Annual Report 2014

NOWITECH

Norwegian Research Centre for Offshore Wind Technology

FME CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH

Offshore wind: We make it possible

Offshore wind energy represents a golden opportunity for development of new knowledge-based jobs. The international market is huge and in strong development. In Europe alone investments in the order of NOK 1000 billion for construction of offshore wind farms are expected during the next ten years.

Offshore wind farms can replace fossil power generation and save CO_2 emissions and will be an important part of a future sustainable energy system as a clean, renewable energy source that can be developed and operated with minimal negative environmental impacts.

Offshore wind energy costs more than land-based wind, but the technology and market are only in the initial phase, and by 2030, the cost is assumed to be reduced to half of the current level.*

Norway has an important role to play. Building on our expertise within the energy and petro-maritime industries, we can develop solutions that provide reduced costs for offshore wind energy, and thereby gain an increased rate of deployment and speed up the phasing out of fossil energy sources.

This is a good and effective climate action that makes a difference. It requires investments in R&D, but will be paid many times through the creation of jobs and the export of goods and services. The timing is ideal now with the oil and gas industry reducing its activity and having free capacity to forward-looking focus areas.

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The technology for offshore wind farms involves bottom-fixed or floating substructures with large wind turbines generating electricity, substations and submarine cables for collecting and transporting the electricity to shore, and systems for operation, control and maintenance of the installations. And it shall all operate in the toughest conditions for twenty years or more.

It is one of the big engineering challenges of the century.

NOWITECH is proud to contribute in addressing this challenge with research and innovation for value creation and reducing risks and costs. The potential is huge.

We make it possible.

Director NOWITECH

John Olav Giæver Tande

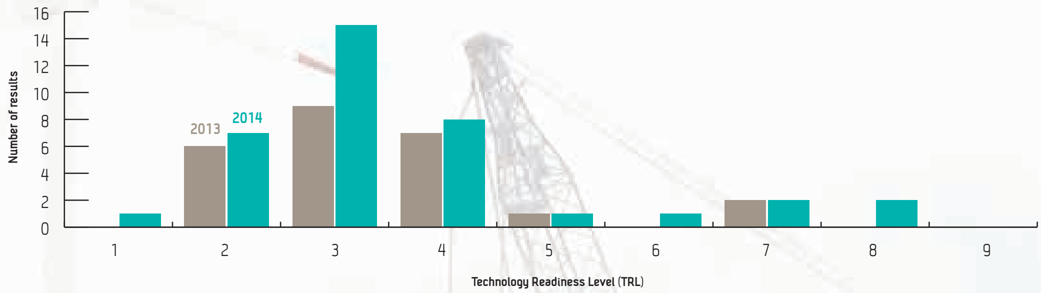
* European Wind Energy Technology Platform, 2014, Strategic Research Agenda

NOWITECH

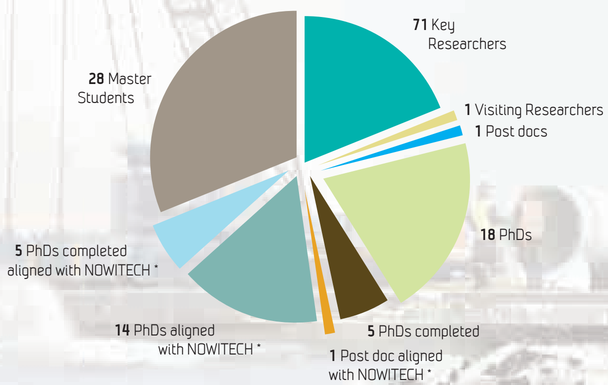
FME CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH

2014 in numbers

Innovations

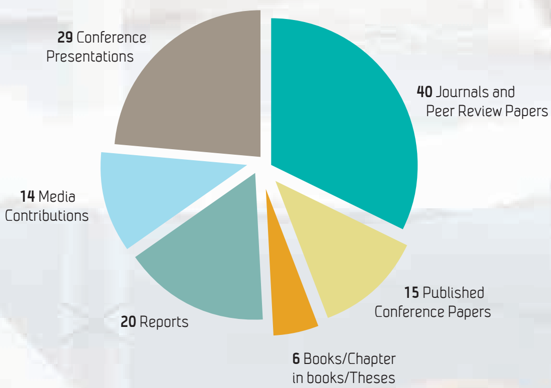


People



*with financial support from other sources

Publications



NOWITECH is an international precompetitive NOK 320 million (2009-2017) research cooperation on offshore wind technology co-financed by the Research Council of Norway, industry and research partners.

Vision

- ✓ Contributing to large scale deployment of deep sea offshore wind turbines,
- ✓ An internationally leading research community on offshore wind technology enabling industry partners to be in the forefront.

Objective

- ✓ Precompetitive research laying a foundation for industrial value creation and cost-effective offshore wind farms. Emphasis is on "deep-sea" (+30 m) including bottom-fixed and floating wind turbines.

Key issues

- ✓ Innovations, knowledge building and education aiming to reduce the cost of energy from offshore wind farms.

Organization

NOWITECH is organized with a General Assembly (GA), a Board, a Centre Director, a Scientific Committee (SC), a Committee for Innovation and Commercialisation (CIC) and a Centre Management Group (CMG).

The research activities are organised into three work packages (WPs): Substructures and numerical tools (WPA), Operation & Maintenance and Materials (WPB), Grid and Wind Farms (WPC).

Results

Excellent research work directed towards industry needs is carried out. A total of 36 industry relevant results and innovations are in progress. This includes new software tools, processes and technology. The results of NOWITECH are migrating to commercial use, licence agreements, and business developments.

The educational programme provides for first-rate recruitment opportunities for the industry. NOWITECH has so far financed 24 PhD students and 5 post-doctoral researchers. In addition, 14 PhD students and 1 post docs on offshore wind energy are on-going at NTNU with finance from other sources, but carried out in alignment with NOWITECH.

The scientific work is of the highest international standard with more than 140 peer-reviewed papers and more than 20 invited keynotes at international conferences since start up.

Very significant spin-off activities have been achieved. Since the start, more than 50 new projects with an accumulated budget in excess of NOK 1000 million have been initiated with participation of one or more of the research partners in NOWITECH. These projects are with separate contracts external to NOWITECH, but carried out in alignment with NOWITECH providing added value.

Value for Industry Partners

- Excellent research with significant budget and duration directed towards industry needs
- First-rate recruitment opportunities from strong master, PhD and post doc programme
- A high gearing of research expenditures and first access to detailed results for business development
- Access to international network and strategic position in important European forums
- Knowledge and innovations contributing to reduced cost of energy from offshore wind farms
- 36 innovations in 2014

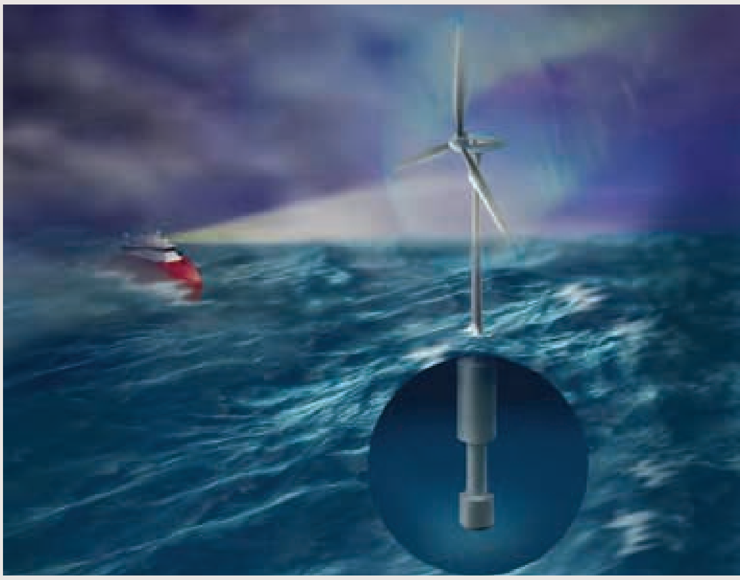


Figure 1: NOWITECH has focus on "deep sea", i.e. +30 m water depth, both bottom-fixed and floating technology. A key target is innovations reducing cost of energy from offshore wind farms. Main areas of research are numerical modelling, materials, substructures, grid connection, maintenance and control.

Contents

NOWITECH – Norwegian Research Centre for Offshore Wind Technology – is one of eleven Norwegian Centres for Environment-friendly Energy Research *(in Norwegian: FME – Forskningssentre for miljøvennlig energi)*. The Centre is co-funded by the Research Council of Norway, a number of user partners and the participating research institutions.

SINTEF Energy Research is the coordinating institution.

ISBN: 978-82-594-3667-2

Editorial: John Olav Tande and Hans Christian Bolstad
Contributions from the following members of the Centre Management Group: Roy Stenbro, Jens Kjær Jørgensen, Harald Svendsen, Karl Merz, Thomas Welte, Ole David Økland, Per Arne Wilson, Trond Kvamsdal, Debbie W. Koreman and Randi Aukan.

Photos and illustrations: Gry Karin Stimo, NTNU, Statkraft, Bjarne Stenberg, Oxygen and SINTEF

John Olav Giæver Tande, Director NOWITECH

2014 highlights

NOWITECH continues to deliver strong results. In 2014 a strategy taskforce was initiated by the Board enhancing the prioritization of the research activities and a new more efficient organization with fewer, but larger work packages. Industry participation increased with Fugro Oceanor re-joining at the end of the year, and Norsk Automatisering AS is expecting to join in 2015.

The educational programme provides for first-rate recruitment opportunities for the industry. A total of ten PhDs successfully defended their theses at NTNU in 2014, of which five were fully funded by NOWITECH and five by other sources, but carried out in alignment with NOWITECH. In addition, 28 master students graduated from NTNU with theses on offshore wind energy.

(...) the innovations have developed towards higher TRL with more results migrating to commercial use and contributing to cost reductions.

The Technology Readiness Level (TRL) methodology is now well established in NOWITECH for communicating results and shows excellent progress of innovations. The total number of innovations allocated a TRL has increased from 24 in 2013 to 36 in 2014 (see Figure 2), and the innovations have developed towards higher TRL with more results migrating to commercial use and contributing to cost reductions. Some example results from NOWITECH are:

- The development of software tools for integrated numerical design of offshore wind turbines by MARINTEK (SIMO/RIFLEX) and IFE (3DFloat) is progressing well with improved capabilities and accuracy and being applied by the industry.
- A new hybrid approach for model testing of offshore turbines in the ocean basin lab is in development to overcome the inherent challenges of different scaling laws for wind and waves. The method combines the well-proven application of the ocean basin for imposing scaled waves and currents on a physical model, while the wind loads are provided through real-time simulation. A successful development means a significant step forward in validating design tools and assessment of novel offshore wind turbines.
- Tools for selecting operation and maintenance (O&M) strategies are made available to the industry, including NOWIcob by SINTEF Energy Research. The tools are now being further validated in a collaborative effort between SINTEF Energy Research, MARINTEK, University of Strathclyde, University of Stavanger, NREL and EDF with a set of reference cases for model benchmarking.
- The patented process for thermally sprayed silicon carbide coating was developed as part of the PhD study by Fahmi Mubarok successfully completed in 2014. It is now being developed as a commercial product through the new spinout company Seram Coatings AS in which he is now employed. The process provides for an extremely hard, wear-resistant, low friction ceramic coating that can be applied to rotating machinery like main bearings in large direct drive wind turbines; ultimately increasing lifetime and reducing cost for maintenance.

- The possibility of supplying offshore petroleum platforms with power from offshore wind turbines has been investigated. The main outcome of these studies is that systems with wind power connected to oil and gas installations can be operationally stable and reliable with the proper design, and are economically and environmentally sound. The results have increased the interest within the oil sector to consider such solutions, and both Statoil and DNV GL are following up these ideas.

- Analysis tools for next-generation large-scale offshore wind power plants are in development with the VIPER and STAS programs. VIPER computes the energy production of an offshore wind power plant, using a boundary-layer model to account for the cumulative wake effects and STAS is a model of an entire offshore wind power plant, represented in a single linearized state space. This type of mathematical representation allows for rapid analysis of different designs and operational control of large offshore wind farms.

- The Remote Presence concept was validated in the PhD study by Øyvind Netland successfully completed in 2014. He is now employed in Norsk Automatisering AS that are commercialising the concept. The Remote Presence concept applies a low-cost robot with camera, microphone and other sensors inside the nacelle with monitoring and control from on-shore, increasing the operational time of the turbine and reducing the need for offshore service visits.

- The SEAWATCH Wind Lidar Buoy by Fugro Oceanor is cost efficient and flexible compared to an offshore met mast and can measure wind profiles (300 m), wave height and direction, ocean current profiles, etc. The development is a result of a NOWITECH "spin-off" joint industry project by Fugro OCEANOR with Norwegian universities, research institutes and Statoil, and is now in a commercial phase.

- New systems for wind farm management and operation are in development by Kongsberg Maritime with support from research activity in NOWITECH and projects aligned with NOWITECH. These new systems have the potential to significantly reduce the cost of energy from offshore wind farms.

The scientific work is of high international standard. In 2014 NOWITECH prepared 124 publications including 40 peer-reviewed papers, 29 conference presentations, 21 reports and 14 media contributions. The use of web, newsletters and organization of workshops and conferences enhance the communication:

- Two seminars were held in the series "Industry meets Science" in cooperation with WindCluster Norway. These facilitate improved interaction between research and industry, also for parties outside NOWITECH and as a Norwegian shadow-group towards the European strategic research agenda on offshore wind.

- The annual offshore wind R&D conference in Trondheim linked up with the European Energy Research Alliance (EERA) joint programme of wind energy in 2014 and became the EERA Deepwind'2014 conference, with three days of presentations of the latest and best on-going R&D on deep sea offshore wind farms. The conference had about 140 delegates from 14 countries, more than 90 presentations whereof 34 papers were peer-reviewed and published in the open access journal Energy Procedia (Elsevier).

Participation in relevant national and international forums is emphasised. These include participation in Energi21 suggesting future research strategy for wind energy in Norway, active participation in IEA Wind research collaboration, IEC TC88 wind turbine standardization working groups and taking leading positions within the European Technology Platform on Wind (TPwind), the European Energy Research

Alliance (EERA) joint programme on Wind Energy and the European Academy of Wind Energy (EAWE). The forums are important networks for improving quality of research, and for developing R&D strategies and new projects.

The existing strong research infrastructure was expanded with procurement of DIPLAB (8 MVA short-circuit emulator) in 2014 with funding from the Research Council of Norway (RCN). The lab has already been used for performing a voltage dip test on a full-scale wind turbine at Valsneset. The data from the test are highly valuable data providing a basis for better understanding how grid faults affect wind turbines and for validating simulation models.

The accumulated costs for NOWITECH in 2014 were NOK 40 million co-funded by the Research Council of Norway (RCN), the industry parties and the research parties.

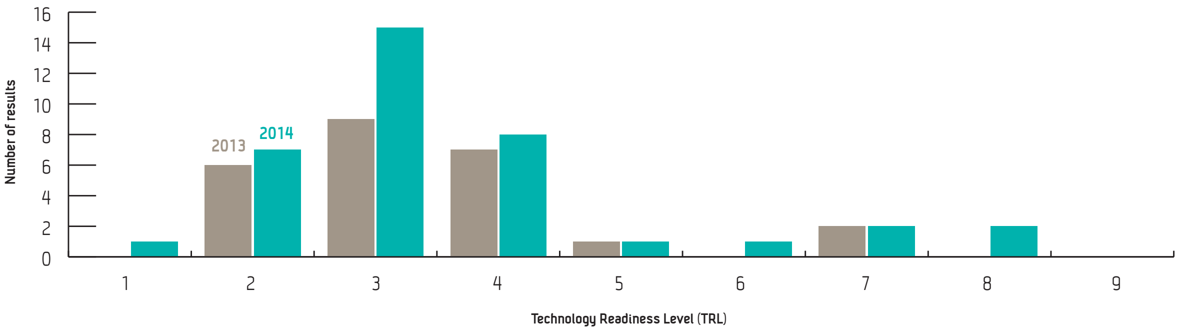


Figure 2: TRL distribution of innovations in NOWITECH. The total number of innovations allocated a TRL has increased from 24 in 2013 to 36 in 2014, and the innovations are moving towards higher TRL.

About Nowitech

Nowitech partners 2014

Host Institution:

SINTEF Energy Research

Research Partners:

Norwegian University of Science and Technology (NTNU)
Institute for Energy Technology (IFE)
Norwegian Marine Technology Research Institute (MARINTEK)
Stiftelsen SINTEF (SINTEF)

Industry partners:

CD-adapco
DNV GL
DONG Energy
EDF R&D
Fedem Technology AS
Fugro OCEANOR AS
Kongsberg Maritime AS
Rolls-Royce SmartMotor
Statkraft Development AS
Statnett SF
Statoil ASA

Fugro OCEANOR re-joined NOWITECH in December 2014. NOWITECH has agreements on cooperation with the following associate partners:

Associate research partners:

- Massachusetts Institute of Technology (MIT), USA
- Michigan Technological University (Michigan Tech), USA
- National Renewable Energy Laboratory (NREL), USA
- DTU, Denmark
- Fraunhofer IWES, Germany
- University of Strathclyde, UK
- TU Delft, Netherlands
- Nanyang Technological University (NTU), Singapore

Associate industry partners:

- Hexagon Devold AS
- Enova
- Energy Norway
- Innovation Norway
- Norwegian Wind Energy Association (NORWEA)
- Norwegian Centres of Expertise Instrumentation (NCEI)
- NVE
- WindCluster Norway

Research Plan

The objective of NOWITECH is to provide precompetitive research laying a foundation for industrial value creation and cost-effective offshore wind farms. Emphasis is on "deep-sea" (+30 m) including bottom-fixed and floating wind turbines.

Important elements in the research strategy are listed below:

- Combine wind technology knowhow with offshore and energy industry experience to enhance development of offshore wind.
- Establish a recruitment and educational programme that provides for highly qualified staff at Master and PhD level for serving the industry.
- Build strong relations with selected top international research partners.
- Facilitate active involvement by industry partners to ensure relevance and efficient communication and utilization of results.
- The research is mainly of precompetitive nature providing for development until Technology Readiness Level 4 or 5 (lab scale testing), and ready for takeover by more commercially directed projects with industry lead.
- Actively pursue opportunities to increase R&D activity on critical issues.

