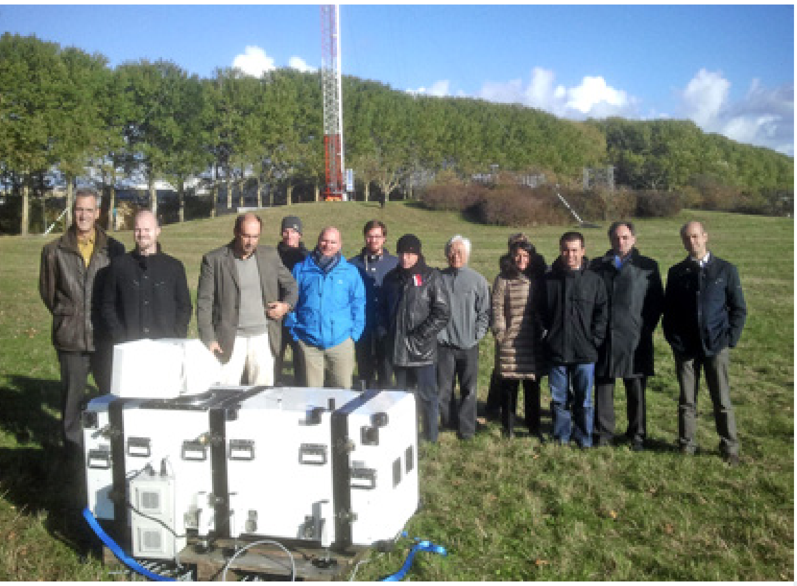
On Monday 24 September The Danish Working Environment Service (Arbejdstilsynet) visited our department.

They didn't find any problems related to our working environment and consequently we have received a green smiley.

14-15 November

Kick-off Meeting FP7 InnWind project

On Nov 14-15, DTU Wind Energy hosted the Kick-off meeting for the EU FP7 supported the very large INNWIND.EU project which aims at innovation that enable the realisation of the giant 20MW offshore wind turbine. Approximately 65 people from twenty seven partners from different European organisations participated in the kick-off meeting.



25-26 October 2012

Kick-off Meeting – ESFRI Project The European WindScanner Facility

DTU Wind Energy hosted the Kick-off meeting of the EC supported ESFRI WindScanner Preparatory Phase project. Thirty participants from 10 different European partner organisations participated in the kick-off meeting held at DTU Wind Energy at DTU Risø Campus.

The aim of the project is to prepare the administrative, legal, financial and technical issues necessary for the establishment and operation of the new European WindScanner Facility, a joint European Research Infrastructure with a central node hosted by DTU Wind Energy, and with several regional nodes distributed in other European countries.

23 November

Deepwind Milestone

In November a milestone in the DeepWind project where the scale model was installed in Roskilde fjord was marked and the involved participants were invited. The scale model is an innovative floating vertical axis wind turbine.

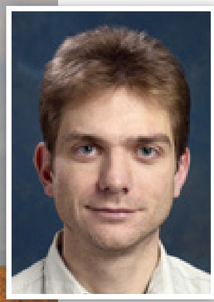
December

IEC 1906 Award 2012 to Poul Sørensen

Poul Sørensen from DTU's Department of Wind Energy has just received the international award "IEC 1906 Award 2012" for his unique efforts in international standardisation work for electricity-generating wind turbines.

THE WIND ATLAS FOR SOUTH AFRICA

The big impact wind resource project that strengthens collaboration within the department engages across national institutions in South Africa and paves the way for national wind resource projects globally.



By Jake Badger

By Jens Carsten Hansen

The Wind Atlas for the South Africa project is an initiative of the South African Government, Department of Energy (DoE), and the project is co-funded by the UNDP-GEF through the South African Wind Energy Programme (SAWEP), and the Royal Danish Embassy. South African National Energy Development Institute (SANEDI) is the Executing Partner who is responsible for coordination and contracting the implementing partners: Council for Scientific and Industrial Research (CSIR), South African Weather Service (SAWS), University of Cape Town (UCT), and DTU Wind Energy.

In Cape Town on 13th March 2012, South Africa's Vice Minister for Energy Barbara Thompson launched the First Verified Numerical Wind Atlas developed by DTU Wind Energy in collaboration with South African project partners. The event attracted a large amount of media attention with 54 broadcast, web and print media, Figure 1.

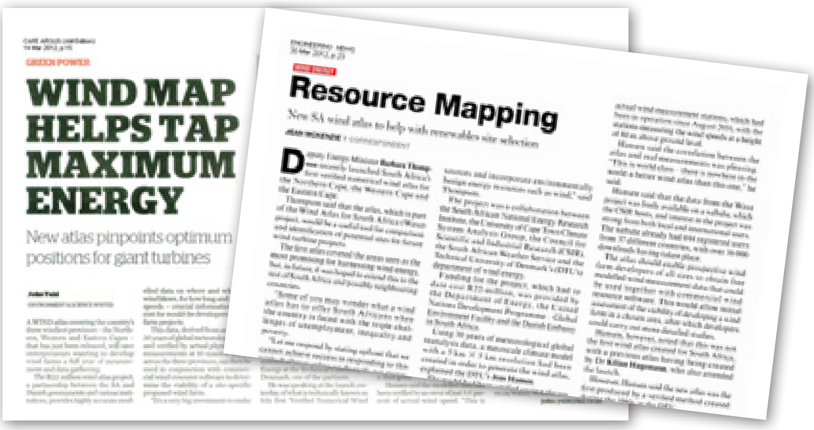


Figure 1:
Newspaper clipping from Cape Argus and Engineering News. Source: At Vogue communications agency.

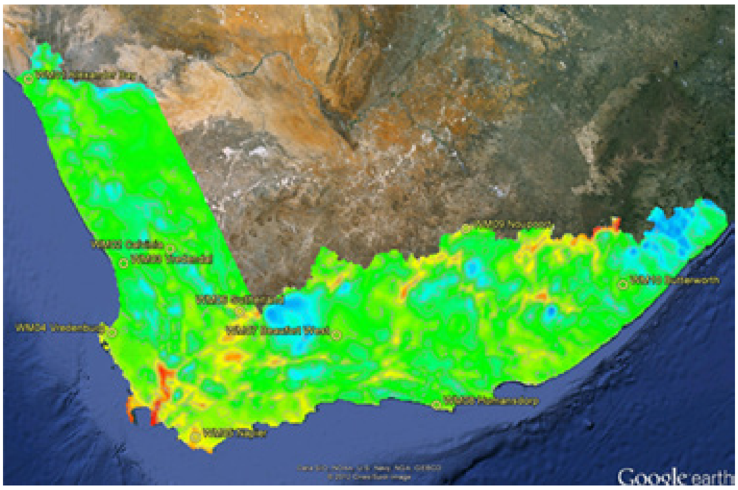


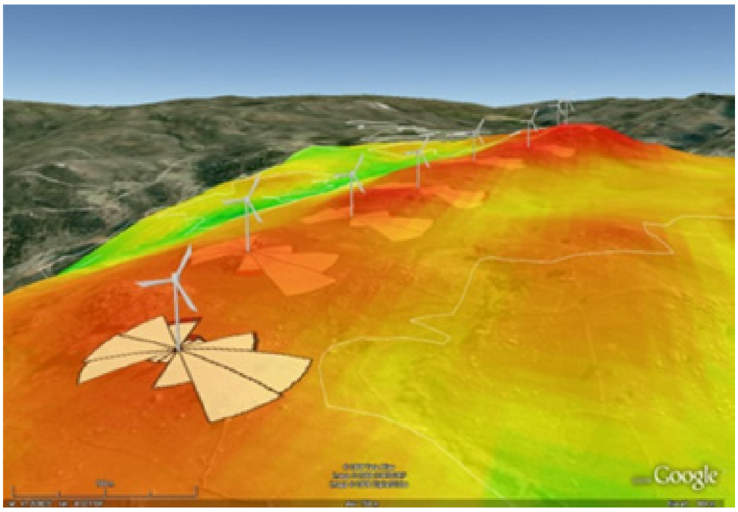
Figure 2:
First Verified Numerical Wind Atlas for South Africa - Generalized climatological (30-year) annual mean wind speed [m/s] 100 m above ground level, flat terrain, 3 cm roughness everywhere. The circles show the location of the projects 10 measurement stations

South Africa aims to replace a significant proportion of it consumption of fossil fuels with generation from sustainable sources. In harmony with that national objective, this project's object is to improve knowledge and quality of wind resource assessment methods and tools, as well as to ensure availability of tools and data for planning and application for wind farm developments, off-grid electrification and extreme wind studies.

