NOWITECH

Norwegian Research Centre for Offshore Wind Technology

ANNUAL REPORT

2013

NOWITECH

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

- to contribute to large scale deployment of deep sea offshore wind turbines
- to be an internationally leading research community on offshore wind technology enabling industry partners to be in the forefront

OBJECTIVE

- 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

KEY ISSUES

- education, knowledge building and innovations aiming to reduce the cost of energy from offshore wind

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 six work packages (WPs): integrated numerical design tools (WP1), blades and generators (WP2), bottom-fixed and floating substructures (WP3), grid connection and system integration (WP4), operation and maintenance (WP5), and assessment of novel concepts (WP6). Industry involvement has high priority: The industry parties participate by in-kind supplies, through participation at dedicated WP meetings, and in the CIC. All industry parties are represented in the GA and the industry parties are active and in majority in the Board.

Results

NOWITECH has so far financed 24 PhD students and 5 post-doctoral researchers. In addition 25 PhDs and 3 post docs are on-going at NTNU with finance from other sources, but carried out in alignment with NOWITECH. Publications since start-up include 101 peer-reviewed papers, 107 reports, 61 media contributions and 146 conference presentations of which 20 were invited keynotes. A conservative count gives twenty-nine industry relevant results / innovations. More than ten software tools are in development, and results are mitigating to commercial use, licence agreements, and business developments. The NOWITECH research partners are attractive: Since start, more than 50 new projects with an accumulated budget excess of NOK 1000 millions 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.

Important benefits for Industry Partners are:

- gaining knowledge giving reduced uncertainties and risks, reducing cost of energy from offshore wind farms and increasing profits
- the possibility to influence the direction of the research
- to interact directly in the research, and network of knowledge
- possibilities for recruitment, new projects
- having the first access to detailed results for business development

TABLE OF CONTENTS

TABLE OF CONTENTS

YEAR HIGHLIGHTS

2013

John Olav G. Tande,
Director NOWITECH

NOWITECH went through the mid-term review concluded by the Research Council of Norway in June 2013 with flying colours and is in excellent progress approved to continue until mid 2017. Industry participation increased in 2013 with two new parties joining, namely Kongsberg Maritime and CD-adapco, and technology transfer and innovation was strengthened through active use of the Technology Readiness Level (TRL) methodology in communicating results. The established Erasmus Mundus European Wind Energy Master (EWEM) programme enhances the MSc education at NTNU, and a positive trend is seen also in gender balance with female master students in 2013 being in majority of those twenty-four specializing in offshore wind at NTNU. The researcher education is impressive with 23 PhD students and two Postdoc positions fully funded by NOWITECH in 2013, and in addition, 25 PhD students and 3 Postdocs funded through other projects at NTNU.

Strong and relevant R&D results with potential for value creation and cost reductions of offshore wind are achieved in which NOWITECH funding provides for development until TRL 4-5 (lab scale testing) and ready for takeover by more commercially directed projects typically with industry lead:

A good number of **software tools** for integrated numerical design of offshore wind turbines are in development with results mitigating to commercial use and contributing to cost reductions.

The NOWITECH 10 MW **reference turbine** is further developed with an award winning tower for bottom fixed turbines, see Figure 2, and progress is made in design and structural integrity of generators and rotor blades. Load alleviation on rotor blades is achieved through a self-adaptive design with unbalanced fibre layup, and detailed models are prepared to improve design of permanent magnet generators.

New knowledge is gained through **IEA OC4** cooperation comparing software for analysing semi-submersible wind turbines and a preliminary design of a semi-submersible platform for a horizontal axis 5 MW wind turbine has been developed.

A NOWITECH 1200 MW **offshore wind farm** is defined as a reference case for research and benchmarking. It resembles characteristics of a future UK round 3 wind farm located far offshore assuming environmental data from Dogger Bank. Studies have been performed to determine the turbine placement in the wind farm and to define the electrical system including voltage levels, collector grid lay out and configuration, substation rating and placement, transmission system, and converter station configuration.

The software tool **NOWIcob** is developed to assist identification of optimized maintenance schemes, and the software is in use by industry parties according to a license agreement.

A novel maintenance-free "corrosion" **protective coating** system for offshore wind turbines is in development comprising thermally sprayed zinc and a top layer of paint, possibly with self-healing properties. Tests show excellent field performance even with a very simple paint system on the top, and give promise of significant cost savings for maintenance of offshore wind turbines.

A system for **Real Time Hybrid Model Testing** (RTHMT) has been identified to overcome the inherent challenges of different scaling laws for wind and wave when performing scaled tests of floating turbines. A successful model test, where the important physical effects of a floating offshore wind turbine can be captured in a physically correct way by RTHMT, would mean a significant step forward in validating design tools and assessment of novel concepts for floating offshore wind turbines.

Grid connection of an offshore wind farm with a **multi-terminal HVDC** network has been demonstrated in lab scale. The lab setup verified numerical simulations of system operation and control. HVDC technology is critical for developing an offshore grid and pawing the way for large far offshore wind farms.

The development of the **Remote Presence** concept is progressing well and set to continue towards industry application through projects outside NOWITECH. 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.

A thermally sprayed **silicon carbide coating** for protecting main bearings etc. is successfully developed and tested in lab. The process is patented, and in progress for industry implementation with potential for value creation and reducing cost of maintaining offshore wind farms, see Figure 1.