Key issues in NOWITECH are education, know-ledge building and innovations aiming to reduce the cost of energy from offshore wind.

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The research methodology includes a mix of analytic work, numerical simulations and development of software tools, laboratory experiments and field measurements. The mix will vary depending on the task addressed, though the main portion of the budget is for scientific staff, while additional funding are sought for any significant investments in experiments or research infrastructure. The general idea is to align research in NOWITECH with other open research activities carried out by the research partners, and by this maximize benefits of the funding.

The educational activity forms part of the research programme with engagement of MSc students and funding of 24 PhD and 5 post doc students at NTNU. PhD and post doc students at NTNU working on offshore wind, but funded through other sources, are carried out in alignment with NOWITECH.

The research is organized in three work packages (WPs):

- WPA: Substructures and numerical tools. The objective is development of novel substructures for offshore wind through development, validation and use of numerical tools and experimental campaigns.
- WPB: Operation & Maintenance and Materials. The objective is to contribute to the reduction of cost of energy of offshore wind power through development of new and cost-effective O&M concepts and strategies, through efficient and optimized use of material and coatings, and through development of new coatings and improved models for structures and materials.
- WPC: Grid and Wind Farms. The objective is to develop technical solutions and methods for cost effective electromagnetic and electrical designs, controls, grid connection and power system integration of offshore wind farms.

These Work Packages are the focal points for the research activities in the Centre, bringing researchers together across traditional fields of engineering science and facilitating team building and innovations. The preparation of joint workshops and research strategies further strengthen the multi-disciplinary team efforts.

Dissemination of the results are through international journals, conference papers and presentations, also continuation and development of the established yearly offshore wind R&D conference in Trondheim (EERA DeepWind), workshops for industry and public bodies, newsletters and web.

Work is carried out in coordination with the other CEER (Centres for Environmental Energy Research; in Norwegian: FME) on offshore wind, namely NORCOWE. The Centres are complementary to each other and constitute together a very strong research effort on offshore wind energy.

Organisation

NOWITECH is organized with a General Assembly (GA), a Board, a Centre Director, a Scientific Committee (SC), a Committee for Innovation and Commercialisation (CIC) and a Centre Management Group (CMG). The research activities are organised into three work packages (WPs): Substructures and numerical tools (WPA), Operation & Maintenance and Materials (WPB) and Grid and Wind Farms (WPC). The organization of NOWITECH is shown in Figure 3.

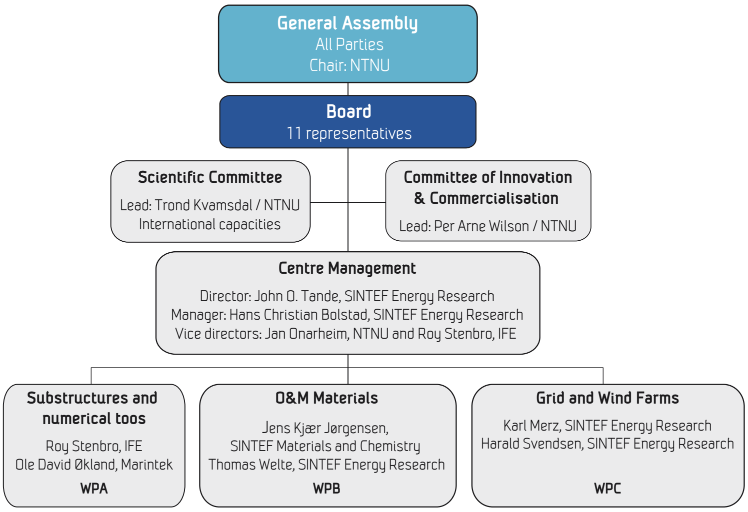

Figure 3: Outline of governance structure for NOWITECH per start of 2015.

There were no changes in the management team in 2014, though NOWITECH has reorganized the work by reducing the number of Work Packages from 6 to 3 effective by start of 2015. Roy Stenbro and Ole David Økland are now joint WP leaders for WPA, Thomas Welte and Jens Kjær Jørgensen are joint WP leaders for WPB, while Harald Svendsen and Karl Merz are joint Work Package leaders for WPC. Professor Torgeir Moan has retired as work package leader as of 01.01.2015, but continues in an advisory role and PhD supervisor. His excellent work in NOWITECH is highly appreciated.

The Board

The Board is the operative decision-making body for the execution of the activities within the Centre. It consists of eleven members whereof eight are representatives of the industry partners and three are from the research partners. The board reports to and is accountable to the General Assembly (GA). The Board monitors the implementation of the Centre and approves the annual working plans and budgets. It also oversees that the activities described in the annual working plans are completed within the defined time frame, hereunder that the in-kind contributions are delivered as specified.

Two ordinary Board meetings were held in 2014, in August and in November. Both meetings were combined with a workshop the day before. Prior to the August meeting a strategy group had worked out recommendations to the board on future priorities in NOWITECH during the first half of the year. The August workshop discussed and concluded on the NOWITECH strategic choices based on the output from this process. The November workshop presented results from the work packages and was combined with the annual GA meeting. Both board meetings had gender balance, innovations and strategy for development of NOWITECH on the agenda. The November meeting approved the budget and work plans for 2015.

The Board members in 2014 were Knut Samdal (chairman), SINTEF Energy Research, Johan Sandberg, DNV AS, Jean Benoit-Ritz/Vincent De LaLeu, EDF, Martin Kirkengen, IFE, Olav B. Fosso, NTNU, Arnulf Hagen, Fedem, Sigurd Øvrebø, SmartMotor, Jørn Holm, Dong Energy, Jørgen Krokstad, Statkraft, Gudmund Per Olsen, Statoil, and Oddbjørn Malmo, Kongsberg.

The strong commitment and competence of the Board is highly appreciated.

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Figure 4: Most board members were highly active in this year's strategy task force work. The work was concluded in work sessions at Gardermoen 16th May, where groups were set together to discuss the prioritization of future research work. The strategy effort also concluded in the reorganization of the activities in the centre.

Centre Management

John Olav Giæver Tande,
Director NOWITECH

Hans Christian Bolstad,
Manager NOWITECH

The objective of the Centre Management is to manage and coordinate the activities of NOWITECH, ensuring progress and cost control according to approved plans.

The Centre Management Group (CMG) is led by the Centre Director and consists of a management team including Centre Manager, the Work Package leaders; the SC lead, vice-lead and secretary; the CIC chair and the project secretary of NOWITECH. Management staff is appointed to follow up on administrative, financial and legal issues supporting the Centre Director in the day-to-day operation of NOWITECH. The Centre Director is responsible for progress and cost control of the project according to approved Working Plans. The Centre Director has the responsibility and the authority to execute management tasks in accordance with the Working Plan, the Consortium Agreement and the Contract and monitor Parties' compliance with their obligations.

The work is divided into Management and Outreach as outlined below.

The Management activity takes care of the day-to-day operation of the Centre, scientific leadership and strategy development. The day-to-day operation includes follow up on administrative, budgeting, financial and membership legal aspects; meetings in the CMG with WP leaders and representatives from the SC and CIC, preparations for the GA and Board, and reporting to the RCN. CMG meetings have been held on a monthly basis during 2014. These are for team-building, information exchange and strategic discussions. Work on strategic development was enhanced on initiative from the Board through establishment of a taskforce with representatives from industry and research. The Centre management was facilitating the process throughout the winter and spring 2014, culminating in a strategy workshop at Gardermoen in May and reporting to the Board in August and November. The task force process gave very valuable results, including SWOT analysis, scientific quality review, prioritization of research activities and organization.

The Outreach activity includes preparing general presentations of the Centre, dissemination of results, keeping contact with prospective new industry parties, overall coordination towards other projects, relevant organisations and CEER's, in particular NORCOWE, and engagement in developing new offshore wind research projects and strategies. The Centre management is engaged in this also through CIC and SC. Dissemination activities by the management in 2014 included hosting delegations visiting NOWITECH, especially there has been interest from Japan, preparation of media contributions, keeping web and e-room updated, preparation of newsletters, organization of the "Industry meets Science" seminars and the annual offshore wind R&D conference in Trondheim, EERA DeepWind'2014, see also Communication and dissemination. The management contact with industry partners resulted in Fugro OCEANOR AS re-joining as partner in NOWITECH in December 2014, and Norsk Automatisering AS (NAAS) expecting to join in 2015.

Engagement in developing offshore wind projects and research strategies in 2014 included both national and international activities:

- Giving input to Energi21 development of Norwegian research strategies on offshore wind energy.
- Participation in the European Technology Platform on Wind (TPwind) heading the working group on offshore wind.
- Leading the sub-programme on offshore wind energy in the European Energy Research Alliance (EERA) joint programme on Wind Energy.
- Participation in the Board of WindCluster Norway

International engagement is further described in International cooperation.

Committee for innovation and commercialization

Per Arne Wilson, NTNU
CIC Chair

The Committee for Innovation and Commercialisation (CIC) is enhancing the industry involvement and assures that results from NOWITECH are communicated to the industry parties and that the possibilities for establishing new projects, products, services or processes with one or more partners are pursued. Commercialisation is by transfer of knowledge to the industry parties and their use of this in developing their business, and through spin-off projects and the creation of new industry. The committee is industry focused and chaired by Per Arne Wilson, NTNU. CIC cooperates with NTNU's Entrepreneurship School (NEC) and NTNU TTO in commercialisation of ideas created in NOWITECH, while Innovation Norway and Enova assist CIC in project development, including also between NOWITECH partners and SMEs outside NOWITECH.

Activities by CIC in 2014 included support towards commercialization of selected NOWITECH results, and in cooperation with the NOWITECH management, assisting in applying the Technology Readiness Level for communicating progress in innovations, and giving support to external parties in developing new business ideas.

Establishment of a spinout company Seram Coatings AS

CIC activity in commercialization of selected NOWITECH results was in 2014 focused on developing the patented process for thermally sprayed silicon carbide coating (ThermaSiC) into a new business. This was successful with the company Seram Coatings AS being established December 2014. The process provides for an extremely hard, wear-resistant, low friction ceramic coating that can be applied to rotating machinery like main bearings in large direct drive wind turbines. This will make them less susceptible to corrosion, more durable and withstand higher temperatures; ultimately increasing lifetime and reducing cost for maintenance. Read more at http://gemini.no/en/2014/04/silicon-carbide-puzzle-solved/.

Figure 5: The patented process for thermally sprayed silicon carbide coating (ThermaSiC) is now being developed as a commercial product through the new spinout company Seram Coatings AS. Picture is copy from http://www.ntnutto.no/thermasic/.

The Technology Readiness Level (TRL) concept

The TRL concept was introduced in NOWITECH in 2012 with assistance from CIC, and the CIC is continuously providing guidance on the application of the scale for NOWITECH. The TRL concept eases the communication of the research results within NOWITECH and externally, and enhances a systematic development of innovations. The TRL scale applied in NOWITECH is shown in Figure 6. A generic interpretation is that TRL 1-5 represents research and development stages, while TRL 6-9 typically is industry driven towards deployment and commercial application.

TRL 1: Basic principles observed	TRL 2: Technology concept forumlated	TRL 3: Experimental proof of concept	TRL 4: Technology validation in lab	TRL 5: Prototype/lab validatin in relevant environment	TRL 6: Pilot system validation in relevant environment	TRL 7: Full scale prototype in operational environment	TRL 8: System Compete and qualified	TRL 9: System proven in operation environment

NOWITECH Working area (Precompetive Research)

Transfer from R&D to Industry

Industry and commercial development

Figure 6: The Technology Readiness Level scale applied in NOWITECH to evaluate and communicate maturity of new ideas and technology under development.

Support to external parties in developing new business ideas

NOWITECH assists also external parties in developing ideas. This may be through CIC or through management outreach or WP activities. A strong link to relevant SMEs is made through NOWITECH's close cooperation with Windcluster Norway, and a number of innovators and SMEs have been assisted in validation of ideas and linking with relevant partners and public bodies for further development. Since start of NOWITECH these include WindFlip (offshore wind installation system), Limsim (computing technology), SubHydro (subsea energy storage), Norsk Automatisering AS (remote presence) and Simis AS (developing ASHES design and analysis software for onshore and offshore wind turbines). Interlinking through the National Centre of Expertise on Instrumentation, NOWITECH was important for Kongsberg Maritime's decision to establish its activity on wind farm management and operation.

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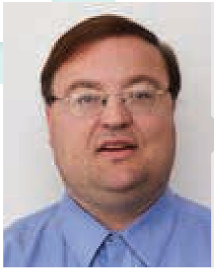
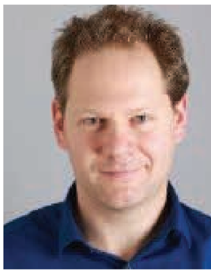
Scientific Committee



Trond Kvamsdal
NTNU, Chair SC



Michael Muskulus
NTNU, Vice-chair

The Scientific Committee (SC) has developed a top quality PhD and Post Doc programme in collaboration with CMG. This includes an active recruitment strategy, invitation of international experts for giving lectures, arrangements of scientific colloquia and seminars, and exposing scholars to industry and leading international research groups through NOWITECHs mobility programme.

The scientific leadership is carried out by the Centre Director and CMG in close collaboration with the Scientific Committee. Decisions as regards scientific directions, contents and prioritisation are executed by the CMG. The SC has the responsibility for the educational part and provides strategic advice on scientific focus and priorities.

The Scientific Committee consists of a core group with relevant NTNU professors and the Centre Director, and an extended group consisting of other Norwegian members and representatives of the associated international research partners. The SC members as per end 2014 are listed below:

SC core group members:

- Trond Kvamsdal, NTNU (Chairman)
- Michael Muskulus, NTNU (Vice chairman)
- Olav Bjarte Fosso, NTNU
- Torgeir Moan, NTNU
- Marta Molinas, NTNU
- Jan Onarheim, NTNU
- Lars Sætran, NTNU
- Tore Undeland, NTNU
- Debbie Koreman, NTNU (secretary)
- John Tande, Centre Director

Other Norwegian members are

- Tor Anders Nygaard, IFE
- Finn Gunnar Nielsen, Statoil/UiB
- Jørgen Ranum Krokstad, Statkraft/NTNU
- Paul Sclavounos, MIT, USA

The associated research partners are represented by:

- Senu Sirnivas, NREL, USA
- Peter Hauge Madsen / Thomas Buhl (stand-in), DTU Wind Energy, Denmark
- Hans-Gerd Busmann, Fraunhofer IWES, Germany
- William E. Leithead / Olimpo Anaya-Lara (stand-in), Strathclyde University, UK
- Gerard J.W. van Bussel, TU Delft – Aerospace Engineering Wind Energy (DUWIND), The Netherlands
- Seri Lee, Nanyang Technological University (NTU), Singapore
- Bruce Mork, Michigan Tech; USA

Finn Gunnar Nielsen participates in NOWITECH SC also to represent NORCOWE, and in the same manner Trond Kvamsdal represents NOWITECH in NORCOWE's SC. This secures communication and alignment of the scientific and educational activities between the two Centres.

During 2014 the Scientific Committee core group met more or less on a monthly basis. They handled day-to-day operations regarding PhD and post doc programme, recruitment, educational issues, etc. and applicants for the mobility programme. In 2014 the programme supported intermediate-term research visits, SC meeting at DTU Risø and an extension of a post doc study to assist the SC operation.

Figure 7: NOWITECH SC's meeting at DTU in Roskilde (Denmark) 17 June 2014 was very fruitful with review of research activities on grids, O&M and novel concepts, and with discussions on reference wind turbines and reference wind farms. The hospitality by the host Thomas Buhl (DTU) is greatly appreciated. From left: Tor Anders Nygaard, Thomas Buhl, Jørgen Krokstad, Harald Svendsen, Trond Kvamsdal, Karl Merz, Gerard van Bussel, Thomas Welte, Olimpo Anaya-Lara, Hans-Gerd Busman, Finn Gunnar Nielsen.

The extended SC accomplished two full meetings in 2014; one in January back-to-back with the EERA DeepWind conference in Trondheim, and one in June at DTU in Roskilde (see Figure 7). These extended SC meetings involved an evaluation of the scientific content of NOWITECH's results and giving strategic advice on direction of research.

Upon a request by the strategy taskforce initiated by the Board, the SC conducted an analysis of the scientific publications in NOWITECH. The main objective of the study was to evaluate the scientific quality of the on-going research in NOWITECH. Based on the publication information from the NOWITECH eroom that were reported within 1st of April 2014 the so-called CRIStin score (normalised by costs) were determined for each work package and each partner respectively. Many interesting observations were made and the study has already resulted in an increase in publications for some of the research partners.

Research work and results

The research work in NOWITECH follows an annual cycle involving the industry partners, researchers and management group. The schedule is illustrated in Figure 8 showing main meetings, reporting events and how the annual work plans for the WPs are prepared with spring and autumn industry meetings before approval by the Board in November.

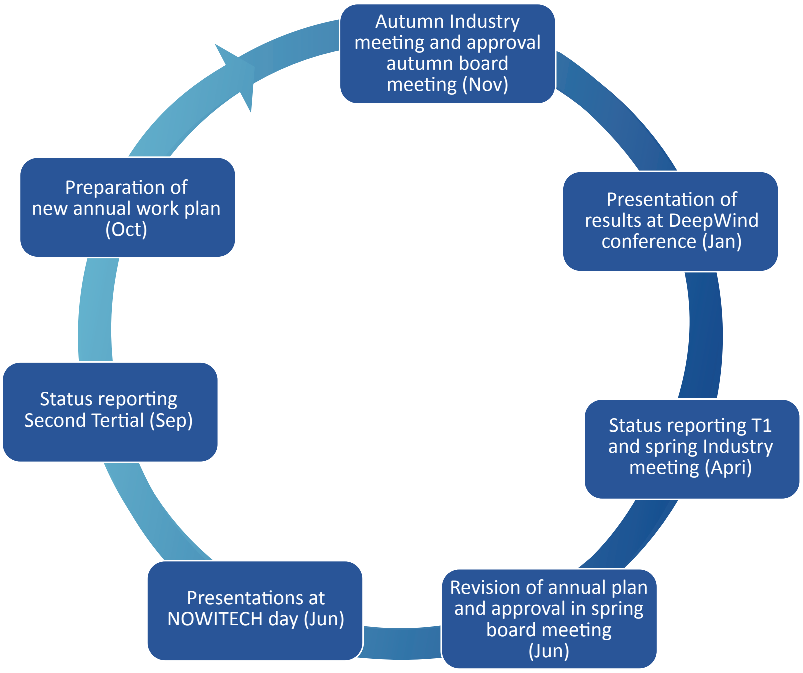


Figure 8: Annual schedule of main meetings, reports and preparation of the annual work plans.