The project has the following component, mesoscale modelling (Figure 2), wind measurement, microscale modelling, application (Figure 3), extreme winds, documentation and dissemination. All the output is in the public domain. For example the first verified wind atlas is available at http://wasadata.csir.co.za/wasa1/WASA-Data and mesoscale wind forecasts are available at http://veaonline.risoe.dk/wasa. Measurement data is available in real-time on http://www.wasa.csir.co.za. Since the launch (as of 7th December) the number of registered users accessing the data is 1099, from 47 countries, with over 28000 downloads. The users range from public, private and education sectors.

The project is a role model for how future national wind resource assessment may be carried out, not only in terms of the project content but also in the interplay between project partners. The South Africa project partners and their engagement with associated government and planning institutions give the wind atlas project a big impact. For example, in a workshop in December 2012 at the Department of Energy, South Africa, it was possible for DTU Wind Energy and the South African partners to speak directly to national planners at the highest level. In addition, it already has strong links with the IRENA coordinated Global Atlas for Solar and Wind. Within DTU Wind Energy the strong team effort across three sections makes such large projects possible, and through the outreach with international partners we are creating the basis for global development.

Figure 3:
Application of wind atlas data for wind farm feasibility studies. Source: Hansen and Mortensen



MORE POWER FROM THE WIND TURBINES – AN INNOVATION STORY

In the lifetime of a 2MW wind turbine it produces power at a value of 10 million Euros. Any small improvement of the turbine will therefore increase the outcome significantly. Such an improvement is achieved with the DTU patented invention, the spinner anemometer. This invention is fully commercialized now as ROMO Wind A/S bought the patent rights and is marketing it for retrofit on the worlds existing 125.000 wind turbines.

By Troels Friis Pedersen

The spinner anemometer consists of the known and robust sonic anemometer technology.

The financial crisis is a strong incentive for wind farm owners to get the most out of their wind turbines. A power increase of 3% will give the wind farm owner 15.000 Euros more – every year. Bad tracking of the wind causes loss of power. A yaw error of 10° gives losses of 3%. The reason should be found in the mounting of wind sensors on the nacelle, behind the rotor, where the wind is very disturbed.

In 2004 professor Troels Friis Pedersen realised that the measurement of the wind could be improved significantly by moving the wind sensors from the nacelle to the spinner. He made an invention to utilize the flow over the spinner to measure yaw error and wind speed. Risø patented the invention which DTU then took over. However, the invention needed funding for verification of the concept. Such funding was achieved from the so-called Gap-funding. The funding was small but enough to produce prototype sensors. The invention was then introduced to manufacturers, and Siemens was interested. They funded testing of the invention in a large wind tunnel. Later they participated in an EFP project for tests on one of their wind turbines at Høvsøre test site. Tests were successful. Then five improved prototypes were produced, and they were tested on contracts with commercial wind turbine manufacturers. However, the manufacturers were still not ready to introduce them on their turbines. Manufacturers are very conservative. When they develop a component for a wind turbine they test various types until they are sure it works sufficiently for twenty years. When they have chosen the best they rely on it and it really takes a lot to accept a substitute. The market was still not ready for the new type of sensor. An EUDP project with Vattenfall was then established to verify performance improvement of a whole wind farm.

In 2011 ROMO Wind A/S was established by very experienced people from the Danish wind industry. The purpose of the company is to improve the performance of wind turbines. They saw the potentials of the spinner anemometer, and they achieved the patent rights in the beginning of 2012. They installed many spinner anemometers on customers wind turbines, and they found yaw error statistics that show 60% of the turbines have a yaw error of more than 6°, with an average of 7.5°, corresponding to losses of 2%.

Cooperation with ROMO Wind and Vattenfall continues in a new EUDP project to demonstrate full retrofit yaw error solutions to wind farm owners.

WIND EXPLORATION; FINDING WIND AND HUMAN RESOURCES

The DTU developed PC-software WAsP has for 25 years been the industry-standard for wind resource assessment and siting of wind turbines. During 2012, a collaborative project between DTU Wind Energy and enterprising industry partners has brought cutting edge technology to WAsP by engaging large human resources at DTU and in the Danish wind industry.

By Andreas Bechmann

Like crude oil, the wind is a resource that can be extracted and utilized. However, similar to finding and estimating the amount of oil in an oil reservoir – the wind needs to be found and the annual wind resource estimated. Because of wind turbine characteristics, only a part of the total wind resource can practically be extracted - this producible part is the annual energy production or simply AEP. Estimating the AEP is a complex task that requires knowledge within wind turbine technology, meteorology, aerodynamics, computational science and measurement techniques. It is a task that requires collaboration!

Because direct AEP measurements are expensive and time consuming indirect techniques are needed when estimating wind resources. This is where WAsP (Wind Atlas Analysis and Application Program) comes in. WAsP uses flow models and long term meteorological measurements at one location to estimate the wind resources at another. This concept of WAsP is wide spread with 4000 licenses sold worldwide and WAsP has become the de facto standard for determining the AEP. Despite its success, the development of WAsP has never halted and the technologies applied are far from standard:

In November 2011 the Danish "Business and innovation fund" funded almost 6 million DKK for the project "Pålidelig beregning af vindeenergi med CFD – et paradigmeskifte" with EMD International A/S as project holder and Vattenfall AB and DTU Wind Energy as project partners. Despite being a relative small company with about 20 employees, the ambition and boldness of EMD was far from small: they wanted to revolutionize the wind industry and with Vattenfall and DTU they found the right partners.

During 2012 the project partners have achieved to completely automate the DTU developed CFD solver EllipSys3D and integrate it with WAsP. EllipSys3D solves the full non-linear Reynolds-averaged Navier-Stokes equations and thus provides a powerful flow model with the potential of lowering the uncertainty on AEP estimates. A second achievement of 2012 was the development of an internet based computer cluster and a suitable business model that makes "cloud computing" with EllipSys3D possible. CFD has always been an expensive tool that requires expensive soft- and hardware as well as specialized personal, but due to resourceful project partners that openly share ideas, the project has managed to make CFD available for everyone.

WAsP 11, including the described CFD developments will be released shortly after EWEA 2013. We hope the program will help everyone searching for wind resources.

INAUGURATION OF TEST CENTER ØSTERILD

Everyone was welcome at the inauguration of Test Centre Østerild which took place on 6 October. Østerild is the first site in the world where mega wind turbines up to 250 meters can be tested and further developed under optimum wind conditions.

Foto: Siemens press picture

Everyone was welcome at the inauguration of Test Centre Østerild which took place on 6 October. Østerild is the first site in the world where mega wind turbines up to 250 meters can be tested and further developed under optimum wind conditions.

By 2020, 50% of Denmark's energy consumption is to be covered by wind turbine electricity, therefore it is of optimum importance to develop wind turbines that are considerably larger than the ones we currently have. A wind turbine is a complex piece of high-tech machinery with up to 20,000 components that must interact for the turbine to produce a satisfactory power output.

At the inauguration DTU President Anders Bjarklev said:

"So far, the test centre is the only place in the world for testing the mega wind turbines of the future. Here, DTU researchers can continue their strong partnership with the wind industry, which has given Denmark a world-leading position within the development of new wind turbine technology. Test Centre Østerild is a prerequisite for retaining expertise as well as safeguarding and creating jobs within the Danish wind turbine industry".

Ida Auken, Danish Minister for the Environment, Lene Kjelgaard, Mayor of the Municipality of Thisted, Ditlev Engel, President and CEO of Vestas Wind Systems A/S, and Henrik Stiesdal, Chief Technology Officer at Siemens attended the ceremony. The minister was pleased that DTU has taken the responsibility of running the state-owned test centre:

"The test centre in Østerild shows the government's commitment to Denmark's transition to green energy. Not only do we need to reduce our energy consumption and leave a smaller footprint on the environment. We must also be the ones to develop the green products which are already being demanded by the rest of the world. Test Centre Østerild will help us ensure that Denmark continues to be at the forefront of developing renewable energy technology", Ida Auken said.

The test centre features a total of seven test stands. Both Vestas and Siemens have bought two stands, and Siemens has already erected a 197-metre turbine on one of them. DTU disposes of the last three stands, of which one has been lease to the Chinese company Envision and two are currently put out to tender. Deputy Head of DTU Wind Energy, Peter Hjuler Jensen says:

Foto: Joachim Ladefoged

Speakers at the inauguration: Ida Auken, Danish Minister for the Environment and DTU President Anders Bjarklev.

"Test Centre Østerild will become a great base for DTU's research activities within meteorology, wind turbine technology, and, not least grid connection which is vital in order for the electricity to reach consumers effectively."

Foto: Siemens press picture

NANOSCALE ANALYSIS OF METAL STRUCTURES IN 3D

A new method has been developed which allows non-destructive 3D characterization of nanocrystalline samples in the transmission electron microscope. The method is in 2012 honored with an innovation award. The use of the method will contribute to the development of nanoscience and nanotechnology strongly relevant to materials industry, sustainable energy and transportation sectors.