The results are disseminated efficiently. In 2013 NOWITECH prepared 86 publications including 25 peer-reviewed papers, 18 conference presentations, 23 reports and 15 media contributions. The use of web, newsletters and organization of workshops and conferences enhance the communication:

- Three seminars were held in the series "Industry meets Science" in cooperation with Access Mid-Norway and WindCluster Mid-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 has developed into an international event with call for papers, peer-review and publication in the open access journal Energy Procedia (Elsevier). DeepWind'2013 had about 140 delegates from 14 countries, mainly European, but also e.g. from USA.

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, developing R&D strategies and new projects.

The NOWITECH research partners are attractive: A total of nine research projects with funding from EU or Research Council of Norway were granted in 2013 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.

The existing strong research infrastructure is expanded with funding from RCN; namely DIPLAB (8 MVA short-circuit emulator) and NOWERI (met-ocean measurements and floating research turbine) jointly with NORCOWE. DIPLAB (ETEST) was procured in 2013 and a first test of the lab is planned for winter/spring 2014. NOWERI is still in preparation with NTNU as the contract partner for the floating test turbine and University of Bergen for the met-ocean measurements.

The accumulated costs for NOWITECH in 2013 were NOK 43 million co-funded by the Research Council of Norway (RCN), the industry parties and the research parties. Overall progress is according to plan with excellent results reported by the mid-term evaluation concluded in 2013 by RCN with the assistance of international experts; quoting from their report:

Research activities:

"The research work is of highest international standard."

Internationalization:

"NOWITECH has become an internationally recognised organisation for research on offshore wind power,..."

Researcher training, engagement in education:

"An excellent scientific programme has been established between SINTEF, IFE and NTNU …"

Plans for final three-year period

"The ambitious plan presented for the final thee-year period is a well-defined and consistent continuation of the current work. Milestones and deliverables are well presented and seem to be realistic. The well-established team and the extended infrastructure give promise of significant achievements, even more so than during the past years."

Organisation and Management of the Centre

"The Centre is well organized and led by a highly competent and deeply engaged Director, supported by an efficient management group."

Conclusion and recommendations to the Centre

"NOWITECH has progressed well towards becoming an internationally recognised organisation for research on deep sea wind power, with a uniquely comprehensive research agenda on this topic. The Centre is a well-managed unit in which communication and exchange of experience between all partners seem to run smoothly."

Strategic work with the Board is initiated on further developing NOWITECH to deliver even better and prepare for continuation also after 2017. Activities are suggested moving towards more applied research, utilising strong research infrastructure, and may also be linked with one or more demonstration wind farm. The international dimension shall be advanced, linking with partners with complementary competences, potentially through EERA JP wind or other set-ups.

Figure 1: No one has ever been able to process silicon carbide in such a way that it can be sprayed as a coating on machine parts. That was before NOWITECH PhD student Fahmi Mubarok began his doctoral research. Read more about this work in chapter 8.5. Photo: synlig.no

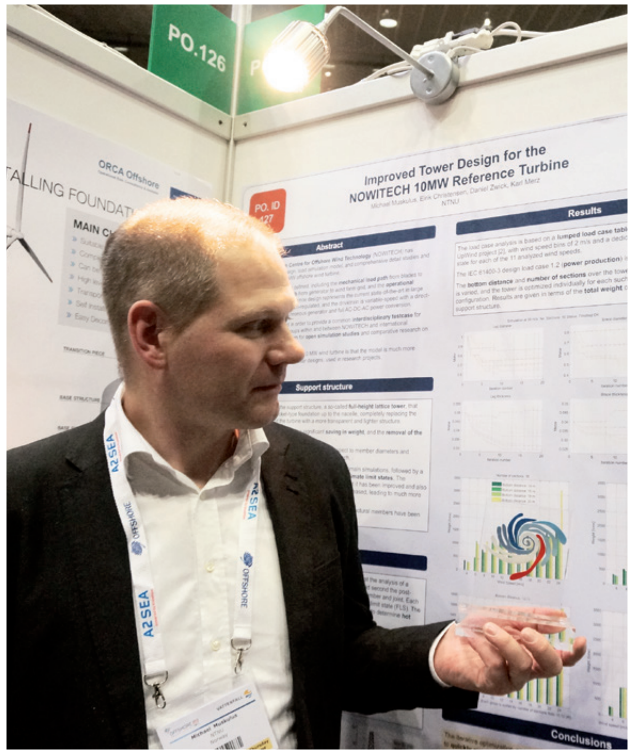


Figure 2: Work by NOWITECH was awarded best poster at EWEA Offshore 19-21 November 2013, Frankfurt with the work: "Improved tower design for the NOWITECH 10 MW reference turbine" by Michael Muskulus, Eirik Christensen, Daniel Zwick and Karl Merz. Read more about this work in chapter 8.3..

1 NOWITECH PARTNERS

NOWITECH Partners in 2013:

The 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
- Kongsberg Maritime AS
- NTE Holding AS
- SmartMotor AS
- Statkraft Development AS
- Statnett SF
- Statoil Petroleum AS

Kongsberg Maritime joined NOWITECH from 2013-01-01 and CD-adapco joined NOWITECH from 01-07-2013. NTE Holding withdrew from NOWITECH with effect from start of 2014 due to conditions outside the Centre.