Figure 9 (left): Industry meetings in the Work Packages are central and the progress, activities and results are presented and discussed. Here from a meeting of WPA in Trondheim in April 2014. Photo: HC Bolstad. Figure 10 (right): Professor Torgeir Moan, NTNU with the award at NOWITECH day, June 2014 for sustained excellent academic achievements. Here with John Olav Tande, NOWITECH Director.


2°

WPA

NUMERICAL TOOLS AND SUBSTRUCTURES

Ole David Økland
WPA co-leader

Roy Stenbro,
WPA co-leader

The objective of WPA is to enhance development of novel substructures for offshore wind through development, validation and use of numerical tools and experimental campaigns.

The work is divided into three tasks:

A.1 Development and validation of numerical models
A.2 Assessment of novel design concepts
A.3 Experiments and demonstrations

WPA

NUMERICAL TOOLS AND SUBSTRUCTURES

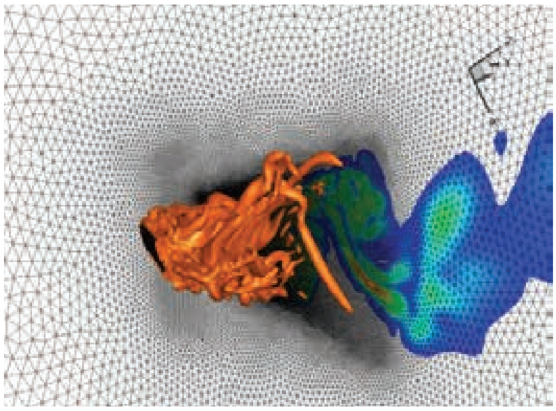
Summary of results 2014

WPA is running well with a strong group of people from both industry and R&D partners, and we have a high productivity of deliverables. Three PhD students in WPA (including one associated) have defended their thesis in 2014, and six of the remaining are expected to follow suit during 2015.

WPA is running well with a strong group of people from both industry and R&D partners, and we have a high productivity of deliverables.

Major achievements/highlights of 2014 are:

- The development of integrated models from both MARINTEK (SIMO/RIFLEX) and IFE (3DFloat) is progressing well. This is an ongoing activity to continually improve the capabilities, accuracy and validity of the software. This year the focus was on aerodynamics, hydrodynamics and control systems. The software is becoming more and more advanced and mature for offshore wind turbine (OWT) use. NOWITECH is on the international leading edge when it comes to integrated modelling of offshore wind turbines. Cooperation with other leading research groups is done through the IEA OC4 project.
- The development of the novel iso-geometry based elements fluid/structure CFD/FEM simulation tool by SINTEF ICT is progressing as planned. Modules for geometric modelling, meshing, 2D & 3D computational fluid simulations and fluid structure interaction modelling has been added and validated against experimental data.
- Wind turbine rotor blades will sometimes fully or partly stall, for example under idling, parked or fault conditions. The result can be undesirable high and/or oscillating wind loads. The most common CFD method is RANS. It however does not predict the loads well for the mentioned load cases. IFE therefore moved on to the Detached Eddy Simulation (DES) method and showed that it could replicate experiments very well also for stalled conditions. The IEA Mexnext project continue to be a good way of meeting and cooperating with some of the world's leading researcher within wind turbine rotor aerodynamics.
- NTNU's third round of the popular "Blind test 3" finished in 2014. There were two unaligned model wind turbines and variations in turbulence of the inflow. This time Acciona, DTU/KTH, GexCon, CD-adapco and CMR submitted their results. Also this time the blind test proved that simulating wind turbine rotor aerodynamics and wakes is not easy.



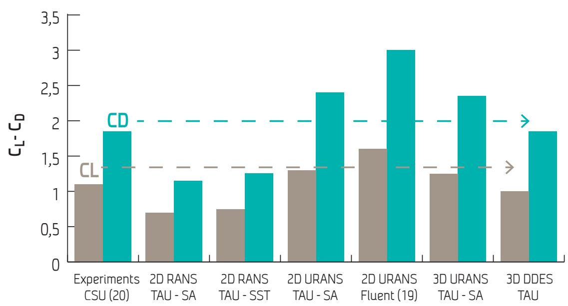


Figure 11: Experiments on stalled wing section replicated with DES CFD simulations by IFE.

Figure 12: NTNU blind test round 3.

- IFE, NTNU and Marintek have all participated in the IEA OC4 benchmark study on semi-submersibles. Work related to further benchmark studies in OC5 has been initiated.
- In addition to benchmarking of tools, comparisons between model tests and numerical analysis have been in focus during 2014. IFE validated 3DFloat simulations against hybrid model test they did together with CENER where the rotor behaviour was simulated in real time and represented by a fan controlled on the wave tank model at Ecole Centrale de Nantes.

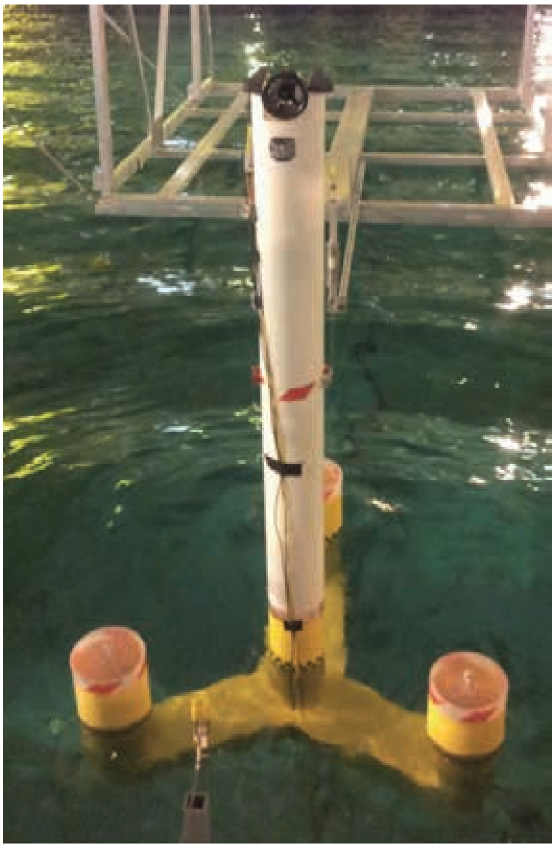


Figure 13: Hybrid model test at Ecole Centrale de Nantes.

- On bottom fixed structures further development of models for prediction of scour and soil-structure interaction have been developed and published by Marintek. Investigations on breaking waves over a reef with a level-set based numerical wave tank (CFD) has been conducted by PhD student M. Chella, and PhD student D. Zwick has studied efficient production methods of bottom supported jacket platforms.
- Marine operations have been pinpointed as an important research area with respect to cost of energy. A screening study to identify available numerical tools/functionality for marine operations in offshore wind has been conducted in 2014. Research on marine operations for installation and maintenance is planned for 2015.
- Two PhD students financed by WPA have defended their thesis in 2014. M.I. Kvittem studied accuracy of time domain and frequency domain analysis of a semi-submersible WT and provided recommendations for guidance for wind turbine analysis. Tania Bracchi studied yaw stability and design of a suitable thin airfoil for downwind rotors. E. Bachynski, who has been an associated PhD to WPA, also defended her thesis in 2014. Her research topic was design and dynamic analysis of TLP wind turbines.
- Several publications on studies of properties of novel floater concepts for offshore wind turbines have been reported in 2014. The topics covered in these studies are: dynamic responses due to emergency shutdown, comparative study of floating vertical axis and horizontal axis wind turbines mounted on a semi-submersible.
- A prototype for a real time hybrid model-testing has been developed and tested in MARINTEKs wave tank in 2014. This work is based on the research of PhD student V. Chabaud and the prototype of the hybrid system is developed together with Marintek. The prototype was tested on a wind turbine with a central tower supported on a novel

semi-submersible developed by PhD student Luan. This concept will be used in a comprehensive model test in Marintek ocean basin in 2015.

Figure 14: Prototype of NOWITECH hybrid system.

Highlights 2014

IFE's integrated model 3DFloat increasingly used by the offshore wind industry

IFE experience increasing interest in 3DFloat from the offshore wind engineering industry, which are the ones that in many cases translate research into tangible real life results. The software has matured from an internal research model to a dependable engineering tool selected by engineers in an internationally competitive environment. 3DFloat for example now has state of the art features within structural mechanics, wind modelling, rotor aero-elastics, wave kinematics, sea loads, moorings and pitch control systems.

Figure 15: 3DFloat simulations of Dr.techn Olav Olsen's 6 MW concrete semi-submersible offshore wind turbine.

Dynamic response analysis of wind turbines under fault conditions

Wind turbines are subjected to faults and failures in their lifetime. A vast number of sensors are installed on a modern wind turbine to detect and isolate faults. Faults such as bearing wear or gear tooth wear are hard to detect at early stages, but they may result in a total breakdown of drivetrain. Design of wind turbines according to should include considerations of the transient responses caused by faults, e.g. grid loss and blade blockage due to loss of pitch control. Figure 16 shows the bottom moment response in the tower of a land based turbine when a blade blockage occurs at the time: 400s. After a time delay of T_d = 0,1 s, an emergency shutdown takes place. The tower bottom bending moment has a change in the mean values during this event. The large negative bending moment is caused by the aerodynamic forces acting at the tower top during the three-blade shutdown. The first tower fore-aft natural bending frequency can be observed in the shutdown process. Significant

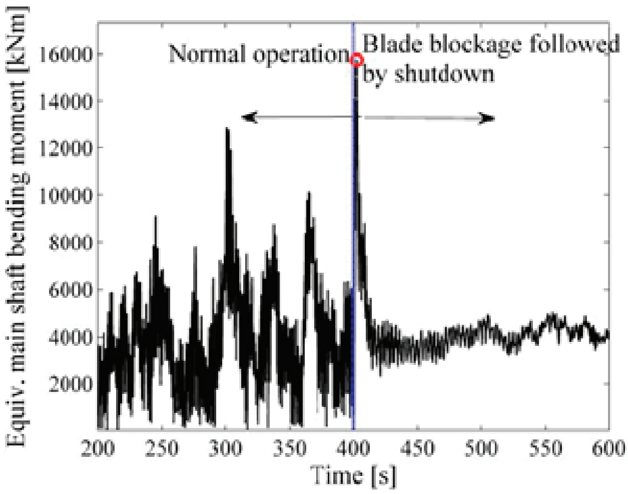


Figure 16: Maximum tower bottom bending moment in grid loss followed by shut-down; land-based turbine, wind speed 17 m/s., HAWC2 simulation.

main shaft bending moment is caused by the imbalanced load acting on the rotor plane. If one blade is seized and hindered from the normal pitch-to-feather activity, the transient response for both fault cases is seen to be large. *Figure* 17 shows the sensitivity of the moment response as a function of the pitch rate during shutdown and compared with the response for idling rotor "in survival condition". In this case, the use of grid connection reduces the response extremes even at a high pitch rate. In *Figure* 17 GS0 means grid disconnected, GS1 means grid disconnected, but with mechanical braking, GS2 means that generator is connected during shutdown. Type 1 and Type 2 are the one-stage and two-stage shutdown, respectively.

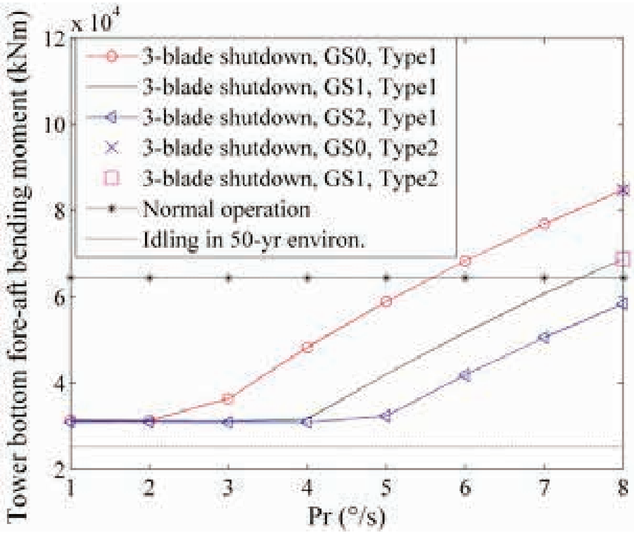


Figure 17: Effect of shutdown procedures on the tower bottom bending moment, wind speed 20 m/s, land-based wind turbine, Simo-Riflex-AeroDyn simulation.

Real time hybrid model testing

A prototype for a hybrid modelling approach has been designed, built and tested in 2014. This work is done by one of the PhD students in WPA together with Marintek. The prototype was tested on a wind turbine with a central tower supported on a novel semi-submersible developed by PhD student Luan. This concept will be used in a comprehensive model test in Marintek ocean basin in 2015. These tests will include full mooring system and various wave and wind conditions for relevant operational conditions.

Frequency versus time domain for calculation of fatigue damage in floating wind turbines.

Figure 18: 5 MW wind turbine on a semi-submersible foundation.

Calculating the fatigue damage for a floating wind turbine requires the use of sophisticated analysis tools. Interaction between rotor and platform motion, non-linearities and large platform displacements suggest that the equation of motion should be solved in the time domain. The iterative solution process of a non-linear time domain finite element system with many degrees of freedom is very time consuming, and is not ideal for long term fatigue analysis, which requires consideration of many environmental conditions. Frequency domain methods are significantly faster, but come with limitations in the accuracy of representing a floating wind turbine's response to wind and waves.

Although the frequency domain method has limitations, it can be a useful tool in performing early stage design assessments. Such an approach is also easier to understand than numerical models for time domain analysis, and makes isolating the effect of different physical factors easier. These two reasons form the background for the study, where fatigue analysis of a single semi-submersible wind turbine was performed in the frequency domain and compared to time domain analysis.

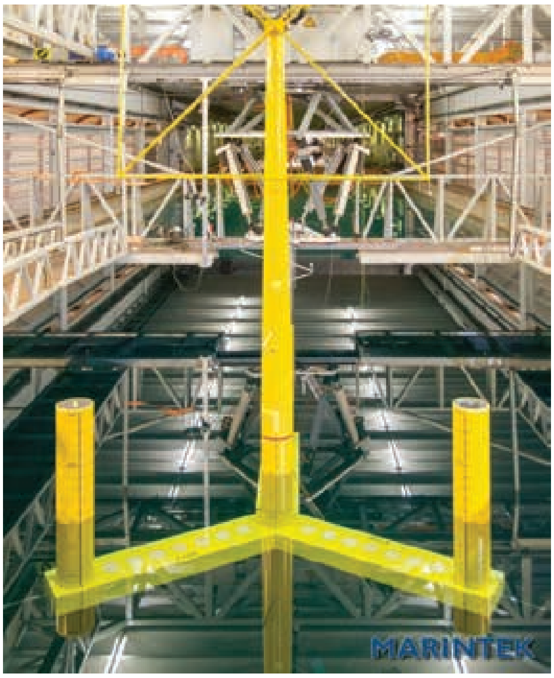


Figure 19: Prototype test of NOWITECH hybrid approach on NTNU novel semi-submersible concept.

Three variants of the frequency domain (FD) model were considered:

1. Rigid tower assumption (FD1)
2. Flexible tower excited by the wind force and platform motion (FD2)
3. Flexible tower excited by the wind force only (FD3)

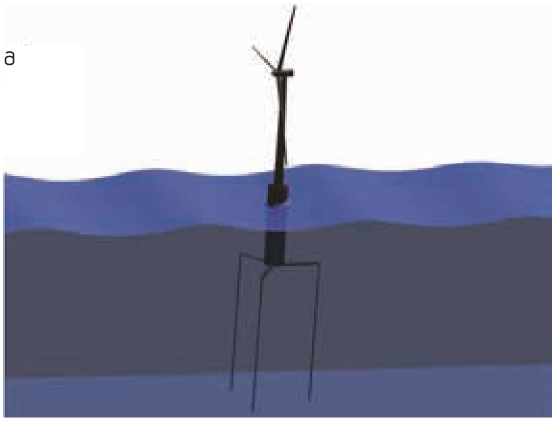
With the assumption that the structure is completely rigid, bending moments were underestimated, but including excitation of the elastic tower and blades, improved the results. The frequency domain fatigue damage predictions were underestimated by 0-60%, corresponding to discrepancies in standard deviations of stress in the order of 0-20%.

Comparative Study of Tension Leg Platform Wind Turbine

Initial studies have shown that TLP has a great potential to support wind turbines. However, one of the concerns regarding TLP wind turbines (TLPWTs) is the natural frequencies of the structure that may be excited by nonlinear wave loads. In order to address this concern, a CFD model is developed to study wave induced responses of a TLPWT and results are compared with the results of potential theory based industrial software, SIMO/RIFLEX. Figure 20(a) shows a snapshot of the CFD simulation.

The CFD results for small and medium amplitude waves are generally in good agreement with the potential theory based model results (Figure 20(b)). A higher drift motion, however, is noticed in the CFD model, possibly because of better representation of hydrodynamic loads. This difference does not highly affect the important design driving parameters such as tendons forces and tower base moment. This comparative study gives more confidence to the CFD model to be further used for analysis of TLPWT in steep waves in which nonlinear phenomena such as ringing might occur.

a



b

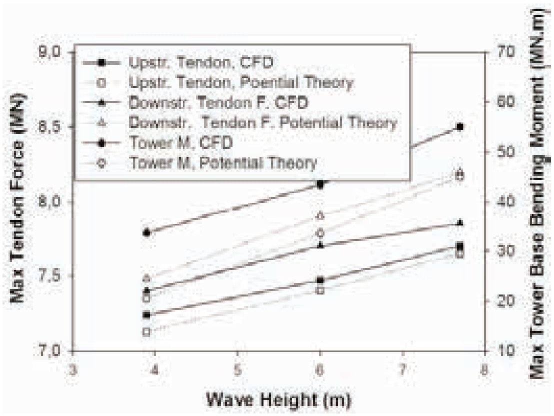


Figure 20: (a) CFD simulation results of TLP wind turbine. (b) CFD and potential theory results for the effects of wave amplitude on TLPWT tendon forces and tower base bending moment.