By Dorte Juul Jensen

By Søren Fæster

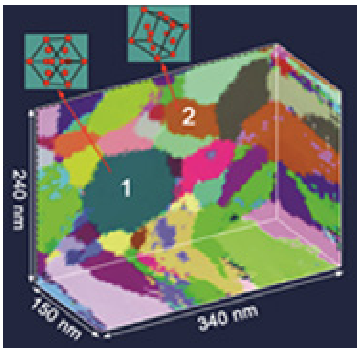
By Xiaoxu Huang

Søren Schmidt and Xiaoxu Huang

Modern materials science and development rely on detailed microstructural characterization and electron microscopy is a very powerful technique which allows a combined analysis of structure and chemical composition of engineering materials. Also some electron microscopes allow simultaneous mechanical testing. However, electron microscopy typically only allows a two dimensional (2D) analysis of the structure. But a recent break-through is a three dimensional (3D) technique developed by 3 scientists at DTU Wind and DTU Physics (all formerly from the Materials Research Division Risø DTU) and 4 foreign colleagues. The method is based on the principles previously used for three dimensional x-ray diffraction (3DXRD), but whereas 3DXRD allows spatial resolutions down to 50-100nm, the new method reach 1-2nm. It differs from other 3D nanoscale transmission electron microscope techniques which rely on absorption contrast, by using diffraction contrast to differentiate different crystals. The new methods can thus also be used for single phase materials.

The principles of the new method and the first results were published in Science in 2011, and were in 2012 honored by the Microscopy Today Innovation Award. It further led to specifications for a new advanced transmission electron microscope procured through a grant from Villum Fonden. The new microscope which is the first of its kind in the world was installed just before Christmas 2012 and the time to record an image as the one shown in the figure is with the new microscope reduced from 60 to 6 hours, which makes the method much more versatile.

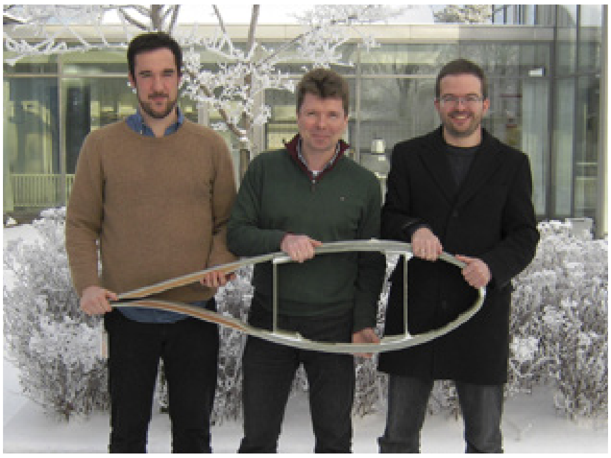
With the new technique and the new microscope, nanosized sample volumes can now be analyzed allowing in depth studies of 3D structural changes as a function of thermal and mechanical loading of metals and alloys. As an example metal surfaces and sub-surfaces in components for wind turbines such as gears and bearings are on the nanoscale and characterization requires advanced electron microscopy techniques as the new one. The characterization results may in a next step be included in finite element models applicable both in design and in failure analysis.



3D grain orientation map from part of a nanocrystalline aluminium sample. The colors represent different crystal orientations

HIGH-FIDELITY MODELS FOR WIND TURBINE BLADES

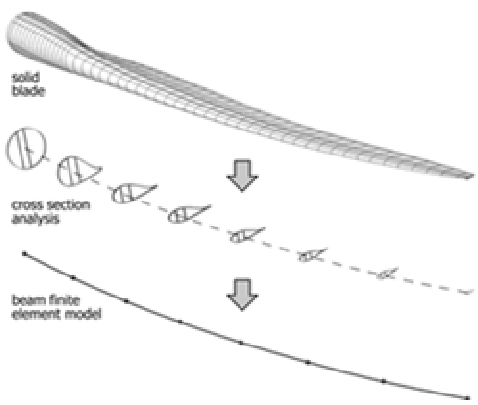
BECAS is an open-source cross section analysis code developed at the Wind Turbine Structures Section (VIM). It is being used for generating high-fidelity models for the analysis and design of wind turbine blades.



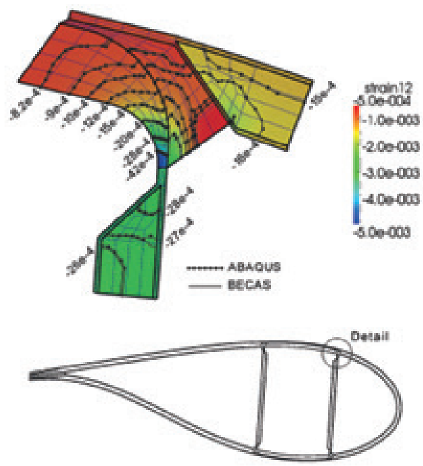
By José Pedro Blasques, Kim Branner and Robert Bitsche

The blades represent about 20-30% of the total cost of an onshore wind turbine. Lighter blades are generally cheaper and may enable a reduction in weight and cost of the remaining structure. In order to generate cost effective, reliable and robust designs, accurate estimates of the aerodynamic loads and corresponding structural response of the turbine are required. The prediction of the loads acting on the blades is typically carried out using aeroelastic codes like the DTU Wind Energy developed HAWC2, where the entire wind turbine is modeled using beam elements. The accuracy of the simulation depends on the quality of the elements used and, as blades grow larger and the design and manufacturing techniques mature, the need for high accuracy models emerges.
The Beam Cross Section Analysis Software, BECAS, developed in VIM, addresses exactly this issue. By using BECAS it is possible to accurately compute the stiffness and mass properties of the blade sections. These results are then used to generate high-fidelity beam elements to represent the blades in aero-elastic analysis codes. Moreover, using BECAS it is possible to account for different geometrical and material effects and thus consider new forms of aeroelastic tailoring, e.g., bend-twist coupled blades with passive load mitigation capabilities. Another aspect of BECAS, which is currently being investigated at VIM, is its ability to perform local strength and fatigue analysis of the blades based on the loads resulting from the aeroelastic analysis. BECAS has been extensively validated and results show that its accuracy is comparable to that of three-dimensional finite element models, while using only a small fraction of the computation time. In summary, BECAS allows for a seamless integration between the structural and aeroelastic analysis groups yielding a high degree of accuracy which is maintained all throughout the design process.

BECAS was originally developed by José Pedro Blasques (DTU Wind Energy) and Boyan Lazarov (DTU Mechanical Engineering) during the project “Anisotropic beam model for analysis and design of passive controlled wind turbine blades” headed by Kim Branner (DTU Wind Energy) and supported by the Danish Energy Agency. Since then, Robert Bitsche (DTU Wind Energy) and José have been developing a framework for wind turbine blade design using BECAS as its engine. Throughout its first year of existence, over 30 academic licenses have been distributed and one commercial license has been sold. BECAS open-source nature is intended to stimulate research collaboration and give developing countries access to wind turbine design tools which would otherwise be unaffordable.
Further information is available online at www.becas.dtu.dk.



BECAS is used to generate high-fidelity beam finite element models of wind turbine blades.



BECAS allows for local strength and fatigue analysis of the blade based on the loads resulting from the aeroelastic analysis.

COMPRESSION BEHAVIOUR OF COMPOSITES

How understanding materials can help make better wind turbine blades and reduce the cost of energy. Advances in the manufacture, testing and modelling of composites with increased compressive performance.

"Results have been so impressive that the fixture has been sold to a number of major industrial wind turbine partners as well as universities."
Says Lars P. Mikkelsen

By Lars P. Mikkelsen

The trend among established wind turbine blade producers is still ever increasing size focused on off-shore application. This trend means that researchers and industry are pushing the materials to new levels. A wind turbine blade is a long slender component mainly loaded in bending, where the fibres in the main direction are taking care of the tensile and compressive loads following that the compression strength is as important as the tensile strength of the material. A reason why the compression performance of high strength composite materials is getting increased attention from the wind turbine blade industry. DTU Wind Energy, Composites and Materials Mechanics Section (KOM) has throughout the last decade been involved in a large number of commercial compressive fatigue test projects. A work which is now being transferred to a deeper understanding of the compression failure mechanism of composite materials.

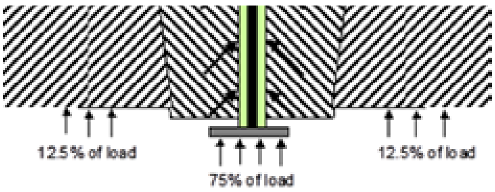


Figure 1 The applied load is a combination of axial and shear stresses in a certain ratio.