NOWITECH associate partners:

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

Michigan Tech joined NOWITECH in May 2013 as a new associate research partner. Access Mid-Norway was dissolved by end of 2013.

2 ORGANISATION

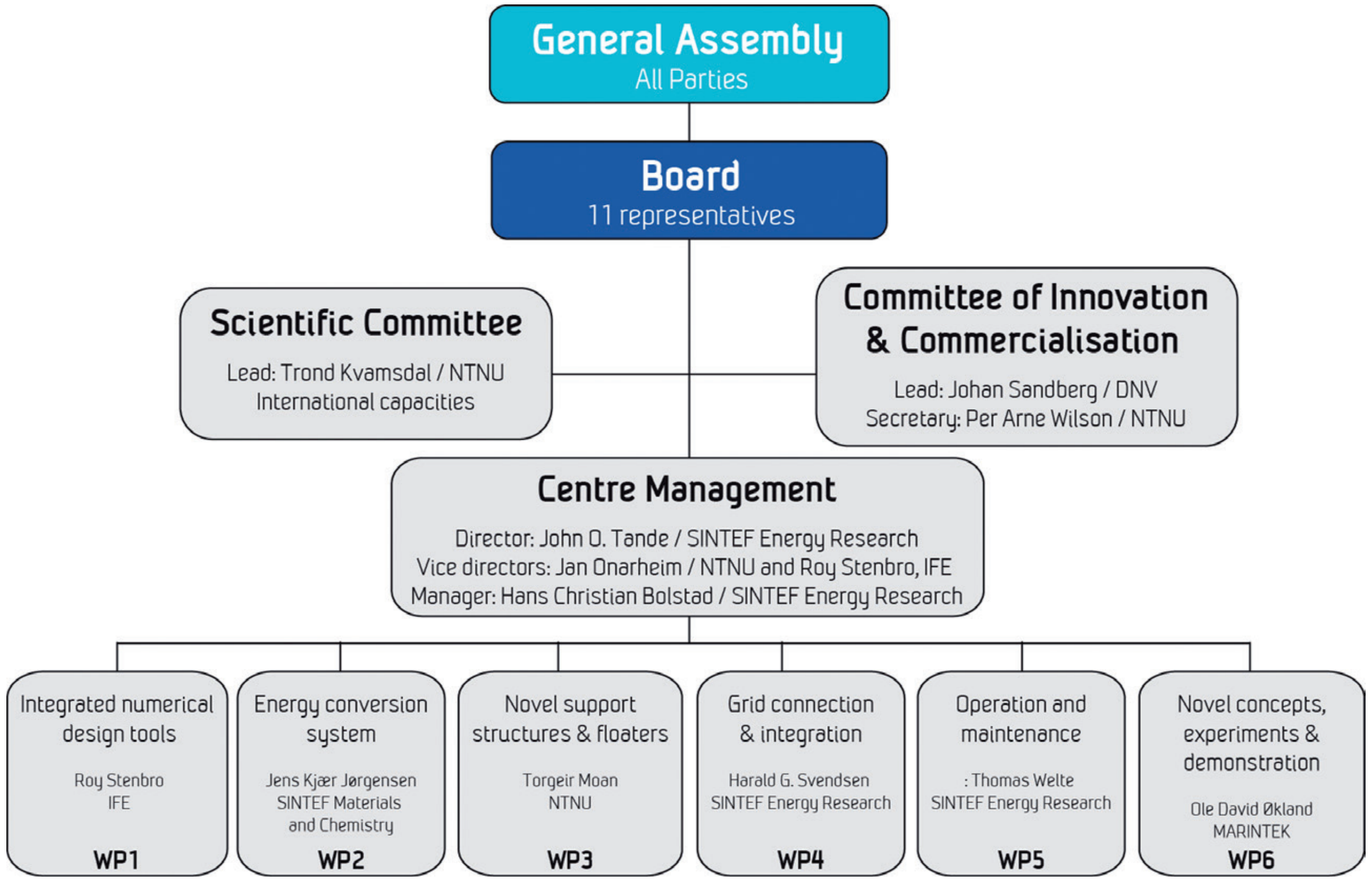


Figure 3 Outline of governance structure for NOWITECH per start of 2014.

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 six work packages (WPs): integrated numerical design tools (WP1), blades and generators (WP2), bottom-fixed and floating substructures (WP3), grid connection and system integration (WP4), operation and maintenance (WP5), and assessment of novel concepts (WP6). The organization of NOWITECH is shown in Figure 3.

Johan Sandberg took over the lead of CIC after Kjell Eriksson by June 2013, and the lead of WP2 was changed in August 2013 with Jens Kjær Jørgensen taking over for Bernd Schmid. Harald Svendsen was appointed new leader for WP4 taking over for Kjetil Uhlen, and Thomas Welte for Matthias Hofmann in WP5, both by start of 2014. Hans Christian Bolstad joined as manager in August 2013, taking over from Nils Arild Ringheim. Tobias Aigner was in an intermediate position to fill the gap between Nils Arild leaving in the spring and Hans Christian taking over in the fall. All changes were due to conditions external to NOWITECH, and all the good works of the previous leaders are greatly appreciated.

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

Industry involvement has high priority: The industry parties participate by in-kind supplies, through participation at dedicated WP meetings, and in the CIC. All parties are represented in the GA and the industry parties are active and in majority in the Board. Eight out of eleven representatives in the Board are from the industry.