Isogeometric Finite Element codes

Isogeometric analysis is a recently developed computational approach that offers the possibility of integrating finite element analysis (FEA) into conventional NURBS[1]-based CAD design tools. Currently, it is necessary to convert data between CAD and FEA packages to analyse new designs during development, a difficult task since the computational geometric approach for each is different. Isogeometric analysis employs complex NURBS geometry (the basis of most CAD packages) in the FEA application directly. This allows models to be designed, tested and adjusted in one go, using a common data set. Applied Mathematics Department, SINTEF ICT (SAM) and Department of Mathematical Sciences, NTNU (IMF) in close collaboration have been advancing this new technology in the field of offshore wind engineering. This has been achieved through the development of an open source code IFEM (www.ifem.no). The code is written in C++ for modularity and parallelized using the PETSc library to take advantage of the most modern high performance computing facilities. The fluid structure interaction simulations are facilitated through the use of the same basis functions. The development of IFEM started with the NFR-project ICADA which focused on isogeometric modules for solid/structural problems. Within NOWITECH the main focus has been on developing modules for 2D and 3D CFD simulations of flow around wind turbine blades. Currently work on fluid-structure interaction for wind turbines are the focus of the NFR-project FSI-WT. Within NOWITECH, SAM and IMF have contributed to the following 5 modules of IFEM:

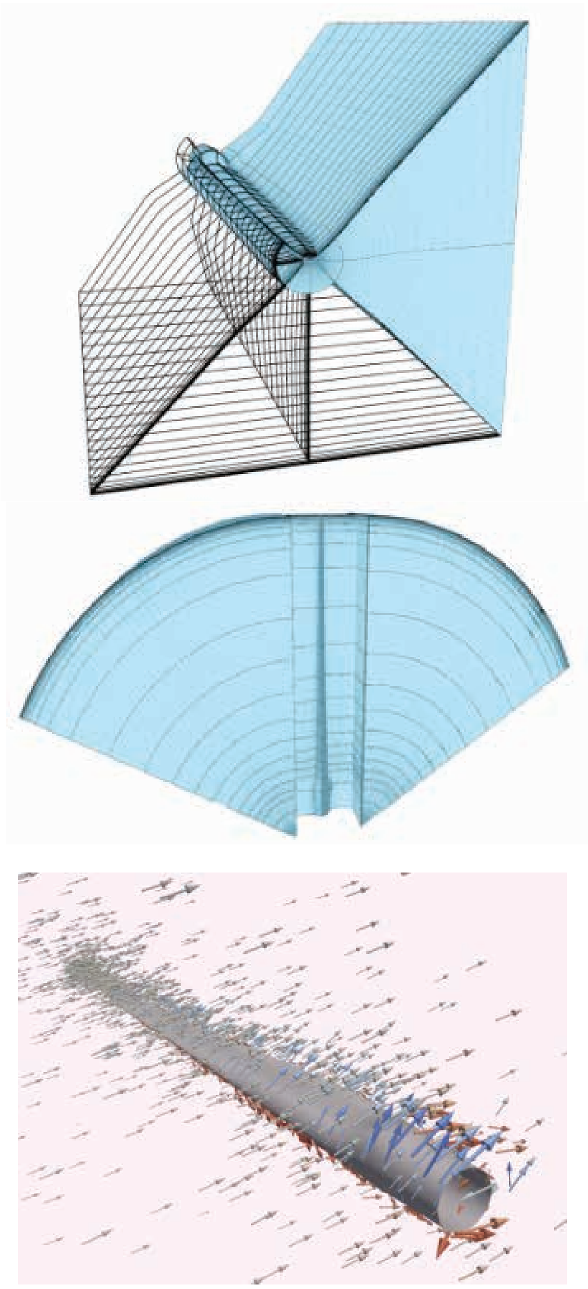


Figure 21: Selected IFEM results.

- IFEM-GeoModeller for creating geometries.
- IFEM-Mesher for 3D spline based block structured mesh generation
- IFEM-CFD2D and
- IFEM-CFD3D for conducting 2D and 3D computational fluid dynamics simulations respectively. IFEM-FSI for fluid structure interaction simulations.

A fully coupled isogeometric finite element solver for the incompressible Navier-Stokes includes pressure stabilization for equal order elements and SUPG stabilization for high Reynold number flows. The Navier-Stokes solver is based on either a Chorin projection method (incremental pressure correction) along with the Spalart-Allmaras turbulence model or a coupled formulation and variational multiscale turbulence approach. Common to both methods are the Navier-Stokes equations that are discretized using equal order

[1] Non-Uniform Rational B-Spline

splines for velocity and pressure. So far linear, quadratic and cubic spline elements have been implemented. The meshes for such simulations are characterized by an aspect ratio of up to 1000-10000 close to the wall resulting in slow convergence rate. To address this issue, efficient preconditioners and linear solvers have been implemented using the open source library PETSc (Portable Extensible Toolkit for Scientific Computation). Traditional computational fluid dynamic codes solve the fluid equations on a fixed (Eulerian) grid but fluid-structure interaction problems usually requires an unsteady moving domain for the fluid part. A classical approach to overcome this difficulty is to consider the so-called Arbitrary Lagrangian-Eulerian (ALE) method where the grid is moved arbitrarily inside the fluid domain, following the movement of the boundary. Furthermore, a fluid-structure interaction problem is not only a two-field (fluid and solid) but a three-field coupling problem (fluid, solid and mesh). These issues are taken into account in the code. Input to the IFEM code is given as a standard XML file while HDF5 is the default output format. However, there are converters to convert the HDF5 format to other formats like VTF and VTK which makes it possible to visualize the results in open-source software like Paraview. Intensive validation work is in progress and the most recent developments are communicated through the www.fsi-wt.no website.

Industry benefits and cooperation

WPA aims to develop software tools that accurately simulate the behaviour of wind turbines. This requires research within various fields, e.g.

- Wave, current and wind loads
- Subsystems (foundation, mooring, blades ...)
- Integrated models for global response
- Parks and wake modelling

Integrated models are essential tools used by many engineers in the offshore industry every day when they design the offshore wind parks of tomorrow. The limitations and capabilities of such models have a real and significant impact on the LCOE of offshore wind energy.

Verification and validation of tools is an important part of the WP. This is achieved through extensive benchmarking and comparison to available measured data. Accomplishment of experiments and demonstrations as a mean to support the development of novel offshore wind farm technology is a high priority task in WPA.

We predict that the hunt for increased accuracy and reduced uncertainties, risks and costs will result in increasing use of CFD in the offshore wind industry. We have shown that we can produce very accurate results for wind turbine aerodynamics, which is knowledge that has been exploited by the industry.

WPA is also assessing alternative designs of novel offshore wind turbines through analytical studies and numerical tools, supported by experiments and demonstration. An important outcome of this activity is to assess relevant design criteria for various bottom-fixed and floating concepts.

CD-adapco, DONG, Statoil and Statkraft have been the most active industry partners in WPA during 2014 and they contribute with valuable input.

Academic achievements

A total of 11 PhD students and 3 post docs have been financed by NOWITECH under WPA. Three PhDs and 2 post docs have now completed. Tania Bracchi and Marit Kvittem defended their thesis in 2014. At present 7 PhDs and 1 Post Doc are financed by WPA. 6 of the PhDs plan to submit their thesis in 2015. In addition 4 PhD students financed outside NOWITECH and 4 master students have been active in WPA in 2014.

24 publications in journals, 19 conference papers, 15 technical reports and 2 technical memos were scheduled for 2014 in WPA. Most of these were completed in 2014 but some of them have been/will be published during spring 2015. In addition several oral presentations and posters have been given during 2014.

The WP has international collaboration through participation in IEA Offshore Code Comparison Collaboration Continuation (OC3/4, integrated models), through the IEA Mexnext project (rotor aerodynamic) and the NTNU series of rotor and wake experiments and workshops (Blind tests 1, 2 and 3).

*** Technology readiness level**

Result	TRL*	Impact
1. Model: IFE - 3DFloat integrate simulation tool	7	Integrated OWT models are essential to research and engineering. The model is in commercial use in the OWT industry.
2. Model: MARINTEK SIMO-RIFLEX simulation software package	7	Integrated OWT models are essential to research and engineering. The model is in commercial use in the OWT industry.
3. Model: IFE - 3DWind offshore wind turbine park wake CFD simulation tool. Development and validation finished 2011.	6	Understanding and simulation of the wake effects are essential to park layout, park energy prediction and important to turbine wind loads predictions.
4. Model: SINTEF ICT & NTNU IFEM-CFD fluid structure simulation tool	3	When further developed the model can be able to simulate how a deforming OWT interacts with sea and air, which can be important for example for advanced rotor research and engineering.
5. Method: NTNU Dept. of Mathematical Sciences - A posteriori based error estimator	3	This method could be used to increased accuracy and/or speed numerical simulations, if it for example were implemented in CFD or FEM simulations software.
6. Software: MARINTEK FloatOpt/WindOpt spare buoy offshore wind turbine and mooring optimization software tool.	4	Can do cost optimized design of spar buoy type OWT substructure and mooring and minimize CAPEX in these areas. Development finished in 2011.
7. Software: IFE - ALSIM / INVALSIM general and offshore wind turbine optimization software tool. Development finished in 2011.	8	When coupled with another model this software is able to cost optimize systems or components and minimize LCOE. Such tools are commonly used in many industries. It has been used for rotor, mooring and tower optimization. Services provided to the OWT industry.
8. Method: IFE - use of the DLR TAU CFD simulation tool on wind turbine rotor.	5	State of the art CFD tools are the computer tools we have that can offer the most insight into fluid dynamics phenomena, for example rotor performance under normal or faulty operations. It's part of the standard toolbox for advanced research and engineering. CFD simulation services have been performed for to the OWT industry.
9. Prototype: Fugro-OCEANOR floating met-ocean buoy with LIDAR for measuring wind speed at different heights above sea level.	8	NOWITECH contributed to the start-up of this development. It is now offered as a commercial product by Fugro OCEANOR. It can drastically reduce the cost of collecting data on current, waves and wind at an offshore site.
10. Comparison of software codes for analysing semi-sub wind turbines pinpointing accuracy	NA	Several research partners in WPA have been involved in the OC4 study under the auspices of IEA regarding comparison of software for analysing semi-submersible wind turbines.
11. Novel design of semi-submersible platform for 5 MW wind turbine	2	A preliminary design of a semi-submersible platform for a horizontal axis 5 MW wind turbine has been developed as a milestone deliverable in WPA.
12. Experimental techniques for offshore wind turbines.	3	Scaled model testing is important for validation of methods and design-tools. Techniques where load effects from wind and waves can be combined for scaled models will lead to more accurate design tools and more optimal and cost effective designs.

WPB

OPERATION & MAINTENANCE AND MATERIALS

Thomas Welte,
WPB co-leader
Tasks B1 and B2

Jens Kjær Jørgensen,
WPB co-leader
Tasks B3, B4 and B5

The objective of WPB is to contribute to the reduction of cost of energy of offshore wind power through development of new and cost-effective O&M concepts and strategies, through efficient and optimized use of material and coatings, and through development of new coatings and improved models for structures and materials.

The work is divided into five tasks:

B.1 Maintenance strategies
B.2 Surveillance and condition monitoring
B.3 Rotor blade structure and materials
B.4 New coatings for better performance
B.5 Testing and qualification of new coatings

WPB

OPERATION & MAINTENANCE AND MATERIALS

Summary of results 2014

- New versions of the NOWIcob life-cycle profit software and the Fleet Optimization Tool have been deployed. Four NOWITECH industry partners have signed a software licence agreement for use of the NOWIcob software.
- The comparison of O&M modelling tools by the so-called “Offshore Wind O&M modelling group” with participants from SINTEF Energy Research, MARINTEK, University of Strathclyde, University of Stavanger and EDF has resulted in a set of reference cases for model benchmarking. NREL joined the modelling group in 2014.
- Fahmi Mubarok’s PhD work on “Thermally Sprayed Silicon Carbide Coating” has resulted in the start-up of the spin-off company SERAM COATINGS AS to further develop and commercialize the technology and the coatings.
- PhD student Amir Rasekhi Nejad received at the EERA DeepWind 2014 conference the best poster award for his poster on “Fatigue Reliability-Based Inspection and Maintenance Planning of Gearbox Components in Wind Turbine Drivetrains”
- A numerical tool to identify fatigue model data from experimental data has been developed, and a composite fatigue test program has been completed.
- Preliminary results show that coating systems with thermally spayed zinc (TSZ) seems to have excellent field performance, even with a very simple paint system on the top (TRL report, D3.3.8).
- Polyurethane capsules containing Ce(NO3)3 water soluble corrosion inhibitor were prepared for testing of the stability and compatibility of the capsules in coating formulations.

Highlights 2014

NOWITECH has led to a large number of spin-off projects and new international cooperation. Examples of successful projects and cooperation initiated by NOWITECH research activities in the field of O&M modelling are the FAROFF project, the Offshore Wind O&M Modelling Group and the EU FP7 LEANWIND project.

NOWITECH has led to a large number of spin-off projects and new international cooperation.

FAROFF (“Far Offshore O&M vessel concept development and optimisation”) was a joint industry project funded by the Research Council of Norway and the industry partners. Statkraft was the project leader. Other project participants have been Statoil, Odfjell Wind, Offshore Kinetics, Fred Olsen Windcarrier, SINTEF Energy Research and MARINTEK. One objective of the FAROFF-project was to develop strategic decision support tools for analysing cost of energy. This includes the development and verification of a life-cycle profit simulation model and a vessel fleet optimization model. Another objective was the development and analysis of innovative vessel concepts and other main cost drivers through functional requirements specifications, and technical analysis and evaluation.

The organization of the research activities in a separate spin-off project has given the possibility to work more focused on specific problems, e.g. related to weather operability analysis. A problem in weather limitation assessment of vessels and access systems is that by using the significant wave height as the only model parameter, the real vessel operability is modelled incorrectly and important characteristics of the vessel design are not taken into consideration. FAROFF was an important contribution to overcome this problem, because the use of more detailed met-ocean parameters was investigated to improve modelling and assessment of access systems. Also, the logistic decision support tools, NOWIcob and the fleet optimization tool, took advantage of an extended and focused industry group in the FAROFF project to make these tools even more advanced and applicable in practical planning phases. This resulted in a newly signed "framework agreement" between Statkraft, MARINTEK and SINTEF Energy Research to ensure further cooperation on a continual small scale basis related to decision support and minor tailor-made tool adjustments.

The FAROFF project results have been made available in NOWITECH for use by NOWITECH industry partners and further development in NOWITECH and other spin-off activities. The FAROFF project was therefore an important contribution to the development of the NOWITECH models and tools for operation and maintenance analysis (NOWIcob) and for fleet optimization. By making results from NOWITECH available in the beginning of FAROFF, FAROFF had a "flying start", and by making the FAROFF results available to NOWITECH, NOWITECH received additional input to ongoing developments – a win-win situation for the partners in both projects.

The models developed in FAROFF and NOWITECH by SINTEF Energy Research and MARINTEK can e.g. be used for simulation of different configurations of the vessel fleet of an offshore wind park. Statkraft, for example, has used the models together with financial analyses for analysis of different vessel fleet configurations to get good estimates of the operating expenses (OPEX) for an offshore wind park. The Dudgeon offshore wind farm is one example of application. Statkraft plans to conduct similar analyses for new offshore wind projects, such as Triton Knoll and Dogger Bank.

Figure 22: Maritime logistics is key to efficient Offshore Wind operation.

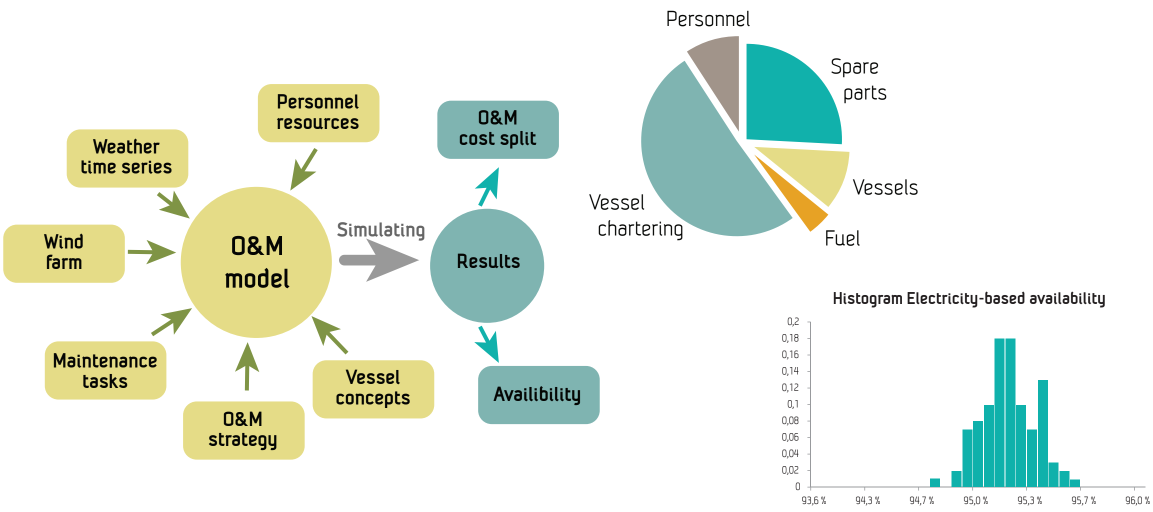


Figure 23: Input parameters and results for the NOWIcob model.