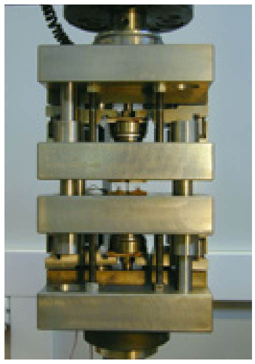
During compressive failure of unidirectional composites a number of different mechanisms are in play, which complicates processing, testing and interpretation of the results. The static strength in tension is mainly given by the fibre strength while the compression strength is limited by e.g. the fibre misalignment and the shear plastic properties of the polymer matrix material. As a consequence, improving the tensile strength of the fibres, will typically not improve the compression strength of a composite.

Due to the more complex nature of the compression properties it is necessary to understand and control the processing conditions in great detail where e.g. by comparing commercial fabrics used in the wind turbine blade industry with in-house produced filament wound composites, it has been possible to dig deeper into the underlying mechanisms.

High strength composites, strong in compression but weak in shear, is a big challenge regarding testing where introducing all loads through the grips, will introduce shear failure between the grips while a pure end loading will crush the end of the test sample. The section has therefore designed a mechanical combined loading (MCL) fixture. A fixture which automatically maintain a fixed load ratio between the end load and clamping load during a full static test as well as throughout the lifetime of the specimen during a compression-compression fatigue test. The obtained results have been so impressive that the fixture has been sold to a number of major industrial wind turbine partners as well as universities.

With a solid experimental base, results can be compared with numerical predictions in order to understand and predict the failure mechanisms in greater detail both on the micromechanics and the macromechanic scale. Here it becomes increasingly evident that it is important to include the highly non-linear effects of the constituents in the composite materials based on their importance as governing parameters for the compressive failure mechanism.

Figure 2 MCL compression fixture.



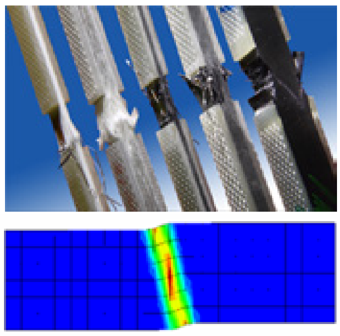
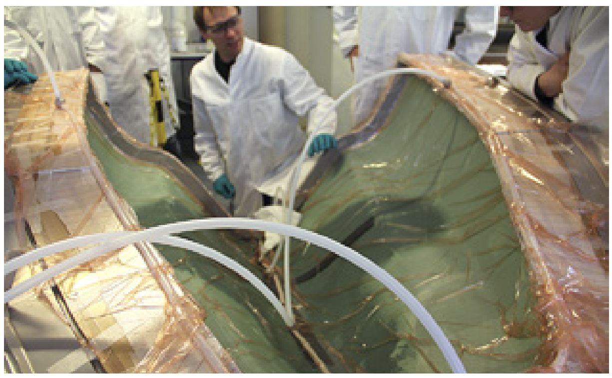


Figure 3 Failed test samples (experimental and numerical)



THE DTU 10-MW REFERENCE WIND TURBINE

By Christian Bak

In the further development of modern multi-mega-Watt wind turbines everything points in the direction of even larger wind turbines to reduce the cost of energy offshore. The largest existing turbines are approximately 7 MW and they have blade lengths in the order of 80 meters. Building such large constructions are subject to many challenges, and one of the challenges is to overcome the physical mechanisms of upscaling. This means that the mass of a turbine is increasing with the cube of the increasing length of tower/shaft/blades. A crucial component in this upscaling process is the rotor, because this is the component that extracts energy from the wind. The masses of existing blades are seen in Figure 1, where it is noted that the mass of the glass fiber blades do not increase with the cube of the blade length.

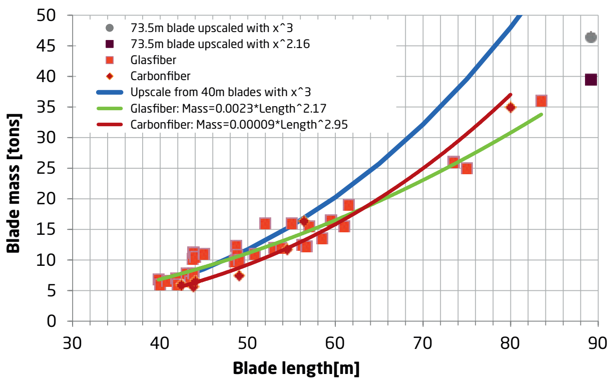


Figure 1

In the EUDP project Light Rotor in cooperation between DTU Wind Energy and Vestas the challenge of upscaling rotors are investigated. This is an inherently interdisciplinary task, where experts in aerodynamics, structure and aeroelastics need to cooperate resulting in an even closer cooperation between the experts in the two sections "Aeroelastic Design" and "Structures" at DTU Wind Energy and together with the experts at Vestas. More specifically, it will be investigated how a 10 MW rotor can be optimized both aerodynamically, structurally and aeroelastically. Therefore, new rotor designs that are aerodynamically, structurally and aeroelastically optimized will be investigated, see Figure 2. The main objective of the project is to create the basis for designing light weight rotors that at the same time are energy efficient.

To evaluate the different rotor designs in the project, a simulation model of a 10 MW wind turbine with a rotor diameter of app. 180 meters and a tower height of 127 meters are created, also called "DTU 10-MW Reference Wind Turbine (DTU-10MW-RWT)", see Figure 3 to 5. A wind turbine of this size is therefore somewhat bigger than the biggest wind turbines that presently exist. The wind turbine is designed for offshore use and is based on existing methods and existing techniques. Since the wind turbine will be used to evaluate future blades in the Light Rotor project, the design is not intended as one that should be realized, but instead used to test and compare simulation models and designs. All the parts of the DTU-10MW-RWT are public available in terms of a full aeroelastic model, detailed shape and detailed structural models. This is the reason why it has been decided to use the DTU-10MW-RWT in the recently started EC project InnWind which is very comprehensive.

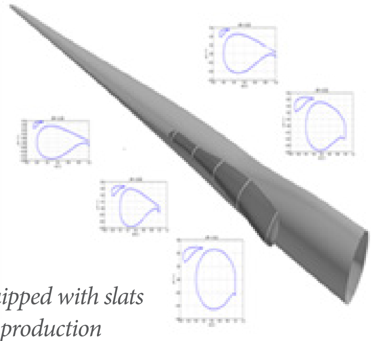


Figure 2 Blade equipped with slats to improve energy production

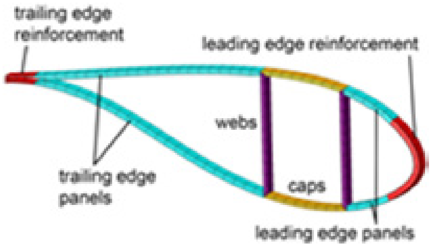


Figure 3 Layup of blade section

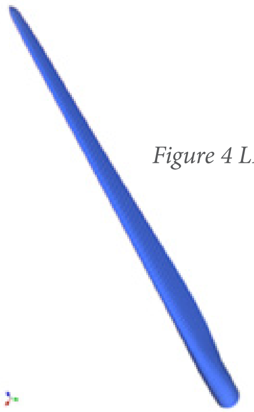


Figure 4 LR10MW-RWT blade shape

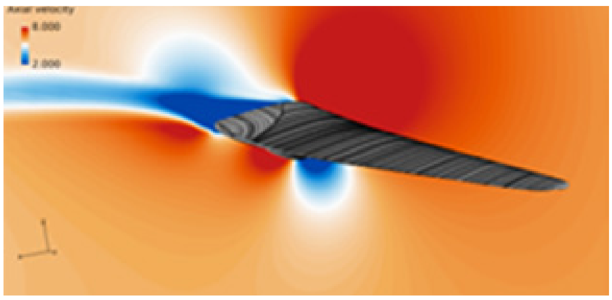


Figure 5 Detailed flow computations to determine the performance of the LR10MW-RWT rotor

The impact of power systems on wind turbine design and vice versa

INTEGRATED ANALYSIS OF WIND TURBINES

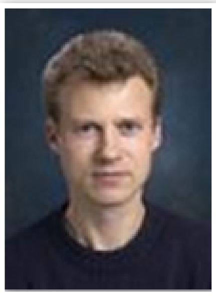
By Poul Sørensen, Nicolaos Antonio Cutululis and Anders Melchior Hansen

Poul Sørensen

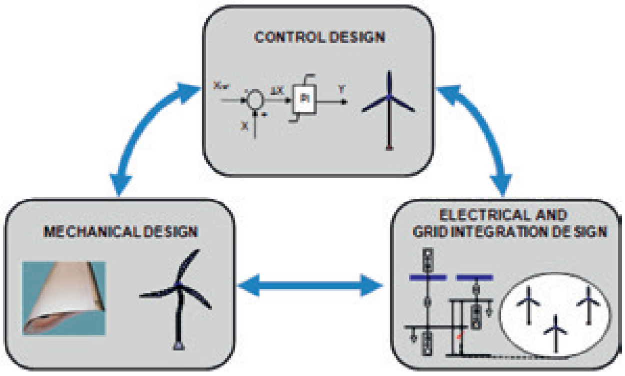
DTU's Wind Energy Department had for years successful tools to design wind turbines for longevity under various loads on the mechanical and structural parts. It also had tools to design the electrical side of wind turbines connected to various types of power Systems. Here, the two sides of turbine design are brought together as integrated design, connecting the electrical parts and the mechanical parts of the turbine through the control design in one integrated tool. Using this **integrated design** approach, turbines' mechanical structures can be designed not only for loads introduced by the wind and turbulence, but also for those introduced by grid faults.