Accounts of the Board, CMG, CIC and SC set-up and activities in 2013 are given in section 3, 5, 6 and 7 respectively.

3 THE BOARD

Figure 4 Meeting of the General Assembly November 2013. From left: Jørn Holm (Dong), Vincent De Laleu (EDF), Lars Kristian Vormedal (Statnett), Michael Muskulus (NTNU), Martin Kirkengen (IFE), Knut Samdal (SINTEF Energy), Øyvind Hellan (Marintek), Jan Onarheim (NTNU), Oddbjørn Malmo (Kongsberg), Gudmund Olsen (Statoil), John Olav Tande (SINTEF Energy), Johan Sandberg (DNV), Alexey Matveev (Smartmotor), Jørgen Krokstad (Statkraft) and Hans Christian Bolstad (SINTEF Energy).

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 shall report to and be accountable to the General Assembly (GA). The Board monitors the implementation of the Centre and approves the annual working plans and budgets. The Board ensures 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 Board meetings were held in 2013, i.e. one in June and one in November. Both meetings were combined with a workshop the day before. The June workshop discussed NOWITECH strategy and was combined with the NOWITECH day, with researchers, PhD and post doc scholars presenting key results. 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 June meeting approved CD-adapco as a new Industry Partner, and the November meeting approved the work plans for 2014.

The Board members for 2013 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, Sven Gjømesli, Fedem, Sigurd Øvrebø, SmartMotor, Jørgen Krokstad, Statkraft, Gudmund Per Olsen, Statoil, Lars Kristian Vormedal, Statnett, Håvard Belbo, NTE Holding.

The GA November 2013 elected DONG Energy and Kongsberg to join the Board by start of 2014 replacing NTE and Smartmotor respectively. DNV was re-elected for 2 years to the board.

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

4 RESEARCH PLAN

NOWITECH is an international precompetitive NOK 320 million (2009-2017) research cooperation on offshore wind technology co-financed by the Research Council of Norway (RCN), industry and research partners. The positive mid-term evaluation that was concluded in 2013 by the RCN nominated evaluation committee has encouraged the Centre to take the next steps and to further enhance it strengths and international position.

The vision is to contribute to large scale deployment of deep sea offshore wind turbines, and to be an internationally leading research community on offshore wind technology enabling industry partners to be in the forefront.

The objective 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:

- Combine wind technology know-how 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.
- Support to industry is through pre-competitive research – commercial development will come as a result and be run in separate projects, i.e. NOWITECH funding provides for development until Technology Readiness Level 4 or 5 (lab scale testing), and ready for takeover by more commercially directed projects with industry lead, see also section 6 and 8 for details on the TRL methodology.
- Actively pursue opportunities to increase R&D activity on critical issues.

Key issues in NOWITECH are education, knowledge building and innovations aiming to reduce the cost of energy from offshore wind. Emphasis is on "deep-sea" (+30 m) including bottom-fixed and floating turbines.

The research methodology includes a mix of analytic work, numerical simulations and development of such 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, see section 8.8. 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 funding, see section 8.9.

The research is prepared through activities at SINTEF, IFE and NTNU and industry in-kind contributions. The educational activity forms part of the research programme with engagement of MSc students and funding of 25 PhD and post doc students at NTNU. PhD and post doc students at NTNU working on offshore wind, but funded through other sources, are affiliated with NOWITECH.

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

WP 1: Development of integrated numerical design tools for novel offshore wind energy concepts. The goal is establishment of a set of proven tools for integrated design of deep-sea wind turbines, hereunder characterization and interaction of wind, wave and current.

WP 2: Investigation of new energy conversion systems for offshore wind turbines. The goal is to contribute to the development of efficient, low weight and robust blade and generator technology for offshore wind turbines.

WP 3: Identification and assessment of novel substructures (bottom-fixed and floaters) for offshore wind turbines. The goal is to pin-point cost-effective solutions for deep-sea wind turbines.

WP 4: Assessment of grid connection and system integration of large offshore wind farms. The goal is to develop technical and market based solutions for cost-effective grid connection and system integration of offshore wind farms.

WP 5: Development of operation and maintenance (O&M) strategies and technologies. The goal is to develop a scientific foundation for implementation of cost-effective O&M strategies and technologies for offshore wind farms.

WP 6: Assessment of novel concepts for offshore wind turbines by numerical tools and physical experiments, hereunder developing control systems and combining results from WP1 and WP5. Assessment is by numerical tools and by utilizing "in-house" labs and results from full scale field tests.

The interaction between the WPs is enhanced through dedicated integration activities. This includes joint development of the NOWITECH 10 MW reference wind turbine; and as a new activity in 2013, also a NOWITECH reference wind farm. These serve as a focal point and baseline case for research activities within the Centre. The activity brings researchers together across traditional fields of engineering science facilitating team building and innovations. The preparation of joint workshops and research strategies further strengthen the team building.

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

Work is carried out in coordination with the two other CEERs (Centres for Environmental Energy Research; in Norwegian: FME) on offshore wind, CEDREN and NORCOWE. The Centres are complementary to each other and contribute to a strong research effort on offshore wind. There is, however, still need for further increase in the research efforts. NOWITECH will in coordination with CEDREN and NORCOWE continuously seek opportunities to establish new research projects, research infrastructure as well as test and demonstration projects.