The development of the NOWIcob and fleet optimization model has also resulted in an interesting international cooperation on model comparison. Several researchers from SINTEF, MARINTEK, University of Stavanger, University of Strathclyde and EDF formed an "Offshore Wind O&M Modelling Group" for comparison of O&M cost modelling software tools that have been developed at the participating research institutions. Since there is a lack of real data for verification and validation of the models, the comparison of model results with those from other models is a step towards verification. The group has therefore developed several references cases that have been used for O&M costs analysis with the different software tools. The results (average annual O&M costs and availability) have been compared and the influence of different modelling assumptions has been discussed.

The activities in WPB on development of cost-effective operation and maintenance (O&M) concepts and strategies and the optimized use of material and coatings for offshore wind turbine applications are two important contributions to cost reduction.

Another project related to NOWITECH is the recently started EU FP7 project LEANWIND (Logistic Efficiencies And Naval architecture for Wind Installations with Novel Developments) that can be considered as a spin-off project to NOWITECH and FAROFF where MARINTEK is the technical coordinator. In this project, the models developed in FAROFF and NOWITECH by SINTEF Energy Research and MARINTEK are being employed to find more cost-effective O&M vessel logistics solutions and to cost-benefit evaluate other innovations and developments in the LEANWIND project.

Industry benefits and cooperation

There is a need for a significant reduction of life cycle-costs and cost of energy for offshore wind power installations. This requires the development of energy conversion systems that are well-adopted to the constraints for offshore deployment, for example through systems characterized by light weight and reliable operation. The activities in WPB on development of cost-effective operation and maintenance (O&M) concepts and strategies and the optimized use of material and coatings for offshore wind turbine applications are two important contributions to cost reduction.

There are a number of WPB results that are currently driven to a higher TRL level and are in a

*** Technology readiness level**

Result	TRL*	Impact
1. NOWIcob software. A life-cycle profit analysis tool for offshore wind farms.	4	A tool to simulate the O&M cost of an offshore wind farm over the lifetime. NOWIcob can serve as a decision support tool to analyse the consequences of different decisions regarding maintenance and logistic strategy.
2. Vessel fleet optimization software. An optimization model and tool for making decisions about optimal vessel fleet to support the maintenance operations.	4	The model will give output results regarding (i) location of maintenance bases (onshore/offshore) and (ii) the vessel fleet size and mix, i.e. which and how many vessels/helicopters to invest in and/or charter.
3. Routing and scheduling optimization software. Tool for optimization of vessel routing and maintenance scheduling	2	An optimization model for daily scheduling of maintenance operations in an offshore wind park (which maintenance task to perform when and in which order and by with which ships and personnel).
4. Remote presence. A remotely controlled robot installed inside wind turbine nacelle.	4	Remote inspection using the robot is an alternative to expensive and time consuming manned inspection. The low cost of a remote inspection allows for more frequent inspections, which potentially can increase the reliability. The system is being commercialized by Norsk Automatisering AS.
5. Wind turbine drivetrain fault detection model. Prognostic model for fault detection in wind turbine drivetrains.	(3)	Model for early detection of wind turbine drivetrain faults based on condition monitoring data.
6. Gearbox inspection and maintenance planning method. Method for fatigue reliability-based inspection and maintenance planning of gearbox components in wind turbine drivetrains.	(3)	Method can lead to more effective inspections and thus reduce the downtime for fault detection and routine inspection, because inspection and maintenance can be focused on those components which hold higher probability of damage.
7. Design space for composite layup in rotor blades with bend twist coupling.	4	More reliable design of self-adaptive blades.
8. Composite fatigue model and test procedures. Model and procedure to identify model parameters.	(4)	Improved prediction of fatigue life of composite structures.
9. Thermally sprayed silicon carbide coating (ThermaSiC). New cost effective thermally sprayed silicon carbide coating useful for components that requires high wear resistance and low friction.	3	The properties of SiC makes the coatings highly attractive for many industrial applications as a new and cost-effective competitor to most hard coating materials on the market. The goal is to reduce wear of components and increase lifetime, and thus reduce O&M costs. The process is patented and being commercialized through the new spinout company Seram Coatings AS.
10. Novel protective coating systems for offshore wind turbines substructures. Maintenance-free coating systems comprising thermally sprayed zinc (TSZ) paint with self-healing properties on top.	3	Longer lifetime and reduced maintenance of steel structures.
11. Erosion resistant coatings for WT blades. Coatings based on nanoparticle modification of commercial coatings.	3	Reduced erosion of WT blade leading edge.
12. Droplet erosion test setup. Laboratory setup for droplet erosion testing of wind turbine blade coatings.	(3)	Simplified and cost-effective droplet erosion testing of coatings.

phase of being transferred to industry (see table on results and TRL level). The results are related to all WPB tasks and cover the whole range of research in WPB from O&M strategy model development, inspection strategies, rotor blade materials and structures, corrosion protection (coating systems) and testing of corrosion protection systems.
Industry partners that have participated in WPB are Fedem, Kongsberg Maritime, Statoil, Statkraft, EDF and DNV GL.

Academic achievements

Three of five PhD students financed by NOWITECH under WPB have finished their work. Among the associated PhD-students, one has finalized the work. The remaining students plan to deliver their theses in 2015.

The PhD students that have finalized their work in 2014 are:

- Kevin Cox - Thesis title: "Lift Control of Adaptive wind Turbine Blades with Bend-Twist Coupling". Investigation of the potential for implementing passively adaptive blades with bend-twist coupling into multimegawatt horizontal axis wind turbine systems to save costs by decreasing loads.

- Lijuan Dai – Thesis title: "Safe and Efficient Operations and Maintenance of Offshore Wind Farms". Investigation and development of methods for improving safety and efficiency of O&M in offshore wind farms.

- Fahmi Mubarok – Thesis title: "Thermally Sprayed Silicon Carbide Coating". Development of a new technology for thermal spraying of Silicone Carbide (SiC) for production of low friction and wear-resistant coatings.

- Øyvind Netland – Thesis title: "Remote Inspection of Offshore Wind Turbines – A Study

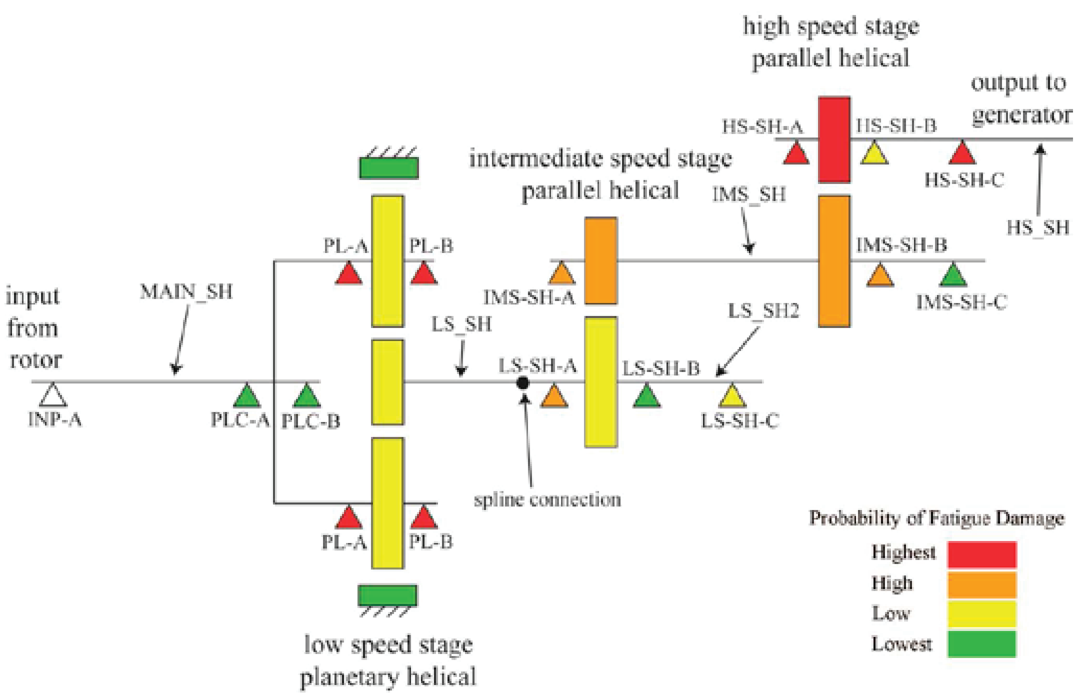


Figure 24: Vulnerability map of 750 kW case study gearbox based on component fatigue damage ranking. Figure with permission from: Nejad A.R., Gao Z., Moan T. (2014). Fatigue reliability-based inspection and maintenance planning of gearbox components in wind turbine drivetrains. Energy Procedia, 53, 248–257).

of the Benefits, Usability and Feasibility". Development of a remotely controlled robot for inspection of wind turbines without the need of accessing the turbine.

In 2014, 9 publications in peer-reviewed scientific journals and 2 publications in international conference proceedings have been prepared. Furthermore, 5 reports and 4 PhD dissertations have been finalized and new software versions of the O&M modelling tools have been deployed.

WPB takes part in the EERA Wind Sub Programme "Structures and Materials" where we contribute with the work related to composite materials and coatings. WPB is also involved in the IEA Wind Tasks 26 and 33 on, respectively, "Cost of Wind Energy" and "Reliability Data". SINTEF Energy Research and MARINTEK participate in the "Offshore wind O&M modelling group" together with EDF R&D, University of Strathclyde, University of Stavanger, MARINTEK and NREL. Furthermore, SINTEF Energy Research participates in the Nordic Wind Power O&M Network, together with Chalmers Univ. of Technology, KTH and Elforsk, VTT, DTU and Energy Norway. A seminar on wind turbine drivetrain O&M with participants from the Nordic countries has been arranged by the network in Helsinki, October 8th. WPB PhD student Amir R. Nejad has a close collaboration with NREL and the Gearbox Reliability Collaborative. MARINTEK as the technical coordinator of the EU FP7 project LEANWIND is ensuring a good cooperation within the field of logistics and related activities in NOWITECH WPB.

Figure 25: Laboratory setup for droplet erosion testing of blade coatings.


2°
Solutions for
offshore grids

WPC

GRID AND WINDFARMS

Harald G Svendsen
WPC co-leader

Karl O Merz
WPC co-leader

The objective is to develop technical solutions and methods for cost effective electromagnetic and electrical designs, controls, grid connection and power system integration of offshore wind farms.

The work is divided into four tasks:

C.1 Wind turbine generator systems
C.2 Wind power plants
C.3 Offshore grids
C.4 Power system integration

WPC

GRID AND WINDFARMS

Summary of results 2014

2014 was an active year with a large scientific output, spurring cost-saving innovations for the wind energy industry related electrical conversion, grid connection and controls.

2014 was an active year with a large scientific output, spurring cost-saving innovations for the wind energy industry related electrical conversion, grid connection and controls.

NOWITECH is continuing its close collaboration with EERA (European Energy Research Alliance) on grid connection and offshore wind. Several on-going Nordic and EU-projects are closely coordinated with WPC activities. Several PhD studies have been submitted or are close to submission.

Major progress has been made in the specification and analysis of a 1200 GW reference wind farm. This work was discussed at a workshop at NREL and is being coordinated with related efforts in NORCOWE.

Multiple studies have addressed the concept of integrating offshore wind power with offshore oil and gas installations, summarised in a milestone report. This work has attracted strong industrial interest in Statoil and DNV GL. A second voltage dip test on a full-scale wind turbine with the DipTest facility was performed under strong wind conditions in December 2014. Analyses of the test results will continue in 2015. An industry initiated activity proposed by Dong Energy on AC connected wind farms and harmonics was started up, and will be continued in 2015

Highlights 2014

Wind power integration with oil and gas platforms

This activity has investigated the possibility of supplying offshore petroleum installations with power from offshore wind turbines. The main motivation is to reduce carbon emissions associated with oil and gas extraction on the Norwegian continental shelf. Both existing platforms that today are being supplied by on-site gas turbines and new platforms electrified with a cable to shore are relevant for wind integration. In the first case, wind power may replace a large amount of the gas fuel. In the second case, connecting an offshore wind farm gives benefits through a sharing of transmission infrastructure and gives a higher utilisation of the cable capacity.

The main outcome of these studies is that systems with wind power connected to oil and gas installations can be operationally stable and reliable with the proper design, and are economically and environmentally sound.

NOWITECH has addressed technical and operational questions in a series of studies that have been presented and published, and summarised in a milestone report in 2014. Power electronics in wind turbines or HVDC transformers enable a high degree of control that can be utilised to ensure stable voltage and frequency on the platform, even during rapid changes in wind power or due to component faults. Different operational strategies combining gas and wind turbines have been analysed to quantify the economic and environmental benefit.

About ten publications have described and analysed the concepts in detail. The main outcome of these studies is that systems with wind power connected to oil and gas installations can be operationally stable and reliable with the proper

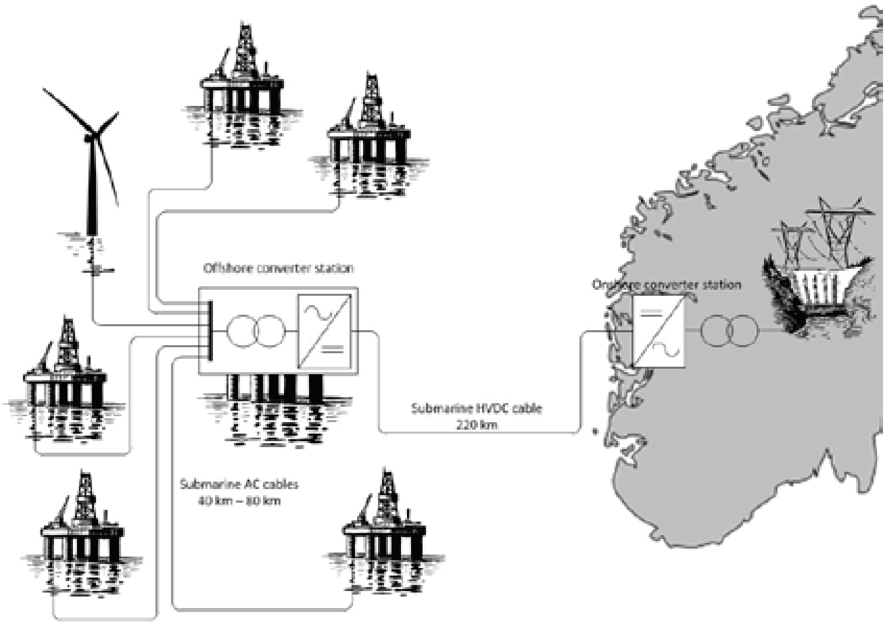


Figure 26: Schematic diagram of electrified oil and gas platform group connected to a wind farm.

design, and are economically and environmentally sound.

These results have increased the interest within the oil sector to consider such solutions, and both Statoil and DNV GL are following up these ideas.

Analysis tools and reference designs for next-generation GW-scale offshore wind power plants

With the VIPER (Norwegian: Vindpark Energiproduksjon) and STAS (State Space Analysis of Offshore Wind Power Plants) programs, NOWITECH is developing the tools needed for the dynamic analysis of the next generation of GW-scale offshore wind power plants. VIPER computes the energy production of an offshore wind power plant, using a boundary-layer model to account for the cumulative wake effects. The tool was used in designing the Dogger Bank Reference Wind Farm, Figure 28.

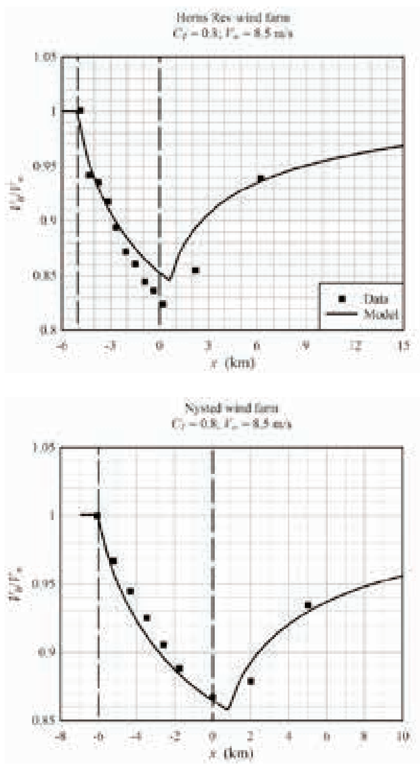


Figure 27: Validation of the hub-height windspeeds predicted by the VIPER program.

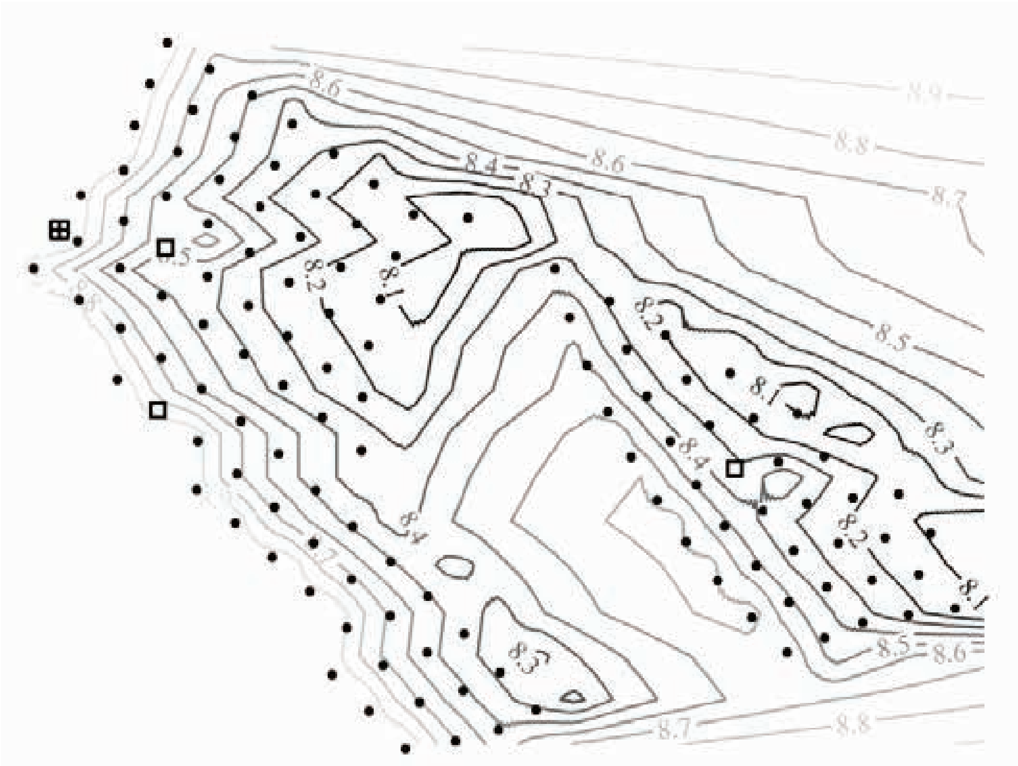


Figure 28: Hub-height windspeed contours across the 39 km wide Dogger Bank Reference Wind Farm.