Wind turbines react with mechanical stress to sudden changes on the power system side, since they induce forces in the generator.

Nicolaos Antonio Cutululis

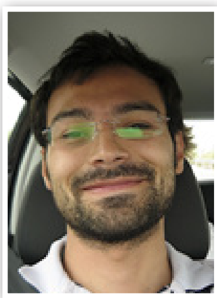


Anders Melchior Hansen



Taking a modular approach, the major achievement is the *development of an integrated simulation platform*, which facilitates an integrated dynamic analysis of the interplay between grid connected turbines and the grid, accounting for relevant aeroelastic, electrical and control aspects. This has involved development of software interfaces for coupling of the aeroelastic code HAWC2 developed at DTU Wind Energy and a commercial simulation tool oriented to control design.

This simulation platform facilitates the analysis of the impact of power system conditions on the wind turbine response and the development of possible solutions. For example, a new *damping control algorithm* for alleviation of loads caused by unbalance voltage fault operation has been developed. The potential for load alleviation was investigated by implementing the developed resonant damping control algorithm with switching functions. Another application for the power system can be the investigation of wind farm capability to provide frequency support. At this point, integrated analysis of the inertial response of the turbines to grid disturbances has shown the impact on structural loads and the benefit to the power system. This inertial response is drawn from the wind turbine rotor through generator and blade pitch angle control. In the future, practical implementation of inertial response control algorithms in variable speed wind turbines, which may impose considerable loading on wind turbine components, can be investigated during the design phase with the new tool.

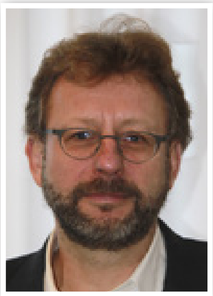


Braulio Barahona

More information is available from the PhD thesis by Braulio Barahona. He defended 25 May 2012.

NEW EUROPEAN WIND ENERGY MASTER'S PROGRAMME LAUNCHED IN 2012

In 2012 a new European Erasmus Mundus study programme started with four university partners from the European Academy of Wind Energy and with DTU Wind Energy as one of the main partners. The programme started in September 2012 with about 40 students enrolled.



By Jens Nørkær Sørensen

The European Wind Energy Master (EWEM) programme is an advanced MSc for elite cohorts of students, with four specializations that follow the energy conversion chain: Wind Physics, Rotor Design, Electric Power Systems and Offshore Engineering. All the students spend their first joint semester at DTU after which they, depending on their choice of specialization, continue at one of the other partner universities. The programme is based on a double degree arrangement, such that graduated candidates receive diplomas from at least two of the partner universities. The specific multi-disciplinary and project-oriented teaching that characterizes the programme gives the students the ability to transfer knowledge and competences beyond their specialization and to embed design choices in a sociotechnical context. The students acquire knowledge in theoretical and applied sciences underlying wind energy systems, and specific competencies necessary to operate in the chosen area of specialization.

The European Wind Energy Master consortium is composed of four Universities, which are generally recognized as world leaders in Wind Energy and Offshore Wind Energy research and education. The universities are Delft University of Technology, Norwegian University of Science and Technology, Carl von Ossietzky Universität Oldenburg and DTU. These four top European universities are all members of the European Academy of Wind Energy, with decades of experience in education and research in Wind Energy and Offshore Wind Energy and Technology, including existing Wind Energy MSc and PhD programs.

The target is to increase this number to at least 100 students in order to satisfy the ever increasing demand for skilled wind energy engineers.

PHD SUMMER SCHOOL IN REMOTE SENSING TOOK PLACE AT BOULDER, COLORADO

The Wind Energy Department at the Technical University of Denmark and the Department of Atmospheric and Oceanic Sciences at the University of Colorado, Boulder, USA, conducted a five-day summer school in Remote Sensing for Wind Energy at the University of Colorado, Boulder from June 11 – 15, 2012.

By Ameya Sathe

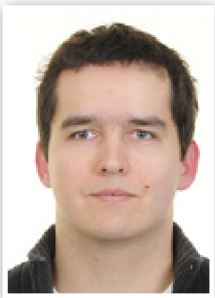
The main organizers of the summer school were Professor Jakob Mann from DTU Wind Energy and Assistant Professor Julie Lundquist from the University of Colorado, Boulder. They were assisted by Ameya Sathe from DTU Wind Energy, and Danielle Felix and Janet Braccio from the University of Colorado, Boulder.

In 2012 the summer school coincided nicely with the ISARS conference at Boulder, Colorado. Upon completion of this five day summer school the participants gained a good understanding of several topics such as fundamental principles of lidar (continuous-wave and pulsed) and sodar measurements, wind profile measurements using lidars, turbulence measurements using lidars, lidar measurement in complex terrain, lidars for wind turbine control, wind turbine wakes measured by lidars, power curves measured by sodars and SAR measurements. Some very basic aspects of boundary-layer meteorology and signal processing were also dealt with. The lectures were supplemented with a five hour hands-on exercise session that included lidar data analysis, and live demonstrations of different remote sensing instruments at the National Renewable Energy Laboratory and Radiometrics in Boulder. An electronic compendium that comprised chapters written by the lecturers was provided to the participants.

The international participants at the summer school were comprised of PhD students from the USA and Denmark, people from the industry and researchers from different research institutions. International experts in the field of remote sensing technology from the USA, Denmark, Germany, France, UK and New Zealand were invited to give lectures at the summer school. The atmosphere at the summer school was very open where lots of stimulating discussions took place. It also paved way for further collaborations between some of the participants and the lecturers. At the end of the summer school participants were asked to fill in a feedback form that resulted in a lot of positive comments about the organization and quality of the lectures given at the summer school.

"EDGEWISE WIND TURBINE BLADE VIBRATIONS AT STANDSTILL CONDITIONS"

The subject of the PhD project was vibration of wind turbine blades in standstill which has recently received increased attention due to wind turbine failures potentially caused by blade vibration at standstill conditions.



By Witold Skrzypiński

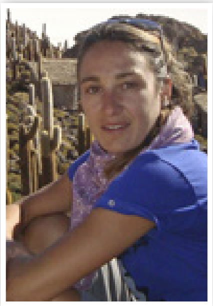
It is currently considered an important new subject of research although no one has officially reported any turbine failures due to standstill vibrations so far. A number of studies have approached different aspects of this problem. Standstill vibrations may potentially be one of two separate phenomena, i.e. vortex-induced vibrations or stall-induced vibrations. Stall-induced vibrations are often referred to as galloping, stall flutter or bluff-body flutter. In stall-induced vibrations, a small velocity of the body causes an increase in the aerodynamic force in the direction of its motion, resulting in negative aerodynamic damping. Vortex-induced vibrations, on the other hand, are vibrations caused by the unsteady aerodynamic forces stemming from vortex shedding, which occur behind objects which have a large region of separated flow. The nature of vortex-induced vibrations is such that the body vibrates in a particular mode at a wind speed for which the frequency of vortex shedding coincides with the natural frequency of the structural mode. In this case, a resonance is created between the displacement and vortex shedding, resulting in an increase of the amplitude of the vibrations. The classical example is vibration of a circular cylinder, but this phenomenon can also occur for airfoils in deep stall.

The PhD project finished 2012 at DTU Wind Energy and the aim was to shed some light on the mechanisms involved in the standstill vibrations. The first engineering models were developed in order to analyze the influence that temporal lag in the aerodynamic response of an airfoil model in deep stall may have on the vibrations. One conclusion was that even a relatively low temporal lag in the aerodynamic response of an airfoil model in deep stall may significantly influence the aerodynamic stability limits. This indicated that state-of-the-art aeroelastic codes may predict inaccurately blade standstill vibrations in deep stall, since these codes effectively have quasisteady aerodynamics in the deep stall range. In stage two of the PhD project, CFD computations were carried out to analyze the risk of vibrations for airfoils. The conclusion was that vortex-induced vibrations, which are not modeled at all in state-of-the-art aeroelastic codes, may occur on modern wind turbine blades while stall-induced vibrations indicated by 3D CFD computations are less likely to occur on these blades at standstill conditions.