The mid-term evaluation by the RCN in 2013 approved NOWITECH to continue according to plans until 2017, but in the process also asked for plans to continue beyond 2017. These are in preparation in dialogue with relevant parties. The SET-plan, TPWind, EERA and Energi21 all emphasise the need for research and development on offshore wind energy. The general message is that the offshore wind market and technology are in an early stage of development, but with large potential provided that cost of energy can be brought down to a competitive level. Combining this with the European commitment to develop offshore with targets set by EWEA at 40 GW offshore wind capacity by 2020, and 150 GW by 2030, continuation of NOWITECH beyond 2017 is highly relevant. The research partners have a long-term commitment towards this area, and have a strong motivation to continue developing education, knowledge building and innovations for reducing the cost of energy for offshore wind. Activities are suggested moving towards more applied research, utilising strong research infrastructure, and may also be linked with one or more demonstration wind farm. The international dimension shall be advanced, linking with partners with complementary competences, potentially through EERA JP wind or other set-ups.

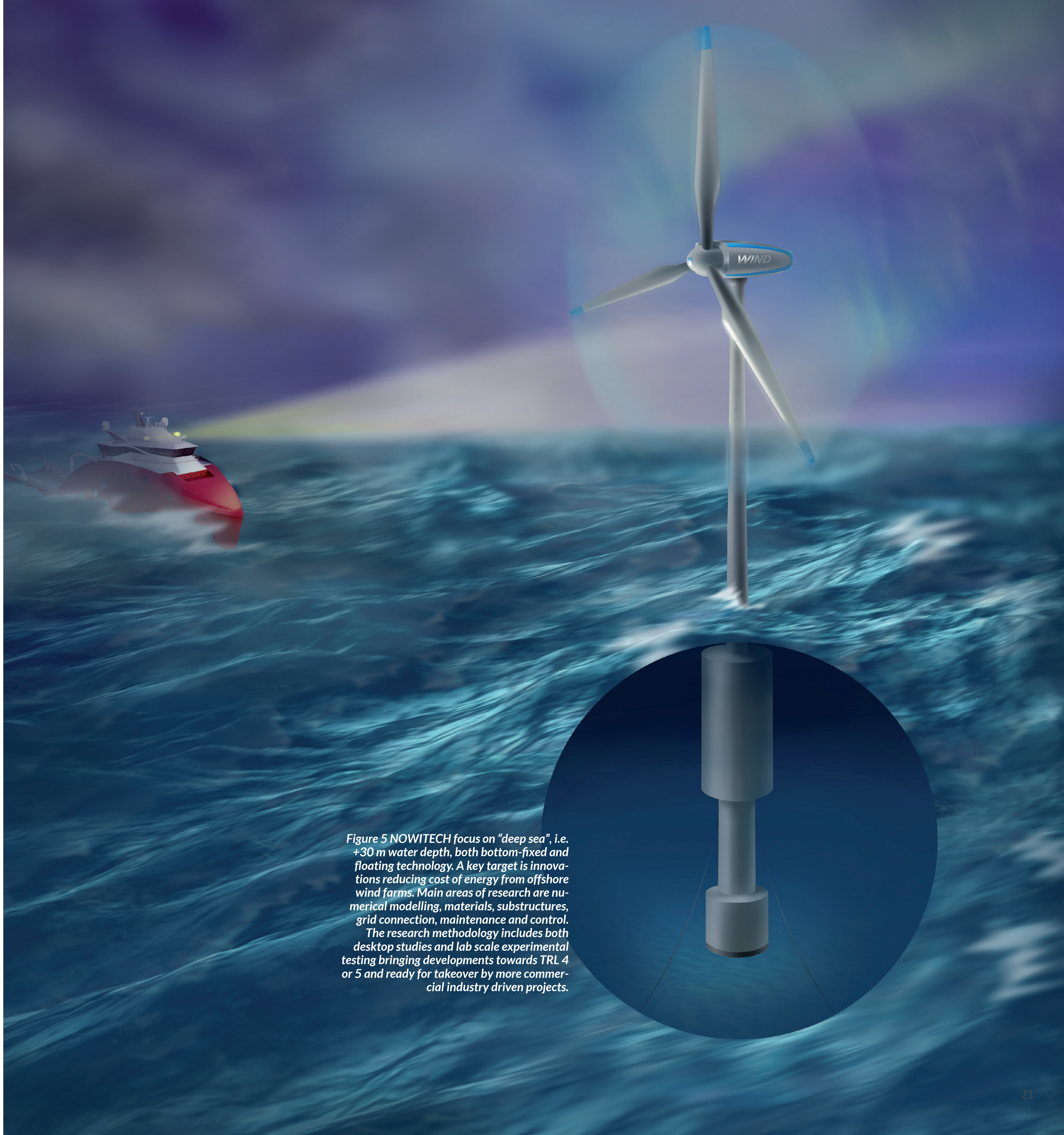


Figure 5 NOWITECH focus on "deep sea", i.e. +30 m water depth, both bottom-fixed and floating technology. A key target is innovations reducing cost of energy from offshore wind farms. Main areas of research are numerical modelling, materials, substructures, grid connection, maintenance and control. The research methodology includes both desktop studies and lab scale experimental testing bringing developments towards TRL 4 or 5 and ready for takeover by more commercial industry driven projects.