STAS is a model of an entire offshore wind power plant, represented in a single linearized state space. This type of mathematical representation allows for rapid analysis of system stability, and is useful for designing and tuning control algorithms, and for analyzing the stochastic dynamic behavior of the wind power plant under normal operating conditions. In 2014 the aerodynamic and structural models of the individual wind turbines were developed and verified. Work continues into 2015, incorporating stochastic wind and wave loads, and extending the model to the entire wind power plant, including the electric grid.

Fault ride-through test of full-scale wind turbine

In December 2014 a team from SINTEF Energy Research and NTNU performed a voltage dip test on a full-scale wind turbine at Valsneset, using the DipLab mobile short-circuit laboratory. Wind conditions were good giving an initial high power output from the wind turbine. Several experiments were conducted, producing highly valuable data for validation of simulation models. Analyses of the test results will continue in 2015.

Understanding and being able to model the response of a wind turbine's electrical and mechanical systems during a low voltage fault is important for the cost-effective design of wind turbine systems.

Industry benefits and cooperation

The industrial benefit of this work package is the development of technical concepts and solutions for generator and electrical design and control with high potential to reduce the cost of offshore wind energy. Risks are reduced through development of proven software models and tools that can be applied in detailed analyses. Improved control strategies can reduce costs through improved reliability and reduced mechanical loads.

Industry partners involved in WPC are Statoil, Dong Energy, Statkraft, DNV GL, EDF, Statnett, SmartMotor and Kongsberg Maritime

*** Technology readiness level**

Result	TRL*	Impact
1. Numerical model of the influence of slot harmonics on magnetic vibrational forces in PM magnet generators	(4)	Identify generator designs with low vibrational forces which will allow reduction in total generator mass
2. Power System Simulation Tool (PSST), software simulation tool	3	The tool can be used to assess future scenarios for wind power integration, concerning cost of energy, nodal prices, grid bottlenecks, benefit of grid reinforcements etc.
3. Net-Op, software simulation tool	3	Tool for optimising offshore grid layout, taking into account variability in wind power, demand and prices. It can be used to identify economic offshore wind farm clustering and grid structures
4. Viper, software engineering tool	(3)	Engineering tool for estimating energy production for an offshore wind farm. It can be used together with electrical models in order to optimise offshore wind farm layout.
5. Electrical laboratory with multiple converters, cable emulators and wind farm emulator	(4)	The laboratory can be used to demonstrate technical solutions and validate numerical models for grid connection and control of offshore wind farms, including multi-terminal HVDC set-ups
6. Operational strategies for integration of wind power with oil and gas platforms	NA	This knowledge can improve profitability and reduce risks for offshore oil and gas platforms powered partially by wind energy.
7. Control of floating offshore wind turbines, advanced strategies and algorithms	(2)	Smart control systems for load mitigation and structural stabilization are important for optimal production of power and cost reduction.
8. Integrated generator design	(3)	Integrated generator design for lower mass per MW
9. Library of wind turbine models for electrical studies	(2)	Ready to use models in Matlab, PSCAD, Simpow, for analyses of grid integration, control and stability
10. Controls for grid connection of offshore wind via multi-terminal HVDC grid, algorithms and models	4	Cost-effective deployment of offshore wind in the North Sea, benefits from efficient and reliable sharing of offshore transmission infrastructure
11. Grid model reduction, algorithm and software tool	(2)	Create simplified, equivalent power flow models that obscures sensitive information and reduces complexity, for simulation of large grids with hundreds/thousands of buses
12. STAS, integrated linear state space model for wind farm, software model	(2)	Fast engineering model to assess wind farm level control strategies

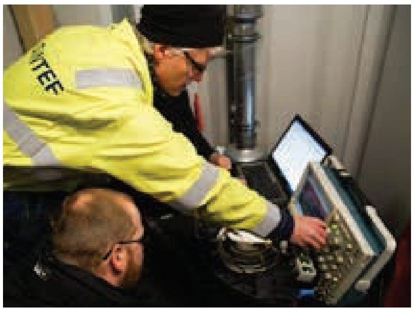
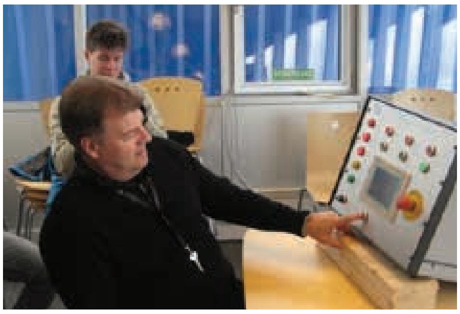




Figure 29: Voltage dip test of wind turbine at Valsneset.

Academic achievements

Of the six PhD students financed by NOWITECH under WPC, two submitted their thesis in 2014; three are expected to submit in 2015, and one in 2016. Of the two associated PhD students at NTNU, both are continuing throughout 2015

There have been 10 publications in journals, 10 conference papers/presentations, and one invited keynote presentation.

International cooperation has been strong, through the participation in multiple European projects and networks. Relevant projects in 2014 were the EU FP7 projects EERA-DTOC, DeepWind, WindScanner, HiPRwind, EuroSunMed, BestPaths, Marinet, and the Nordic project Offshore DC. Additional fora for cooperation have been EERA Joint Programme Wind, with a leading role in the offshore wind sub-programme; IEA Task 25: "Large Scale Integration of Wind Power"; IEA-ISGAN Annex 6: "Power Transmission and Distribution Systems"; IEC 61400-27 standardization group; CIGRE working group A2/C4.39: "Electrical transients interaction between transformers and the power system".

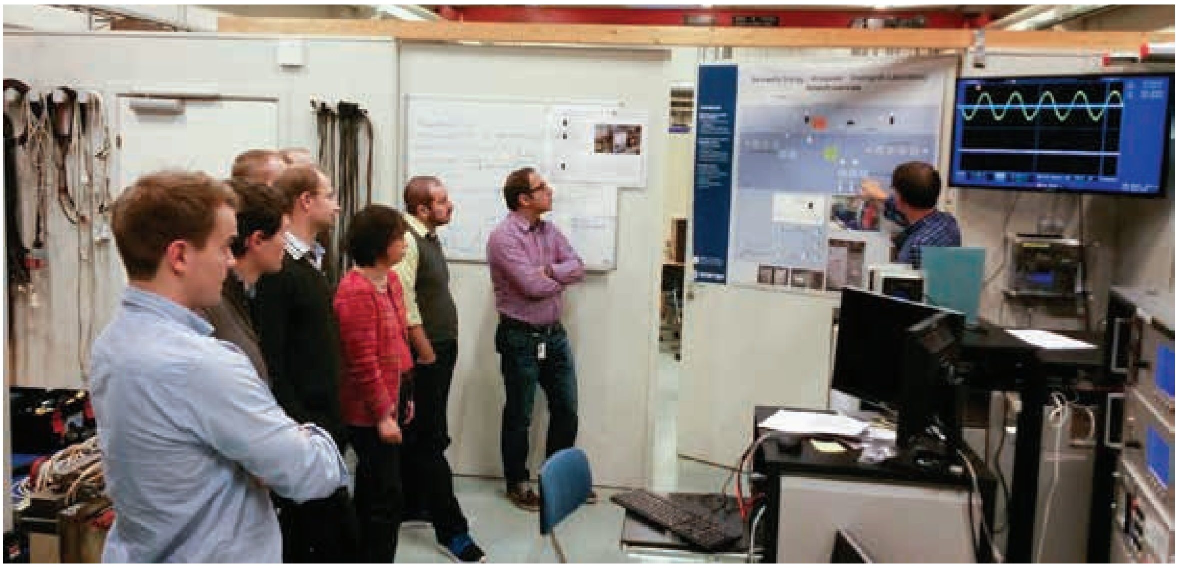


Figure 30: Visit to laboratory facilities at SINTEF/NTNU during the WPC industry reference group meeting in October 2014.

Research infrastructures

Spin-off projects

International cooperation

Recruitment

Communication and Dissemination

Research Infrastructure

The research partners have access to strong research infrastructures in the form of in-house labs and field facilities, e.g. test station for wind turbines at Valsneset, four met-masts at Frøya, EFOWI (lidars and met-ocean buoys) together with NORCOWE, wind tunnel at NTNU (11x3x2 m), ocean basin lab at MARINTEK (80x50x10 m) and SmartGrid lab at NTNU/SINTEF. The parties also utilize research infrastructure through international cooperation as part of HYDRALAB IV and MARINET, see International cooperation.

The research partners have access to strong research infrastructures

An application to develop the SmartGrid lab was granted by the Research Council of Norway (RCN) by the end of 2013. Thanks to this, a very significant upgrade of the lab was started in cooperation between NTNU and SINTEF Energy Research. The lab has a broad use, but highly relevant also for research in grid connection of offshore wind farms. Further, the DIPLAB (8 MVA short-circuit emulator) also granted by the RCN is now operational.

DIPLAB[2] was procured and delivered to Trondheim in 2013. DIPLAB is a mobile test laboratory for creating a controlled voltage-dip emulating the effect of a grid fault, and by this, the response of a wind turbine subject to grid faults can be tested. A first test of DIPLAB was performed at Valsneset test station for wind turbines (VIVA AS) in spring 2014, and a follow up test was done in December 2014. The aim of the test was to get aquatinted with the equipment and to gain knowledge about the response of the wind turbine subject to voltage dips. Both electrical and mechanical loads were measured during the test, and provide a basis for validating numerical simulation models.

WindScanner.eu is a European Strategy Forum on Research Infrastructures (ESFRI) preparatory phase (PP) project (2013-2015) coordinated by DTU (DK). The objective is to provide catalytic and leveraging support towards the construction of the facility, in order to bring the project to the level of legal, organizational, technical and financial maturity required to establish and operate the facility by 2016 onwards. The operational European WindScanner Facility is expected to become a distributed and mobile research infrastructure for lidar based 3-D wind speed measurements. SINTEF Energy participates in this as a Norwegian node coordinating work between Norwegian stakeholders, including NOWITECH and NORCOWE research parties, to establish such lidar based facilities in Norway. An application on investments for this infrastructure was made to the RCN Infrastructure Program in October 2014.

The research infrastructures are developed with separate contracts external to NOWITECH, but prepared in alignment with NOWITECH.

[2] http://www.sintef.no/DipLab/

Figure 31: A system test with 6 Lidar Wind Scanners were made in Kassel in Germany in the summer of 2014. The lidar units were placed around Rödeser Berg close to Kassel where a 200 m wind measurement mast offered an ideal test site for the Wind-Scanner facilities in complex terrain. The purpose was to prove the concept of several synchronized wind-scanning LiDARs as virtual meteorological masts in complex terrain.

Spin-off projects

The NOWITECH research partners are attractive: A total of five new major research projects were started in 2014 with participation of one or more of the research partners in NOWITECH. Since start-up the count is 58 new projects with an accumulated budget of over NOK 1000 million. The projects are with EU or Nordic funding (24), competence building projects (22) or research infrastructure projects (3) funded by the Research Council of Norway (RCN), or industry driven projects with co-funding from the RCN (9). A selection of the projects is listed in Table 1. A number of bilateral projects directly for industry come in addition.

A total of five new major research projects were started in 2014 with participation of one or more of the research partners in NOWITECH.

Table 1: Selection of projects (granted, started, on-going or finished in 2014) with participation of one or more of the research partners in NOWITECH.

Project title	Type	Partners	Status
IRPWIND	EU FP7	DTU, NTNU, SINTEF Energy Research, Marintek, etc.	Started
SmartGrids lab	RCN infrastructure	NTNU, SINTEF Energy Research	Started
Best Path	EU FP7	Red Electrica , Iberdrola, SINTEF Energy Research, etc	Started
Wind farm Energy storage	Industrial	SINTEF Energy Research, Iberdrola, Gamesa	Started
Kon-Wake	IPN	Kongsberg, SINTEF MC	On-going
WiWind	IPN	Kongsberg, SINTEF ICT	On-going
Offshore Energy Storage system	IPN	Sub Hydro, SINTEF Energy Research, etc	On-going
DIMSELO	RCN KPN	IFE, DTU, STATOIL, STATKRAFT, NTNU	On-going
TP WIND	RCN	SINTEF Energy Research	On-going
EERA JPWIND	RCN	SINTEF Energy Research	On-going
WindScanner.eu	EU ESFRI	DTU, Fh IWES, ECN, ForWind, CENER, SINTEF Energy Research, LNEG, University of Porto and CRES	On-going
NOWERI	RCN infrastructure	CMR, UiB, NTNU, SINTEF, IFE etc.	On-going
EWEM: European Wind Energy Master	EU	TU Delft, DTU, NTNU, Universität Oldenburg	On-going
ProOfGrids: Protection and Fault Handling in Offshore HVDC Grids	RCN KPN	SINTEF Energy Research, NTNU, RWTH Aachen University, Statnett, Statoil, NationalGrid, EDF, GE Power Conversion, NVE, Siemens, Statkraft	On-going
Fluid Structure Interactions for Wind Turbines	RCN KPN	SINTEF IKT, Statoil, TrønderEnergi, Kjeller Vindteknikk, FFI, NTNU, SINTEF	On-going
MARE-WINT: new Materials and Reliability in offshore WINd Turbines technology	EU FP7	Polish Academy of Sciences, NTNU, Marintek, etc.	On-going
InnWind: Innovative wind conversion systems (10-20MW) for offshore applications	EU FP7	Risø DTU, SINTEF Energy Research, etc.	On-going
EERA-DTOC: EERA Design Tools for Offshore Wind Farm	EU FP7	DTU Risø, SINTEF Energy Research, etc.	On-going

MARINET: Marine Research Infrastructures Network for Energy Technologies	EU FP7	HMRC University College Cork, Risø DTU, NTNU, University of Strathclyde, Fraunhofer IWES, SINTEF Energy Research, etc	On-going
MARINA Platform: Marine Renewable Integrated Application Platform	EU FP7	Acciona, NTNU etc.	On-going
Mitigation measures and tools to reduce bird-associated conflicts in space and time for onshore and offshore wind-power plants	RCN KMB	NINA, NTNU, SINTEF M&C, SINTEF ICT, Statkraft etc.	On-going
HiPRwind: High Power, high Reliability offshore wind technology	EU FP7	Fraunhofer IWES, SINTEF Energy Research, NTNU etc.	On-going
Offshore DC: DC grids for integration of large scale wind power	Nordic	Risø DTU, AAU, Chalmers, SINTEF Energy Research, VTT, Dong, Vestas, ABB, Energinet.dk, NTNU,	On-going
PowerUP: Effektive verdikjeder for offshore vindmøller	RCN Mid-Norway	SINTEF, NTNU, Høgskolen i Molde, Møreforskning	On-going
Nordic wind power O&M network	Nordic Energy Research	Energi Norge, SINTEF Energy Research, VTT, Vindforsk, Chalmers, Risø DTU	On-going
Beppo - Blue Energy Production in Ports	EU Interreg	Port of Oostende, SINTEF Energy Research, Marintek, etc.	On-going
WINDSENSE: Add-on instrumentation system for wind turbines	RCN IPN	Kongsberg Maritime, Statoil, NTE, SINTEF Energy Research, Marintek, NTNU, etc	Finished
FAROFF: Far off shore operation and maintenance vessel concept development and optimization	RCN IPN	Statkraft, MARINTEK, Fred Olsen, Odfell, SINTEF Energy Research	Finished
Offwind: Prediction tools for offshore wind electricity generation	Nordic	IRIS, SINTEF, FFI, WindSim, Storm Geo etc.	Finished
DeepWind: Future Deep Sea Wind Turbine Technologies	EU FP7	DTU, Statoil, SINTEF Energy Research, etc.	Finished
DIPLAB (ETEST, 8 MVA short-circuit emulator)	RCN infrastructure	SINTEF Energy Research	Finished

International cooperation

NOWITECH participates in relevant international activities with significant efforts in the following international entities:

European Energy Research Alliance (EERA) joint programme (JP) on wind energy, www.eera-set.eu; SINTEF, NTNU and IFE participate in EERA JP Wind Energy developing network, scientific work programmes, workshops and project proposals. John Tande (SINTEF Energy Research) coordinates the sub-programme on Offshore Wind Energy. The programme is enhanced with the EU FP7 IRPWIND project started in March 2014 with coordination by DTU and objectives closely aligned with EERA JP wind.

European Technology Platform for wind energy (TPwind), www.windplatform.eu; John Tande (SINTEF Energy Research) is Chair of the offshore working group within TPwind, and a member of the TPWind Steering Committee. A main outcome of TPwind in 2014 was the Strategic Research Agenda and Market Deployment Strategy launched at EWEA 2014 in Barcelona.

European Academy of Wind Energy (EAWE), www.eawe.eu; SINTEF, NTNU and IFE participate. Michael Muskulus (NTNU) was President of EAWE in 2013/2014. Tor Anders Nygård (IFE) is member of the Executive Committee.

European Wind Energy Master (EWEM), www.windenergymaster.eu, is a joint (NTNU, TU Delft, DTU and University of Oldenburg) Erasmus Mundus MSc programme on wind energy providing for a 2 year specialization within Wind Physics, Rotor Design, Electric Power Systems and Offshore Engineering. NTNU is engaged in EWEM offering specialization in Electric Power Systems and Offshore Engineering.