The three year period within which the PhD project was running, was by far the most intensive and defining. It was crucial to find a balance between PhD work, family and intensive language courses.

PHD PROJECT: "OFFSHORE WIND ENERGY: WIND AND SEA SURFACE TEMPERATURE FROM SATELLITE OBSERVATIONS"

Wind holds a key role amongst renewable energy resources. Wind farms, originally sited on land, are currently planned for offshore sites. Knowledge of the physical environment offshore is not as advanced as for land and estimating the offshore wind potential is challenging due to the limited availability of measurement sites. Satellites can provide long term data, useful for the initial evaluation of the wind potential over large domains.



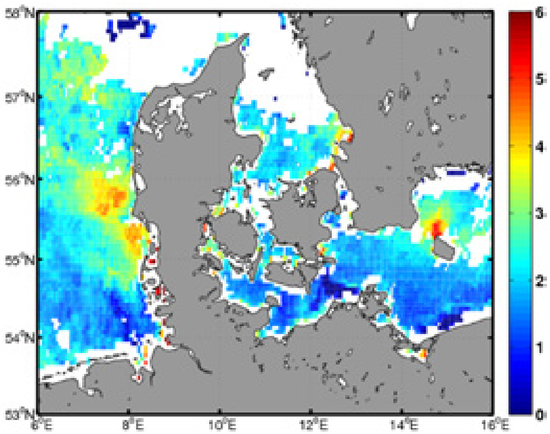
By Ioanna Karagali

The PhD project "Offshore Wind Energy: Wind and Sea Surface Temperature from Satellite Observations" aimed at tackling issues related to data availability offshore and air-sea interactions. The study was partly funded by the EU project NORSEWInD (Northern Seas Wind Index Database) which provided an offshore wind atlas of the North, Irish and Baltic Seas. The core idea of the PhD project was to use long-term datasets of wind and sea surface temperature observations from satellites to:

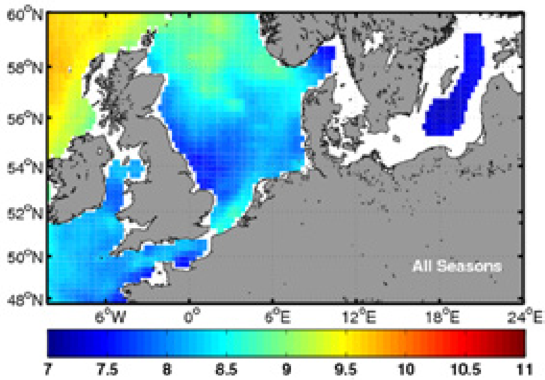
- describe the averaged wind characteristics of the Northern European Seas and evaluate seasonal trends and
- quantify the daily variability of the sea surface temperature which holds a key role in the interaction between the ocean's surface and the lower atmosphere.

Key findings of this PhD project were (i) satellite derived wind atlases for the Northern European Seas based on 10 years of two daily observations, (ii) the characterization and quantification of the spatial and temporal variability of the wind over the ocean, (iii) an evaluation and classification of the daily variability of the sea surface temperature in the North and Baltic Seas and (iv) the inter-comparison of models that predict this daily variability.

Being a PhD student at DTU Wind Energy provided solid ground for high quality research and a valuable network of experienced researchers. My three supervisors played a key role in the successful completion of the project. They guided and supported me in a unique way, setting brilliant examples of independent and efficient research. What they taught me in a very successful manner was collaboration, co-operation and interdisciplinary thinking. Such practices are present in the everyday working environment at DTU Wind Energy.



Example of the difference between the hourly Sea Surface Temperature field at 15:00 UTC and the night-time temperature field from the 04/07/2006. Areas around Denmark experienced an increase of temperature up to 4-5 degrees in this specific case. White areas indicate lack of data.



Mean wind speed in m/s estimated from 10 years of twice daily QuikSCAT wind retrievals over the North, Irish and Baltic Seas and part of the North Atlantic Ocean. White areas indicate lack of data.

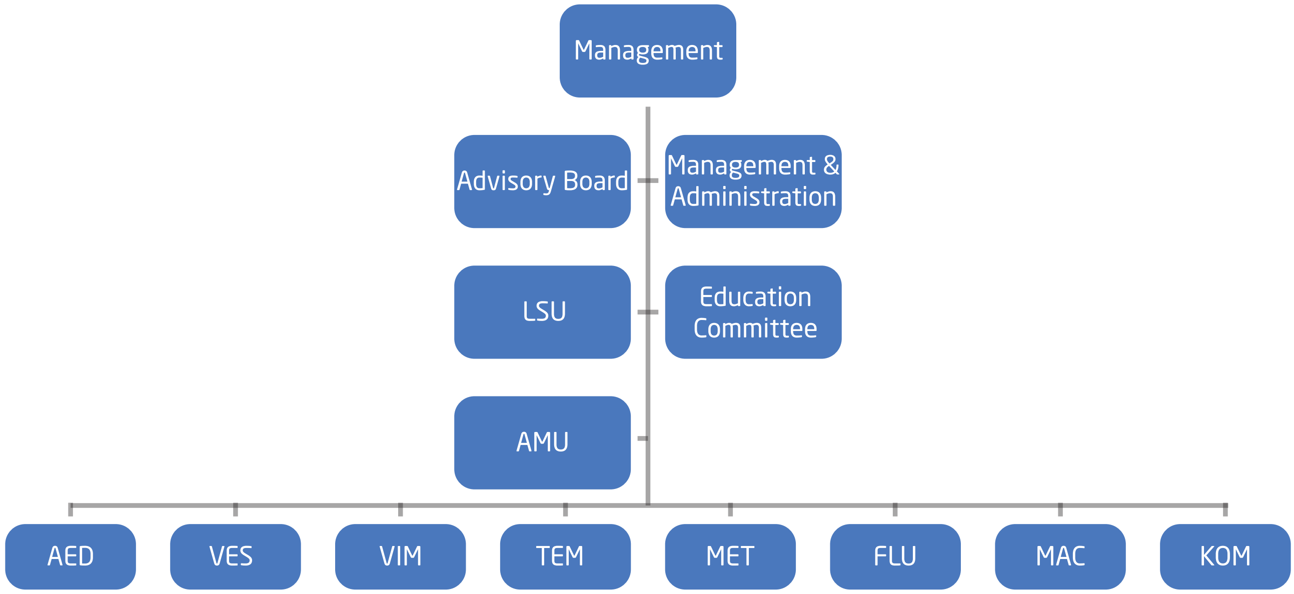
PHD STUDENTS WHO FINISHED THEIR PHD

1.	Ioanna Karagali	01-03-2009	29-02-2012	Charlotte Bay Hasager
2.	Caroline Draxl	15-12-2008	14-03-2012	Gregor Giebel
3.	Andreas Fischer	01-10-2008	31-10-2011	Helge Aagaard Madsen
4.	Vladimir Fedorov	01-03-2008	11-06-2012	Christian Berggreen
5.	Mustafa Aslan	15-10-2008	14-01-2012	Bent F. Sørensen
6.	Braulio Barahona	01-02-2009	31-01-2012	Poul Ejnar Sørensen
7.	Peter Bæk	01-12-2008	30-11-2011	Mac Gaunaa
8.	Tianbo Yu	01-08-2008	31-07-2011	Xiaoxu Huang
9.	Damien Castaignet	01-12-2008	29-02-2012	Thomas Buhl
10.	Witold Skrzypinski	15-12-2008	31-12-2011	Mac Gaunaa