CENTRE MANAGEMENT

5

John Olav G. 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 secretary 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 dayto-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, Outreach and Integration as outlined here:

Management
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, financial and legal issues, meetings in the CMG with WP leaders and representatives from the SC and CIC, preparations for the GA and Board, reporting to the RCN etc.

CMG meetings have been held on a monthly basis during 2013. These are mainly for team-building, information exchange and strategic discussions. In addition telephone, e-mail and web-based meetings are prepared as required.

Outreach
The Outreach activity includes preparing general presentations of the Centre, dissemination of results, keeping contact with prospect new industry parties, overall coordination towards other projects, relevant organisations and CEER's, in particular CEDREN and NORCOWE, and engagement in developing offshore wind projects and research strategies. The Centre Director is engaged in this also through CIC and SC.

NOWITECH was represented at the EWEA offshore conference and exhibition, 19-21 November 2013 in Frankfurt, Germany with its own stand to inform the visitors and interested parties of the ongoing results and research taking place in NOWITECH. The event is the main conference and exhibition for the offshore wind sector attracting thousands of visitors from both Europe and internationally. Further dissemination activities by the management in 2013 included key-note presentations at international conferences, hosting numerous delegations visiting NOWITECH, preparation of media contributions, keeping web and e-room updated, preparation of newsletters, the "Industry meets Science" workshops and the annual offshore wind R&D conference in Trondheim DeepWind'2013. Further accounts of the dissemination activity of NOWITECH are given in section 11.

Engagement in developing offshore wind projects and research strategies in 2013 included both national and international activities:

- Participation in Energi21 and SFFE (www.sffe.no) 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.

International engagement is further described in section 9.

Integration
The integration activity shall improve the common understanding of challenges and their interplay between the WPs, and may potentially lead to new innovative ideas and solutions that exist in the boarders of a traditional split between the engineering sciences. The main activity in 2013 was the joint development of the NOWITECH 10 MW Reference Turbine and 1200 MW Reference Wind Farm, see section 8.7.

COMMITTEE FOR INNOVATION AND COMMERCIALIZATION

6

Per Arne Wilson,
Secretary CIC

Johan Sandberg
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, through spin-off projects and the creation of new industry. The committee is industry driven, with chairman from DNV GL and secretary Per Arne Wilson from NTNU. The chairman was Kjell Eriksson until June 2013, and thereafter Johan Sandberg. The 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 between SMEs and NOWITECH partners.

Activities by CIC in 2013 included:

- CIC ordered NTNU Technology Transfer Office (TTO) to assess four ideas with commercial potential for possible further development. These were a) unbalanced fibre layup of wind turbine blades for enhanced buckling resistance, b) NOWICOB operation and maintenance simulation tool, zc) thermal spray silicon carbide coating and d) turbine diffuser technology. This has resulted in transfer of NOWICOB with a license agreement to a number of NOWITECH industry partners and further development of the silicon carbide coating with a patent application and negotiations with potential industry parties for manufacturing the coating as a commercial product. The end result of this is industrial value creation and lower cost of energy from offshore wind farms. The other two ideas were decided not to process any further by TTO, but referred back to the inventors for possible publication or others as they see fit.

- The Technology Readiness Level (TRL) guideline is adapted to the Centre activities and several iterations of the method have now been implemented in the working plans with assistance by CIC. The method is a useful communication platform between researchers and industry partners as regards contents and maturity of WP results, and in particular to identify the next steps for taking an innovation closer to the market.

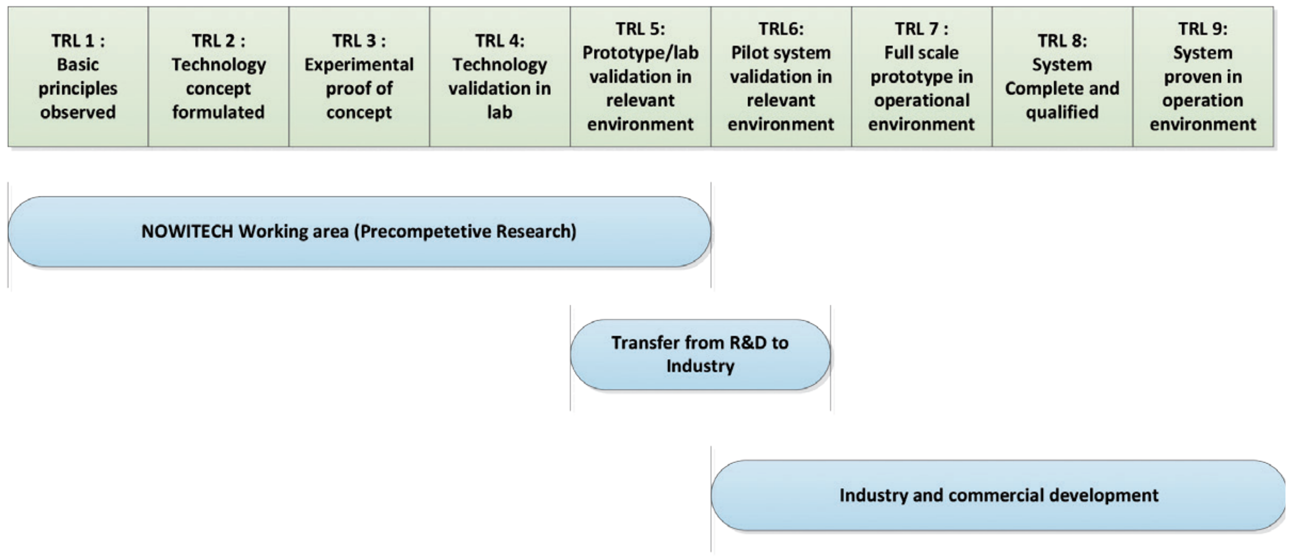


Figure 6 NOWITECH uses the Technology Readiness Level concept to evaluate and communicate maturity of new ideas and technology under development. See also chapter 8.