IEA Wind, www.ieawind.org; The research partners of NOWITECH are active in all relevant tasks of IEA Wind, including:

- IEA Wind Task 25: Design and operation of power systems with large amounts of wind power
- IEA Wind Task 26: Cost of wind energy
- IEA Wind Task 29: Mexnext: Analysis of wind tunnel measurements
- IEA Wind Task 30: Comparison of Dynamic Computer Codes and Models for Offshore Wind Energy (OC4, OC5)

IEC TC88, www.iec.ch. The research partners of NOWITECH are active in all working groups with relevance for offshore wind turbines. SINTEF Energy Research is heading the Norwegian sister-organization NK88 and represents Norway in TC88.

International cooperation is also through research mobility programmes, transnational laboratory access programmes, participation in EU projects, meetings and collaboration with the international associated research parties of NOWITECH through SC and other means, guest lectures, the involvement of international industry parties, hiring of internships etc. In 2014 the research parties in NOWITECH participated in more than 15 projects with EU or Nordic funding providing for very substantial international collaboration.

Recruitment

Since the start of NOWITECH, 24 PhD scholars and 5 Postdocs at NTNU have been funded by the Centre. In addition, another 15 PhD and Postdoc students were associated to the Centre in 2014. These do research within the thematic area of the Centre at NTNU, and participate in relevant Centre activities, but their grants are funded outside the Centre.

The PhD and Postdoc positions are carried out as an integrated part of the work packages. The Scientific Committee (SC) has the overall responsibility for developing the PhD and Postdoc programme. This include an active recruitment strategy, organization of joint PhD forums and training, exposing them to industry and leading international research groups by organising the PhDs and Postdocs in groups contrary to the unfortunate ivory tower model. A total of 10 PhDs successfully defended their doctoral work in 2014 at NTNU on offshore wind energy. Of these five had funding from NOWITECH and five had funding from other sources. A list of all PhD students and Postdocs financed through NOWITECH or by other sources on offshore wind energy at NTNU can be found in the table PhD Students with financial support from the Centre.

The remaining PhD and postdocs financed by NOWITECH are due to finish in 2015-2017, see Figure 32. Thus, to keep up the momentum, significant additional funds for a next wave of PhD students are needed. Hopes are that the new call for FMEs announced by the Research Council of Norway can facilitate this.

MSc students are engaged in summer jobs with the research partners, and the partners are also active in proposing relevant subjects for their final projects and theses. The MSc education on wind energy has been enhanced at NTNU through NOWITECH, with the PhD and Postdocs assisting in the education, and the engaged professors cooperating through the SC and other NOWITECH activities across faculties.

During 2014, professors and scientific staff at NTNU, with relations to NOWITECH, were supervisors for 28 Master Degree theses specializing in offshore wind energy (see Appendix). The Erasmus Mundus European Wind Energy Master (EWEM) programme gives further weight to the MSc education at NTNU, in particular in the fields of electro and marine which are areas of NTNU engagement within the EWEM.

A total of 10 PhDs successfully defended their doctoral work in 2014 at NTNU on offshore wind energy.

Studies on offshore wind energy are generally popular among the students. A search at the research portal Diva (ntnu.diva-portal.org) gives more than hundred MSc theses at NTNU with the keyword "wind" over the last few years.

Figure 32: NOWITECH PhD student Tania Bracchi defended her thesis titled "Downwind rotor: studies on yaw stability and design of a suitable thin airfoil" in May 2014. She is now with the Sør-Trøndelag University College (HiST) and active in wind energy research.

Increased recruitment of women is promoted by active profiling of female candidates specializing within the field of offshore wind energy. In hiring students for summer job, PhD or Postdoc positions, women are especially invited to apply, and will be selected over male candidates if otherwise equally qualified.

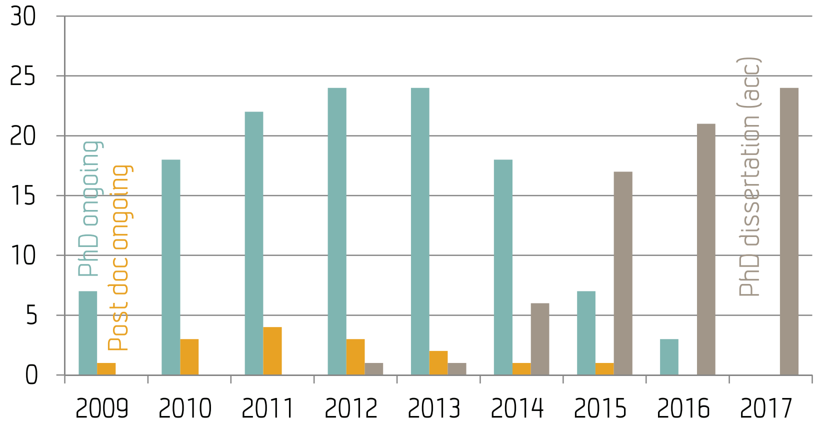


Figure 33: Timeline of PhD and post doc programme funded by NOWITECH. Data for 2015-2017 are estimates.

Communication and Dissemination

The scientific results of the Centre are disseminated efficiently and achieving international recognition. Publications since start-up include 148 peer-reviewed papers, 125 reports, 75 media contributions and 167 conference presentations of which more than 20 were invited keynotes, see Figure 37. NOWITECH prepared 124 publications, including 40 peer-reviewed papers, 21 reports, 15 conference papers, 14 media contributions and 29 conference presentations. Details of these are given in the appendix. All NOWITECH partners have access to a project e-room, where all internal information, publications and project results are presented.

The main channels for open communication of activities and results in NOWITECH are listed below:

- www.NOWITECH.no gives open information about NOWITECH, short news on offshore wind and announcements of relevant seminars etc. The site is mainly for the interested

Vindkraft i medvind

Offshore vindkraft er en gylden mulighet for utvikling av nye kunnskapsbaserte arbeidsplasser i Norge.

Det internasjonale markedet for offshore vindkraft er stort og i medvind. I Europa alene forventes investeringer i størrelsesorden 1000 milliarder kroner til bygging av offshore vindparker i løpet av de neste ti årene og vil være en viktig del av et fremtidig bærekraftig energisystem.

Offshore vindkraft er en ren, fornybar energikilde som kan bygges ut og driftes med minimale negative miljøvirkninger og gi store besparelser i CO_2-utslipp ved at den vil erstatte fossil kraftproduksjon. Offshore vindkraft er teknologi for en bedre verden.

Offshore vindkraft koster mer enn landbasert vindkraft. Men teknologien og markedet er bare i startfasen og innen 2030 antas kostnaden å være redusert til halvparten av dagens nivå.

Norge har en viktig rolle å spille. Vi har sterke forskningsmiljø, og med vår erfaring fra offshore olje og gass kan vi utvikle løsninger som gir reduserte kostnader for offshore vindkraft, og dermed få økt utbyggingstakt i Europa og raskere utfasing av fossile energikilder. Dette er et godt og effektivt klimatiltak som monner.

En norsk satsing koster, men vi vil få mange ganger betalt gjennom arbeidsplasser og eksport av varer og tjenester. Tidspunktet er ideelt nå, hvor olje- og gassindustrien har satt bremsene på, til å tilby ledig kompetansevirksomhet innen et nytt og fremtidsrettet satsingsområde. I Norge har vi forskningsmiljøer i høy internasjonal klasse med våre to Forskningssentre for Miljøvennlig Energi (FME), Nowitech og Norcowe, som spydspisser. Norske aktører er med i alle de viktige nye forskningsprosjektene innen offshore vindkraft i EU. Dette gir verdifull kunnskapsbygging, og gjør at norske bedrifter er helt i kunnskapsfronten, og er med på å skape innovasjoner som gir norske arbeidsplasser.

Offshore vindkraft er teknologi for en bedre verden, skriver artikkelforfatterne. Her Statoils Hywind-turbin utenfor Karmøy. Foto: Øyvind Hagen, Statoil

Teknologi
John Olav Giæver Tande, Kristin Guldbrandsen Frøysa, Trond Kvamsdal og Siri Kalvig

Statoil og Statkraft er tungt inne som utbyggere av offshore vindparker i britisk sektor. Aibel lever store understell til tyske vindparker. Nexans har store leveranser av kraftkabler. Andre bedrifter er på vei inn, for eksempel Kongsberg Maritime som utvikler systemer for optimalisert drift av offshore vindparker, StormGeo som leverer operasjonelle skreddersydde værvarsler og Fugro Oceanor som har utviklet en flytende målebøye for måling av offshore vindressurser. Nettverksorganisasjonen innen fornybar energi, INTPOW, har identifisert 150 norske selskap med virksomhet innen offshore vindkraft.

Den internasjonale konkurransen er sterk, og de fortrinn vi har gjennom å utnytte vår petromaritime erfaring har begrenset varighet.

Hywind, verdens første flytende turbin i full skala, er utviklet av Statoil og installert utenfor Karmøy. Turbinen har vært i drift siden 2009 og har høstet stor internasjonal interesse. En neste utvikling av Hywind er nå under planlegging med bygging av fem flytende turbiner i Skottland. Dette er flott og viser verdi av norsk forskning og ingeniørkompetanse, men vi ville få enda større verdiskaping gjennom å ta teknologien videre her i Norge. Vi trenger derfor et taktskifte i vår egen satsing.

Helt konkret bør satsingen på offshore vind forsterkes i en videreføring av FME-ordningen samtidig som det etableres attraktive økonomiske rammebetingelser for utbygging av et par offshore vindparker i Norge, både bunnfast og flytende. Dette trengs for å få utviklet teknologi og kompetanse som kan redusere kostnaden for offshore vindkraft og sikre fremtidige norske kunnskapsbaserte leveranser til det internasjonale markedet.

Potensialet er stort. Offshore vindkraft er teknologi for en bedre verden og en vinn-vind-situasjon for Norge. La oss satse nå.

John Olav Giæver Tande, seniorforsker Sintef Energi, leder Nowitech
Kristin Guldbrandsen Frøysa, seniorforsker Christian Michelsen Research, leder Norcowe
Trond Kvamsdal, professor NTNU, leder for Nowitech Scientific Committee
Siri Kalvig, ph.d., Partner StormGeo as

Norway's largest business newspaper, Dagens Næringsliv, published an op-ed 28. November written by NOWITECH Director, John Olav Giæver Tande, together with research partners from Christian Michelsen Research, NTNU and StormGeo. The message was that offshore wind technology represents a great opportunity for new knowledge based jobs in Norway. (Facsimile: Dagens Næringsliv, 28. November 2014) professional. New of this year is twitter feed of relevant news to users. The web page layout was reorganized in 2014.

- Popular articles, adverts, media contributions and interviews are generally important means for raising public education and opinion. NOWITECH was contributing to media stories etc. on average more than once per month throughout 2014.

- The NOWITECH newsletters give short teasers of results and information on activities in NOWITECH. The newsletters are distributed through e-mail and our website. Links for further reading are however to the NOWITECH e-room that is for partners only. Two newsletters were produced in 2014. The December newsletter included an interview with Statkrafts Jørgen Krokstad, who is also is an associate professor at NTNU and supervisor of Post Doc Lene Eliassen.

- In 2014 the seminar series "Industry meets Science" was continued in cooperation with Wind Cluster Norway. The aim of the seminar is to facilitate an improved interaction between the research in NOWITECH and relevant industry, also to those that are not partners in NOWITECH. www.sintef.no/Industry-meets-science/

Figure 34: Prof II Jørgen Krokstad and Post Doc Lene Eliassen.

- The annual offshore wind R&D conference in Trondheim has developed with association to EERA as an important international event with call for papers, peer-review and publication in the open access journal Energy Procedia (Elsevier). EERA DeepWind'2014 had about 140 delegates from 14 countries, and more than 90 presentations whereof 34 papers where peer-reviewed and published in the open access journal Energy Procedia (Elsevier). Wind energy master students are engaged each year as assistants in the Deep Wind conference, which also gives the students a very good insight into the status of the research as well as giving them future valuable contacts.

- The NOWITECH Day is an annual event bringing together all NOWITECH partners to share information, discuss and enjoy research on offshore wind technology. The programme was a mix of oral presentations and posters with ample time for discussions and mingling. At the NOWITECH day 2014, Professor Torgeir Moan, NTNU were awarded for his sustained excellent academic achievements (Figure 10), and the awards for best poster were given to PhD students Knut Nordanger and Morten Dinhoff Pedersen (Figure 36).

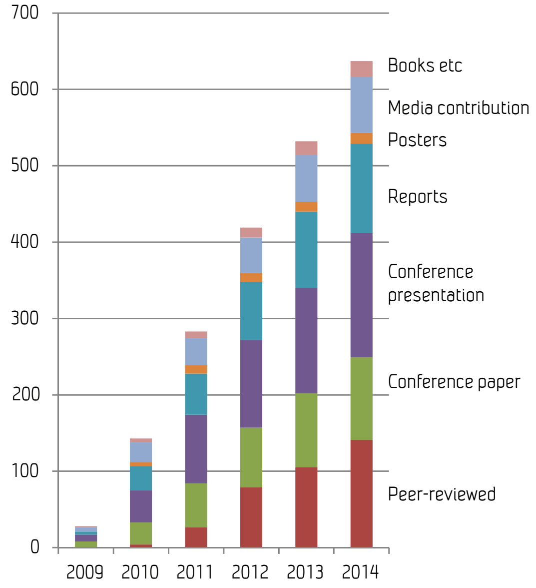


Figure 38: Accumulated number of publications in NOWITECH.

Figure 35: The Industry meets Science series have been well attended and is a bi-annual seminar. Pictures show Marte dePiccio, DNV presenting at the November meeting (left) and a glimpse of the audience in the coffee-break (right).

Figure 36: EERA DeepWind 2014 22nd -24th January in Trondheim was accomplished in excellent manner. Pictures are from the opening session with NOWITECH director John Olav Tande presenting innovations in offshore wind energy (left) and the EU commission representative Matthijs Soede presenting "Progress of offshore wind through R&D in FP7 and H2020' (right).

Figure 37: The award committee and award winner for best poster at Nowitech Day. From left: Trond Kvamsdal (Chair NOWITECH SC), PhD student Knut Nordanger (left), PhD student Morten Dinhoff Pedersen (right), John Olav Tande.

People

People

Acting Centre Management and Committees

John Olav G. Tande,
Centre Director

Hans Christian
Bolstad, Centre Mgr.

Roy Stenbro,
Co-chair WPA

Ole David Økland,
Co-chair WPA

Jens Kjær Jørgensen,
Co-chair WPB

Thomas Welte,
Co-chair WPB

Karl Merz,
Co-chair WPC

Harald Svendsen,
Co-chair WPC

Trond Kvamsdal,
Chair SC

Michael Muskulus,
Vice-chair SC

Per Arne Wilson,
Chair CIC

Debbie Koreman,
Higher Exec. Officer

Randi Aukan,
Centre Secretary

NOWITECH would like to thank the following for their contributions in 2014

Torgeir Moan
Chair WP3
until 31.12.2014

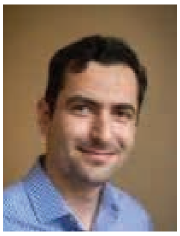
Johan Sandberg
Chair CIC
until 12.11.2014

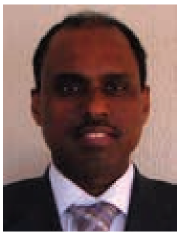
NOWITECH Postdoctoral Researchers since 2009


Madjid Karimirad

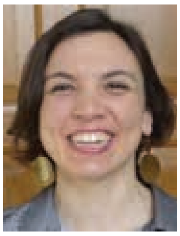

Steve Völler


Mukesh, Kumar


Ali Nematbakhsh


Anthonippillai Antonarulrajah

NOWITECH PhD students since 2009

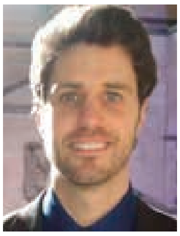

Tania Bracchi

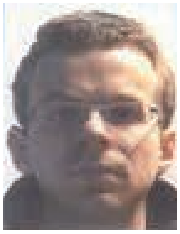

Lars Morten Bardal


René A Cárdenas

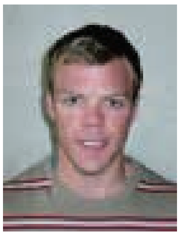

Valentin Chabaud


Mayilvahanan Chella

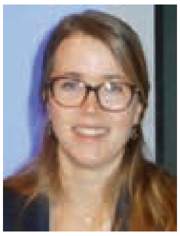

Kevin Cox


Emmanuel Dombre


Pål Egil Eriksen


Lars Frøyd

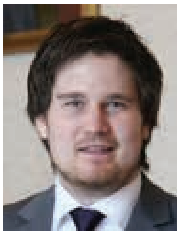

Zafar Hameed


Marit Irene Kvittem

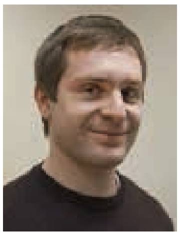

Chenyu Luan

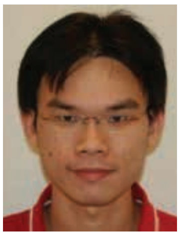

Fahmi Mubarok


Amir Nejad


Øyvind Netland


Knut Nordanger


Morten Dinhoff Pedersen


Phen Chiak See

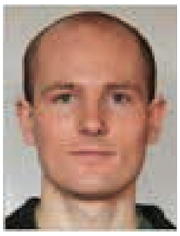

Amir Hayati Soloot


Mostafa Valavi


Eric Van Buren


Kai Wang


Zhaoqiang Zhang


Daniel Zwick

Key Researchers

Name	Organization	Work Package
Armada, Sergio	SINTEF MC	WPB
Berthelsen, Petter Andreas	Marintek	WPA
Bjørgum, Astrid	SINTEF MC	WPB
Bolstad, Hans Christian	SINTEF Energy Research	Centre Manager
Dahlhaug, Ole Gunnar	NTNU	WPA, Management, SC
D'Arco, Salvatore	SINTEF Energy Research	WPC
De Vaal, Jacobus	IFE	WPA
Echtermeyer, Andreas	NTNU	WPB
Elisabete FR da Costa	SINTEF MC	WPB
Endegnanew, Atsede	SINTEF Energy Research	WPC
Farahmand, Hossein	SINTEF Energy Research	WPC
Fonn, Eivind	SINTEF ICT	WPA
Foques, Sebastien	Marintek	WPA
Fossen, Thor Inge	NTNU	WPA
Fosso, Olav	NTNU	WPC, Board
Fylling, Ivar	Marintek	WPA
Gaarder, Rune Harald	SINTEF MC	WPB
Gao, Zhen	NTNU	WPA
Giovanni Perillo	SINTEF MC	WPB
Hals, Jørgen	Marintek	WPA
Halvorsen-Weare	Marintek	WPB
Hofmann, Matthias	SINTEF Energy Research	WPB
Huertas Hernando, Daniel	SINTEF Energy Research	WPC
Høidalen, Hans Kristian	NTNU	WPC
Johnsen, Heidi	SINTEF MC	WPA
Johnsen, Roy	NTNU	WPA
Juan Yang	SINTEF MC	WPB
Jørgensen, Jens Kiær	SINTEF MC	WPB, Management
Karimirad, Madjid	Marintek	WPA
Kirkeby, Henrik	SINTEF Energy Research	WPC
Kolstad, Magne	SINTEF Energy Research	WPB
Krogstad, Per Åge	NTNU	WPA
Kvamsdal, Trond	NTNU / SINTEF ICT	SC, WPA
Kvarving, Arne Morten	SINTEF ICT	WPA
Lars Sætran	NTNU	WPA
Ljøkelsøy, Kjell	SINTEF Energy Research	WPC
Merz, Karl	SINTEF Energy Research	WPC, Management
Moan, Torgeir	NTNU	WPA, Management, SC
Monika Pilz	SINTEF MC	WPB
Muk Chen Ong	Marintek	WPA
Muskulus, Michael	NTNU	WPA, Management, SC
Muthanna, Chittiappa	Marintek	WPA
Niklas Magnusson	SINTEF Energy Research	WPC
Nilssen, Robert	NTNU	WPC