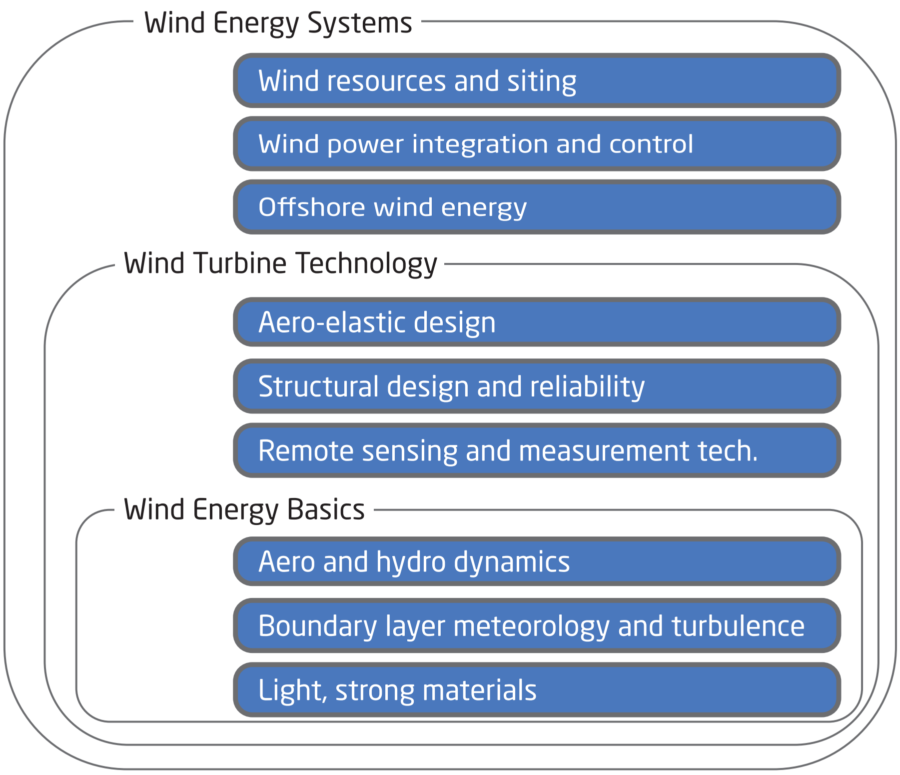
Titles of their PhDs

1.	Offshore Wind Energy: Wind and Sea Surface Temperature from Satellite Observations
2.	New data assimilation techniques for short-term wind energy forecast models with a rapid update cycle
3.	Experimental characterization of airfoil boundary layers for improvement of aeroacoustic and aerodynamic modelling
4.	Strukturel modellering af vindmølleblade med passiv kontrol
5.	Characterization and modelling of wood fibre composites
6.	Integrated design of wind power systems
7.	Unsteady Flow Modeling and Experimental Verification of Active Flow Control Concepts for Wind Turbine Blades
8.	Recovery and recrystallisation of nanostructured metals - mechanisms and kinetics
9.	Sensor Design and Control Algorithm for Flaps on Wind Turbine Blades
10.	Analysis and modeling of unsteady aerodynamics with application to wind turbine blade vibration at standstill conditions

ORGANISATION



The management of the department consists of the Head of Department and the Deputy Head of Department. The management structure of the department is organized with a single management team with the Head of Department as chairman and the Deputy Head of Department and the 8 head of sections as members. The organization of DTU Wind Energy is shown in the organizational chart below:



The technical/scientific competences within the department are embedded in the eight sections. The research is organized in 9 research programmes within three main research themes: Wind energy systems, where the turbine enters as a component, wind turbine technology and wind energy basics. Each strategic research programme typically has contributions from other sections from the department and cooperation with other DTU departments.

Head of Department:
Peter Hauge Madsen

Deputy Head of Department
Peter Hjuler Jensen

Advisory Board:

Tove Feld, Senior Director, Deputy Wind Power Engineering, DONG Energy

Michael Høgedal, Senior Vice President, Product Integration, Vestas Turbines R&D

Henrik Stiesdal, CTO, Chief Technology Officer of the Wind Power Business Unit, Siemens Energy, Siemens AG

Sections:

Aeroelastic Design
Flemming Rasmussen, Head of Section

Composites and Materials Mechanics
Professor Bent F. Sørensen, Head of Section

Fluid Mechanics
Professor Jens Nørkær Sørensen, Head of Section

Materials Science and Characterisation
Professor Dorte Juul Jensen, Head of Section

Meteorology section
Dr. Hans E. Jørgensen, Head of Section

Test and Measurements
Dr. Poul Hummelshøj, Head of Section

Wind Energy Systems
Jens Carsten Hansen, Head of Section

Wind Turbine Structures
Dr. Thomas Buhl, Head of Section

Study Programmes:

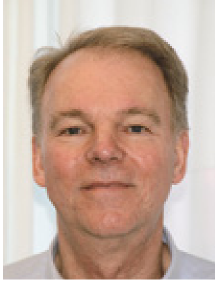
Master Programme in Wind Energy
Ass. Professor Martin L. Hansen

Erasmus Mundus European Wind Energy Master
Professor Jens Nørkær Sørensen

Study Committee
Dr. Niels-Erik Clausen, chairman

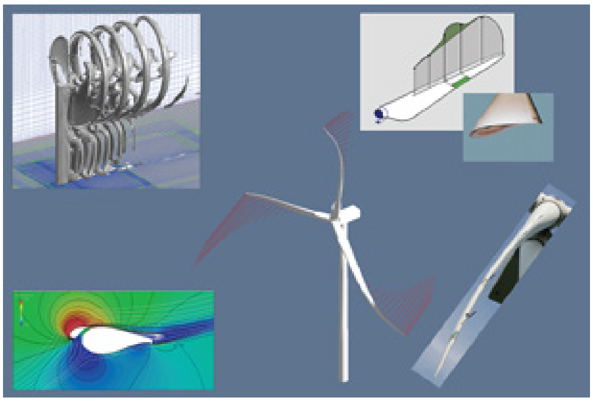
SECTIONS AT DTU WIND ENERGY

Aeroelastic Design



Flemming Rasmussen

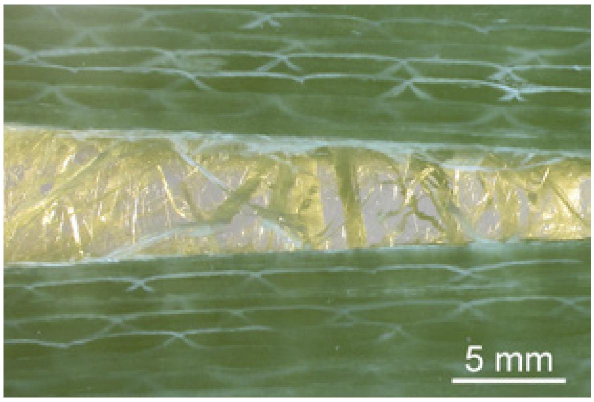
The focus of the research is development of aero-servo-elastic simulation methods, computational fluid dynamics (CFD) codes and software design tools of aerofoils, blades and wind turbines. Offshore operation is also simulated taking wave loadings or floating conditions into account. The tools are used for cost optimal layout of wind farms, taking a variety of parameters into account.



Composites and Materials Mechanics

Bent F. Sørensen

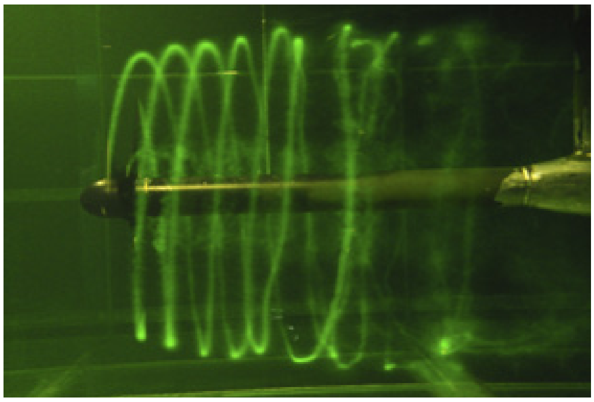
The research focuses on development of new fiber composite materials and on increasing knowledge and description of existing composite materials with respect to strength, fatigue, durability and damage tolerant behavior. The research covers processing, microstructural and mechanical characterization, modelling and non-destructive evaluation of composite materials.



Fluid Mechanics

Jens Nørkær Sørensen

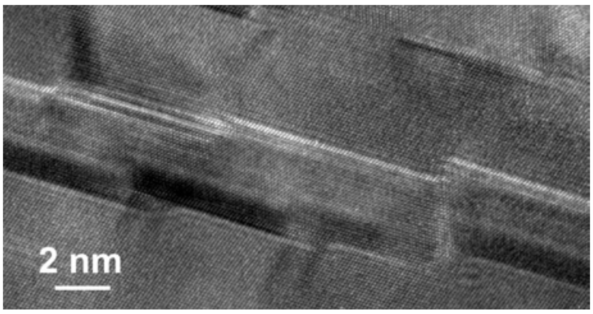
The fundamental research in fluid mechanics includes laminar-turbulent transition, flow control, aero-acoustics, rotating flows, turbulence, and convection and heat transfer in boundary layers. The research has focused on offshore wind energy and computing codes for predicting the combined loadings from wind and waves, and wake interaction within wind farms.



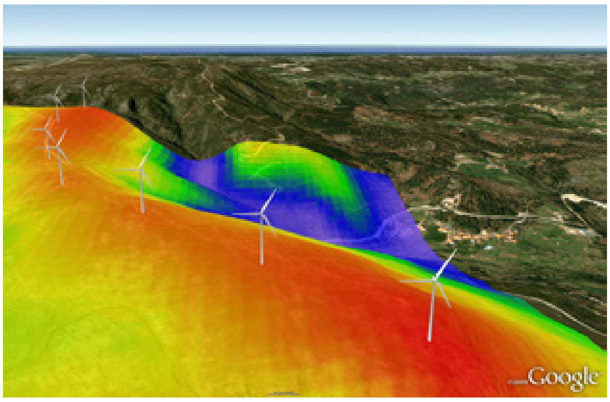
Materials Science and Characterization

Dorte Juul Jensen

The research activities deal with light and strong metals, steels as well as nano-metals. The research covers procession of metals and alloys, structural and mechanical characterization, modeling, properties and performance. Advanced characterization techniques include electron microscopy and non-destructive 3D x-ray measurements of internal structures using international synchrotron facilities.