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 Mid-Norway (WMN) and Access Mid-Norway (AMN), 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, e.g. WindFlip (offshore wind installation system), Limsim (computing technology), SubHydro (subsea energy storage), Norsk Automatisering (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.

SCIENTIFIC COMMITTEE

7

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 capacities 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 advices 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 research partners.

The SC members as per end 2013:

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
- Ivar Langen, UiS
- Finn Gunnar Nielsen, Statoil/UiB
- Terje Gjengedal, SFE/UMB
- Jørgen Ranum Krokstad, Statkraft/NTNU

The associated research partners are represented by:

- Paul Sclavounos, MIT, USA
- 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

Ivar Langen and Finn Gunnar Nielsen are participating in NOWITECH SC also to represent NORCOWE, and in the same manner Trond Kvamsdal and Michael Muskulus are representing NOWITECH in NORCOWE's SC. This is securing communication and alignment of the scientific and educational activities between the two Centres.

Michigan Tech joined as a new associated research partner with NOWITECH during 2013 and is warmly welcomed to be represented by prof. Bruce Mork. This reinforces an already strong cooperation between NTNU and Michigan Tech within electro-technical issues, and with Bruce frequently visiting NTNU for shorter and longer stays. Michigan Tech has research activities on wind farms in the Great Lakes, and brings in new perspectives on offshore wind developments.

Activities by Scientific Committee 2013 include:

During 2013 the Scientific Committee core group met more or less on a monthly basis. They handled dayto-day operations regarding PhD and post doc programme, recruitment, educational issues, etc. and applicants for the mobility programme. In 2013 the programme supported intermediate-term research visits, a student excursion to Bremerhaven (described below) and an extension of a post doc study to assist the SC operation.

The extended SC accomplished two full meetings in 2013; one in January back-to-back with the DeepWind conference in Trondheim, and one in June in Bremerhaven aligned with an excursion and PhD/post doc seminar hosted by Fraunhofer IWES. These extended SC meetings involved an evaluation of the scientific content of NOWITECH's results and giving strategic advice on direction of research.

Excursion to Bremerhaven

The excursion to Bremerhaven 25-27th of June 2013 included two professors (Trond Kvamsdal and Lars Sætran) and ten PhDs from NTNU/NOWITECH. The host was Hans-Gerd Busmann at Fraunhofer IWES providing for an excellent programme and generous hospitality that is greatly appreciated. The visit started out with a Tour the Wind Bremerhaven on Tuesday 25th of June. The Bremerhaven is really "The Offshore Wind Harbour of Europe" and it was very interesting to get the opportunity to have a close up look at the different types of Offshore Wind Substructures and Blade Test Facility, see Figure 8. Then there was NOWITECH and Fraunhofer IWES PhD/Postdoc Seminar on Wednesday 26th June, see Figure 7. More than 20 posters were on display and each was introduced by means of a speed presentation (3 minutes each). The discussions among the participant in front of the posters were both informative and intense. Finally the SC meeting was held on Thursday 27th of June.

Figure 7a: NOWITECH and Fraunhofer IWES PhD/Postdoc Seminar – Bremerhaven 26th June. Speed presentation of posters by PhD-students.

Figure 7b: The audience is very interested!

Figure 8a and 8b: NOWITECH SC's excursion to Bremerhaven in 25-27 June 2013. Bremerhaven - "The Offshore Wind Harbour"

8 RESEARCH WORK AND RESULTS

The Technology Readiness Level assessment methodology represents a communication tool between different stakeholders. A Technology Readiness Level (TRL) scale combines the definition of the attributes for a defined maturity grade and the step between different grades.

The Technology Readiness Level concept

The TRL concept was taken into use in NOWITECH to improve communication on the research results:

Key elements communicated may be:

- Maturity of theoretical basis (documentation)
- System maturity (component level or system level design)
- Extent of physical testing (scale and type of tests)

The TRL methodology was initially developed by NASA IN THE 1980s. The initial scale had seven levels which were not formally defined until 1989. In the 1990s NASA adopted a scale with nine levels which gained a wider acceptance and was further refined under implementation in US governmental agencies and their contractors. Examples of public organisations applying the TRL concept are US Department of Defence, US Department of Energy (DoE) and the European Space Agency. The methodology has gained use also in the oil industry by a number of companies based on the recommended practices from DNV and American Petroleum Institute (API). The EU Horizon 2020 R&D Programme has now also implemented TRL levels as a means to communicate expectations in project calls.

A TRL scale combines the definition of the attributes for a defined maturity grade and the step between different grades. A generic interpretation of the definition of TRL is that TRL 1-3 represents research and development stages while 4-5 represents development stages. At TRL 6 the development typically is industry based as the higher TRL levels are associated with integrated solutions with elements of early deployment and commercial application. In NOWITECH twenty-six results have been allocated a TRL value, either by formally assessment with full documentation (16) or as ad-hoc estimates (10). The two high TRL=7 results are achieved through commercial/industrial developments outside NOWITECH, but originated from NOWITECH.