Nonås, Lars Magne	Marintek	WPB
Nygaard Tor Anders	IFE	WPA
Nysveen, Arne	NTNU	SC, WPC
Oggiano, Luca	IFE	WPA
Ormberg, Harald	Marintek	WPA
Passano, Elizabeth	Marintek	WPA
Rasheed, Adil	SINTEF ICT	WPA
Rødseth, Harald	Marintek	WPB
Sauder, Thomas	Marintek	WPA
Simon, Christian	SINTEF MC	WPA
Sin, Jorge Rituerto	SINTEF MC	WPB
Skavhaug, Amund	NTNU	WPB
Skjetne, Roger	NTNU	WPA
Sperstad, Iver	SINTEF Energy Research	WPB
Spro, Ole Christian	SINTEF Energy Research	WPC
Stansberg, Carl Trygve	Marintek	WPA
Stenbro, Roy	IFE	WPA, Management
Stålhane, Magnus	NTNU	WPB
Svendsen, Harald	SINTEF Energy Research	WPC
Tande, John Olav Giæver	SINTEF Energy Research	Centre Director
Torres Olguin, Raymundo	SINTEF Energy Research	WPC
Uhlen, Kjetil	NTNU	WPC
Valland, Anders	Marintek	WPB
Vatn, Jørn	NTNU	WPB
Welte, Thomas	SINTEF Energy Research	WPB, Management
Økland, Ole D.	Marintek	WPA, Management
Årdal, Atle	SINTEF Energy Research	WPC

Total 71

Visiting Researchers

Name	Affiliation	Nationality	Sex	Duration	Topic
Olimpo Anaya-Lara	University of Strathclyde	UK	M	2014	Power system dynamics and modelling

Postdoctoral Researchers with financial support from the Centre

Name	Nationality	Period	Sex	Topic
Nematbakhsh, Ali	UK	2014–2015	M	Alternative floating wind turbine concepts for moderate water depths

PhD Students with financial support from the Centre

The following are working towards a PhD

Name	Nationality	Period	Sex	Topic
Eric Van Buren	American	2009 -2012	M	Bottom-fixed support structure for wind turbine in 30-70 m water depth
Knut Nordanger	Norwegian	2010 -2014	M	Coupled fluid-structure interaction simulation of offshore wind turbines
Pål Egil Eriksen	Norwegian	2010 -2014	M	Rotor wake turbulence
Mostafa Valavi	Iranian	2010 -2014	M	Magnetic forces and vibrations in wind power generators
Alegan Mayilvahanan Chella	Indian	2010 -2014	M	Wave forces on wind turbine structures
René Alexander Barrera Cárdenas	Columbian	2011 –2014	M	Multi-domain optimization model for the evaluation of power density and efficiency of wind energy conversion systems
Valentin Chabaud	French	2011 –2016	M	Experimental investigation of coupled hydrodynamic and aerodynamic performance of floating wind turbines
Chenyu Luan	Chinese	2011 -2015	M	Efficient stochastic dynamic response analysis for design of offshore wind turbines
Dombre Emmanuel	Frankrike	2011 -2015	M	Hydrodynamic modeling and analysis of floating wind turbines (EDF)
Phen Chiak See (Bryan)	Malaysia	2012 -2015	M	Development of market models incorporating offshore wind farms and offshore grids
Amir Rasekhi Nejad	Iran	2012 -2015	M	Condition monitoring of the mechanical system of a windfarm
Lars Morten Bardal	Norway	2012 -2015	M	Design wind and sea loads for offshore wind turbines
Zhaoqiang Zhang	Chinese	2010 -2013	M	Novel generator concepts for low weight nacelles. Integrated design of generator and mechanical structure for a maintenance free system
Daniel Zwick	German	2009 -2013	M	Design and production of offshore jacket structures
Amir Hayati Soloot	Iranian	2009-2013	M	Analysis of switching transients in wind parks with focus on prevention of destructive effects
Zafar Hameed	Pakistani	2009 -2012	M	Maintenance optimization of wind farms from design to operation (models, methods, framework)
Kai Wang	Chinese	2010 -2014	M	Comparative studies of floating concepts
Morten Dinhoff Pedersen	Norwegian	2010 -2013	M	Design of control systems for load mitigation and stabilization of floating wind turbines

Total 18

The following PhD candidates financed by NOWITECH have completed their degree. Lars Frøyd successfully defended his thesis in 2012; the other five in 2014.

Name	Nationality	Period	Sex	Topic
Bracchi, Tania	Italian	2009-2013	F	Assessment of benefits of downwind rotors due to weight savings using new and thinner airfoils and improved directional stability of turbine
Cox , Kevin	American	2010-2013	M	Lift control of wind turbine blades by using smart composite materials manipulating aerodynamics rotor properties
Frøyd, Lars	Norwegian	2009-2012	M	Evaluation of the design criteria and dynamic forces on large floating wind turbines
Kvittem, Marit Irene	Norwegian	2009-2013	F	Life cycle criteria and optimization of floating structures and mooring systems
Mubarok , Fahmi	Indonesian	2010-2014	M	Novel coating and surface treatment for improved wear resistance
Netland, Øyvind	Norwegian	2010-2013	M	Cost-effective monitoring for remote environmental friendly O&M of offshore wind turbines

Total 6

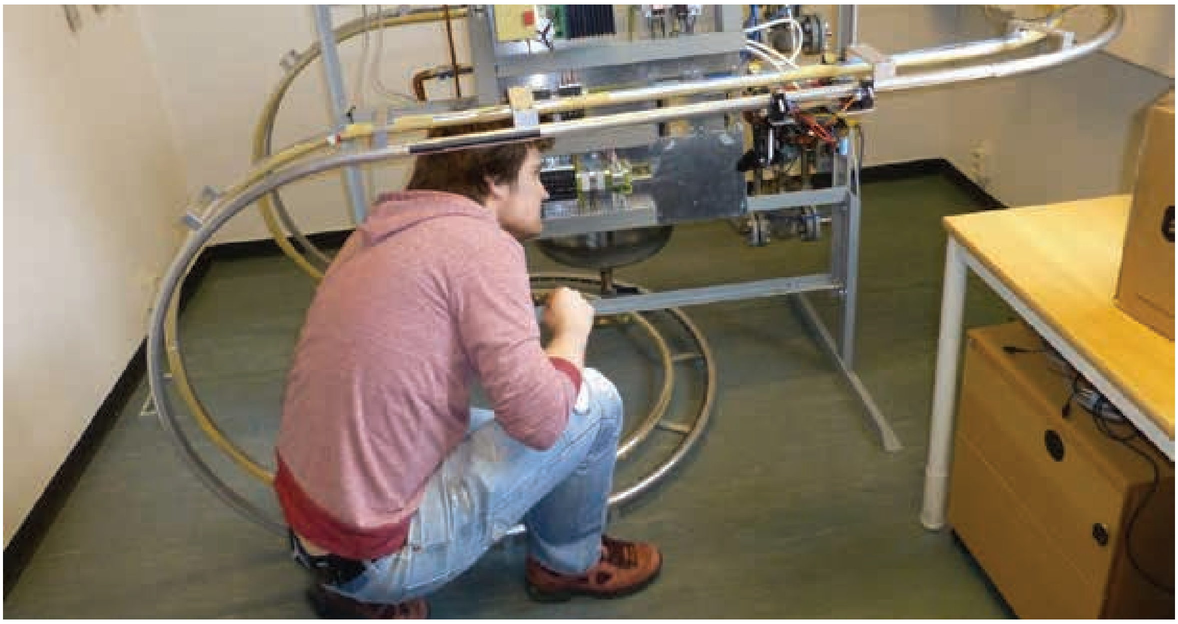


Figure 39: Remote inspection. Dr Øyvind Netland built his own lab to do the observations necessary to prove the theories in his PhD thesis that was defended in March 2014. Later he has joined Norsk Automatisering AS, where they are commercialising the concepts and systems for remote monitoring developed in NOWITECH.

Postdoctoral Researchers aligned with NOWITECH, financial support from other sources

Name	Nationality	Period	Sex	Topic
Magnus Stålhane	Norwegian	2013-2015	M	Optimization of maritime logistics

PhD Students aligned with NOWITECH, financial support from other sources

Name	Nationality	Period	Sex	Topic
Bachinsky, Erin	USA	2010-2014	F	Design and Dynamic Analysis of Tension Leg Platform Wind Turbines
Bartl, Jan	Germany	2014-2017	M	Wind Turbine Wake Interactions
Dombre, Emmanuel	France	2012-2015	M	Hydrodynamic modelling and analysis of floating wind turbines
Hansen, Thomas Henrik Hertzfelder	Norway	2014-2016	M	Design and analysis of wind turbine rotor blades for off-shore applications
Hansen-Bauer, Øyvind Waage	Norway	2014-2017	M	Investigation of the structure of turbulent wakes formed behind wind turbines
Heidenreich, Sara	Germany	2010-2014	F	Public engagement in offshore wind energy
Holtsmark, Nathalie	Norway	2010-2014	F	Wind Energy Conversion using high frequency transformation and DC collection
Langhamer, Olivia	Germany	2010-2014	F	Renewable offshore energy and the marine environment: biofouling and artificial reefs
Olsen, Pål Keim	Norway	2011-2014	M	Electrical Degradation phenomena in insulation materials exposed to combined DC and AC voltage
Schafhirt, Sebastian	Germany	2013-2017	M	Modelling of support structure dynamics for offshore wind turbines
Slimacek, Vaclav	Czech	2011-2015	M	Reliability analysis of offshore wind turbines/plants and their connection to Smart Grids
Steen, Markus	Norway	2010-2014	M	Commercialization of new technology and industrial development in new renewable energy - the case of offshore wind
Tasar, Gürsü	Tyrkey	2009-2014	M	Full Scale Measurements of Wind Conditions Relevant for Offshore Wind Turbines
Tu, Ying	China	2014-2018	F	Inverse modeling of wave slamming forces for offshore wind turbine jacket substructures

Total 14

The following PhD students aligned with NOWITECH, but financed from other sources, completed their degree in 2014:

Name	Thesis title
Bachinsky, Erin Elisabeth	Design and Dynamic Analysis of Tension Leg Platform Wind Turbines
Dai Lijuan	RAMS engineering in the development of offshore wind turbines
Heidenreich, Sara	Blowing in the wind: The socialization of offshore wind technology
Long, Haiyan	A bottom fixed lattice tower for offshore wind turbines
Sjolte, Jonas	Marine renewable energy conversion: Grid and of-grid modelling, design and operation

Total 5

Master Degrees during 2014 in offshore wind at NTNU

Name	Sex	Topic
Barcena Pasamontes, L.	F	Topology optimization of jacket support structures with genetic algorithm.
Gomez Torres, F.	M	Topology optimization of jacket support structures with genetic algorithm.
Bense, M. P.	M	Comparison of Numerical Simulation and Model Test for Integrated Installation of GBS Wind Turbine.
Brauer, S. A.	M	Damage Identification of an Offshore Wind Turbine Jacket Support Structure.
Bredesen, K. O.	M	Design of Nacelle and Yaw Bearing for NOWITECH 10 MW Reference Turbine.
Brodtkorb, A. H.	F	Dynamic Positioning in Extreme Sea States: Improving Operability Using Hybrid Design Methods
Chen, J.	M	Non-linear Wave Loads on Offshore Wind Support Structure.
Christensen, E.	M	Multidisciplinary design analysis and optimization of support structures for offshore wind turbines.
Cook, T. W.	M	Buckling of Cylindrical Shells with a Granular Core Under Global Bending: Strength Gains and Imperfection Sensitivity.
Dekker, M. J.	M	The Modelling of Suction Caisson Foundations for Multi-Footed Structures.
Hembre, J. M.	M	Stochastic Analysis of an Offshore Wind Turbine Using a Simplified Dynamic Model.
Jerkø, A.	M	Reactive Power and Voltage Control of Offshore Wind Farms
Laks, A.	F	Mooring system design for floating wind turbines.
Lome, I. B.	F	Validation of a Combined Wind and Wave Power Installation.
Martens, J. H.	M	Topology Optimization of a Jacket for an Offshore Wind Turbine: by Utilization of Genetic Algorithm.
Midthaug, A. H.	M	Nonlinear Wave Loads on Offshore Wind Turbines in Storm Condition.
Paulshus, O.	M	Critical Assessment of Non-linear Wave Loads in the Design of Offshore Wind Turbines.
Pedersen, H. B.	M	Investigation and implementation of turbulent wind in a specialized software tool for offshore wind turbines
Rausa Heredia, I. E.	M	Characterization of wave slamming forces for a truss structure within the framework of the WaveSlam project.
Skaar, V.	M	Optimization of routing and scheduling for performing maintenance at offshore wind farms
Stettner, O	M	Numerical simulation for installation of jacket foundation of offshore wind turbines
Straume, J. G.	M	Dynamic buckling of marine structures
Syed, J. A	M	Simplified dynamics of offshore structures.
Taffese, A. A.	M	Multilevel Converters for Offshore Wind Systems: A Comparative Study.
Thomassen, O. S.	M	Sensitivity Analysis of large Rotor Diameter on Offshore Wind Turbines with Suction Foundation.
Trøen, T. L.	F	Fatigue Loads on Large Diameter Monopile Foundations of Offshore Wind Turbines
Tvare, O.	M	Fatigue Analysis of Column-Pontoon Connection in a Semi-submersible Floating Wind Turbine.
Xing, Z.	M	Response and Structural Analysis of a Flap-type Wave Energy Converter in a Combined Wind and Wave Concept.

Total 28

Master students are all registered through Diva Research Portal as NTNU students with topic offshore wind.

Financial statement 2014

Funding

1000 NOK

Name		
Research partners		
The Research Council of Norway		20 000
SINTEF Energi AS		2 339
NTNU		6 566
IFE		775
MARINTEK		2 086
SINTEF		1 221
Industry partners		
Kongsberg	513	
Det Norske Veritas	500	
CD-adapco	505	
EDF R&D	944	
Dong Energy Power	500	
Fedem Technology	284	
Smart Motor	558	
Statkraft Development AS	1 500	
Statnett SF	500	
Statoil Petroleum AS	1 150	
Subtotal Industry Partners		6 954
Other contributors		300
Public Partners		0
Total		**40 241**

Costs

Name		
Research partners		
SINTEF Energi AS		9 354
NTNU		11 957
IFE		3 100
MARINTEK		8 343
SINTEF		4 882
Industry partners		
Kongsberg	513	
CD-adapco	505	
EDF R&D	444	
Fedem Technology	284	
Smart Motor	558	
Subtotal Industry Partners		2 304
Other costs		300
Public Partners		0
Total		**40 240**

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2. Bachynski, E., et al. “Wind-Wave Misalignment Effects on Floating Wind Turbines: Motions and Tower Load Effects.” Journal of Offshore Mechanics and Arctic Engineering 136.
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7. Nicolai, F., et al. (2014). Effects of increased voltage in distribution grids; Nordac 2014; Stockholm; 8. Sep 2014

8. Uhlen, K., et al. (2014). Laboratory Demonstration of an Offshore Grid in the North Sea with DC Droop Control; EVER'14;Session: Offshore renewable energy: technologies and applications; March 25-27, 2014; Monte-Carlo
9. Valavi, M., et al. (2014). Multiple-Airgap Iron-Cored Direct-Driven Permanent Magnet Wind Generators; ICEM 2014; Berlin; Germany
10. Valavi, M., et al. (2014). Analysis of a Low-Speed PM Wind Generator with Concentrated Windings in Eccentricity Conditions; ICEMS 2013, 26 - 29 October 2013; Korea
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2. Dai, L.; Safe and efficient operation and maintenance of offshore wind farms; ISBN: 978-82-326-0064-9, Doctoral thesis
3. Cox, K.; Lift control of adaptive wind turbine blades with bend-twisting coupling; 978-82-326-0352-7
4. Kvittem, M.I.; Modelling and Response Analysis for Fatigue Design of a Semi-Submersible Wind Turbine, ISBN; 978-82-326-0586-6; Doctoral thesis
5. Bracchi, T.; Downwind Rotor: Studies on yaw Stability and Design of a Suitable Thin Airfoil, ISBN: 978-82-326-0186-8; Doctoral thesis
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26. Zwick, D. (2014). Poster; The simulation error caused by input loading variability in offshore wind turbine structural analysis. NOWITECH Day, NTNU, Trondheim; 19th June 2014
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Production: www.fagtrykk.no Printworks eco-label certified, licence no 241 811

NOWITECH Annual Report 2014

ISBN 978-82-594-3667-2