Meteorology



The research areas in this section are boundary layer meteorology, mesoscale and microscale modelling, assessment of wind resources for power production and external design conditions for wind loads on turbines and various other structures. The scientific work includes models of mean flow, turbulence, wake modelling from single turbine wakes to large wind farm cluster wakes.

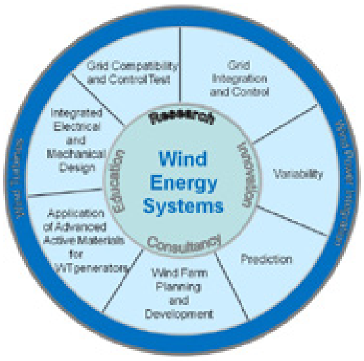
Hans Ejsing Jørgensen

Test and Measurements

The research is aimed at development of instrumentation and methods for the experimental determination of wind turbine characteristics, including test methods for the wind turbine industry at the test centres in Høvsøre and Østerild. Remote sensing techniques using wind lidars are used, for measurements of wind and turbulence in three dimensions around wind turbines.

Poul Hummelshøj

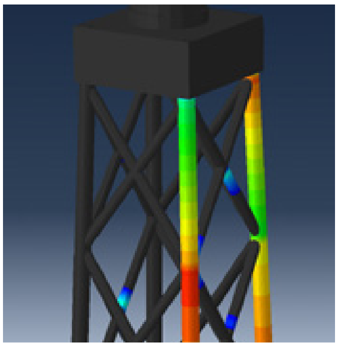
Wind Energy Systems



The research in wind power integration and control covers wind power plants in the power system, variability, prediction and predictability of wind power, integrated design and control of wind turbines and wind farms and application of advanced materials for wind turbines generators. The work combines theoretical and experimental aspects in time scales.

.Jens Carsten Hansen

Wind Turbines Structures



The research focuses on loads, structures and design. Thus developing methods to determine reliable design loads and structural design of wind turbines with emphasis on reducing the risk of failure. Furthermore there is modelling and analyses of the extreme environmental conditions of waves and wind for offshore turbines and development of methods to predict structural response of the turbine and its components.

Thomas Buhl

NATIONAL AND INTERNATIONAL PARTNERSHIPS

The ambitious energy targets that have been set up in both Europe and globally, partnerships and interrelating cooperation are of imperial importance in order to continue the zeal to reduce our dependence on fossil fuels.

DTU Wind Energy has a unique position in a global context and has a wide range of project department collaboration with a large number of world leading research institutions and universities all over the world.

The department collaborates nationally with a number of universities, research organizations, departments, technological institutes, authorities and companies, including technical standards organizations where DTU Wind Energy has led the Danish Committee and numerous international working groups during the last twenty years. The main research partners in Denmark are assembled in the Danish Research Consortium for Wind Energy, which in addition to DTU includes Aalborg University, Aarhus University, DHI Force Technology and DELTA.

At the European level, DTU Wind Energy is visible and active in the European context in order to influence the future priorities of the next EU Framework Programme Horizon 2020 and bring research funds into the wind energy sector. The department is active in TPWind (European Wind Energy Technology Platform) in the Executive Committee, Secretariat and Working Groups. Furthermore, the department coordinates the European Energy Research Alliance (EERA) joint programme on wind energy, which is key player in implementing strategic, public research in the framework of the SET-Plan. EERA is the research-based counterpart to the industry-led TPWind. Finally, DTU Wind Energy participates in the European Academy of Wind Energy (EAWE), which primarily works with education and PhD collaboration. The substantial presence on the European stage is materializing in a number of concrete projects with industry and other universities. DTU Wind Energy has so far participated in 31 FP7 projects and is coordinating 5 of them.

Globally DTU Wind Energy pursues partnerships established through DTU's strategic alliances, the IEA's program for wind energy research and bilateral agreements. Examples include KAIST, the National Renewable Energy Laboratory (NREL), National Centre for Atmospheric Research (NCAR), Sandia and Texas A & M, China Academy of Science in connection with the SDC cooperation, Korea Pusan National University, KAIST, Mokpo University. In the area of materials a Sino-Danish Centre (SDC) for Nano-Metals has been established together with the universities of Tsinghua and Chongqing, and the Institute of Metal Research in Shenyang.

UpWind meeting held at DTU Risø Campus, February 2012, where 70 people participated and 42 partners from research and industry participated.

RESEARCH FACILITIES AT DTU WIND ENERGY

An important prerequisite of continuously being in the forefront of wind energy within research and innovation is to constantly update and further develop advanced national research facilities.

State of the art research infrastructures can ensure unique research opportunities both in full scale and reduced scale in the development of new materials and structures, research in wind energy meteorology, technological systems and components, mathematical models and sensor systems to the benefit of both research and industrial development.

DTU Wind Energy has a strong position with the existing infrastructures, and in the years to come we have ambitious plans for the development of new infrastructures and upgrading of existing infrastructures. Several of the infrastructures are also used by other DTU departments and in projects together with other research and industry partners both in Denmark and abroad. DTU Wind Energy operates the Test Centre for Large Wind Turbines, Høvsøre and the newly inaugurated Test Centre Østerild.

At the European level, DTU Wind Energy is leading the European consortium behind the establishment of the European WindScanner Facility, which is the first large scale European research infrastructure in the field of wind energy. The project is part of the European Road Map for research infrastructures (ESFRI) and the only project in ESFRI's Road Map lead by a Danish partner. The bullet points present a list of key research performed at DTU Wind Energy.

Existing research facilities:

- Wind turbines at Risø Campus for research and courses
- Test Centre for Large Wind Turbines at Høvsøre
- Test Centre for "Very" Large Wind Turbines at Østerild
- Risø met-mast
- Blade test Facility for Research
- 1 MW drive-train test facility
- Atmospheric measurement stations and equipment, incl. Lidars
- Structural test laboratory
- Material tests lab, incl. Microscopes etc
- Fiber lab
- PC-clusters (Thyra and Gorm)
- Smaller wind tunnels
- The WindScanner facility.

Under development or in planning phase:

- National Wind Tunnel
- Østerild Grid Test Facility
- New PC-cluster

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DK- 4000 Roskilde

Phone: 4677 5085

Other locations:

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Campus Lyngby
Building 403
Nils Koppels Alle
DK-2800 Lyngby

DTU Wind Energy
Campus Risø
Building 228
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DK- 4000 Roskilde

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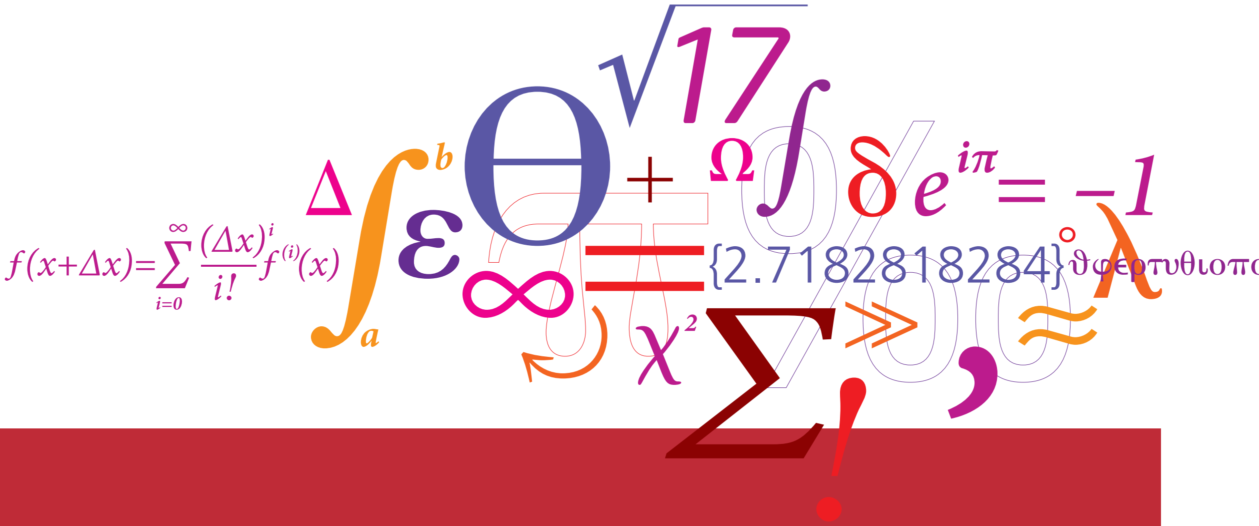

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