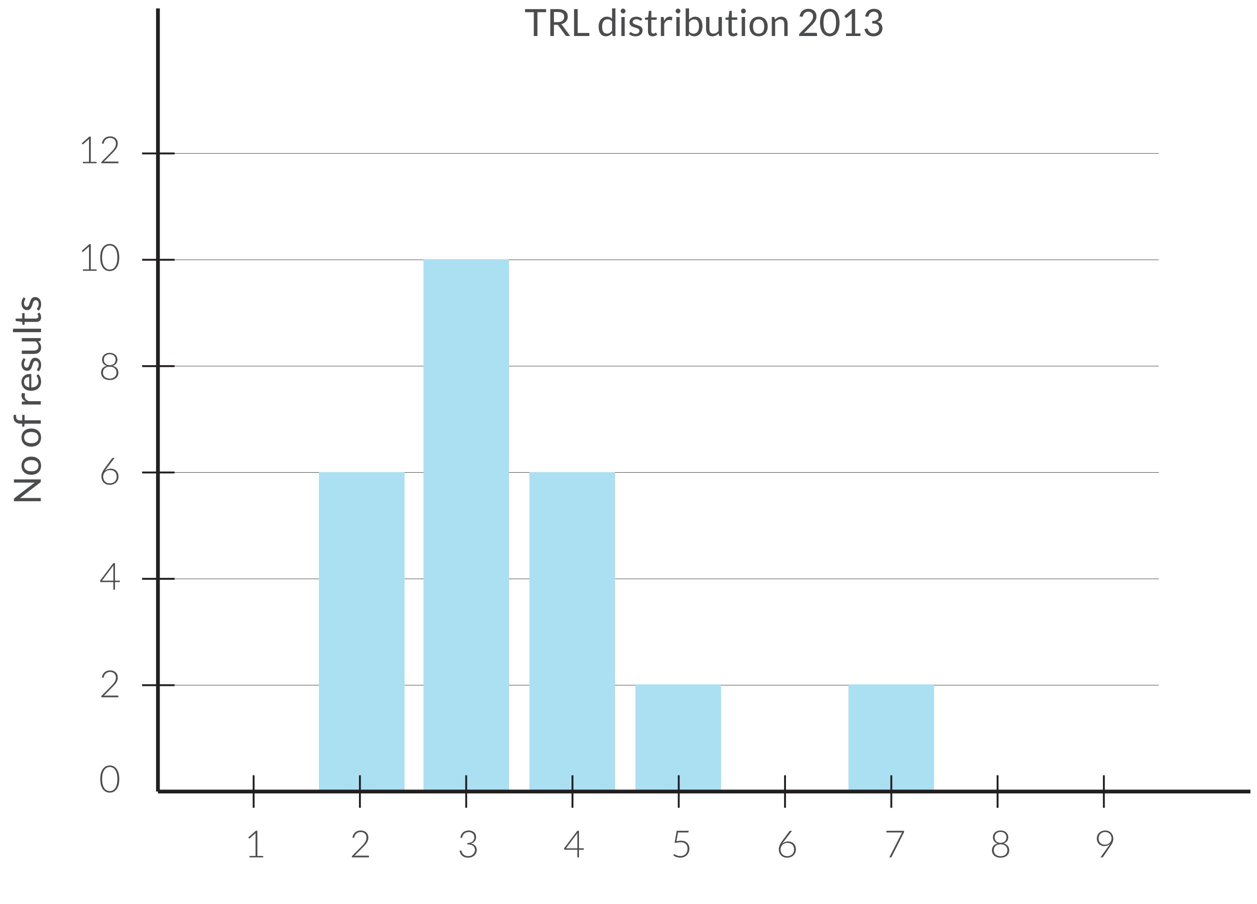


Figure 9 Distribution of results maturity in NOWITECH 2013 sorted according to TRL value.

INTEGRATED NUMERICAL DESIGN TOOLS

8.1

Roy Stenbro,
WP1 leader

The objective is establishment of a set of proven offshore wind turbine simulation tools and building knowledge of wakes.

The work is divided into two tasks:

1.1 Software Development
1.2 Wakes

Summary of achievements 2013

WP1 is running well with a strong group of people from both industry and R&D partners, and we have a high productivity of deliverables.

- 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 and accuracy of the software. The software is becoming more and more mature and we feel we are international very competitive. 2013 has had focus on validating the codes for semi-submersibles via IEA OC4 participation. This is a challenging concept and therefore a good benchmark due to its more complex substructure, sea loads and mooring.

- The development of the novel iso-geometry based elements fluid/structure simulation tool by SINTEF ICT is progressing well.

- IFE has this year moved on to CFD simulations of rotor cases with stalled blades that can occur for idling or faulty rotors. Such blade states can result in high and/or oscillating loads.

- NOWITECH/NTNU in cooperation with NORCOWE did a third round of the popular wind turbine and wake blind tests. This time the difficulty level was increased another notch. Two unaligned model wind turbines were tested to shed light on a common situation in wind parks that can results in significantly unsymmetrical turbine loads. Such measurements are valuable to those interested in understanding and modelling wind turbine park effects both when it comes to energy production and dimensioning structural loads.

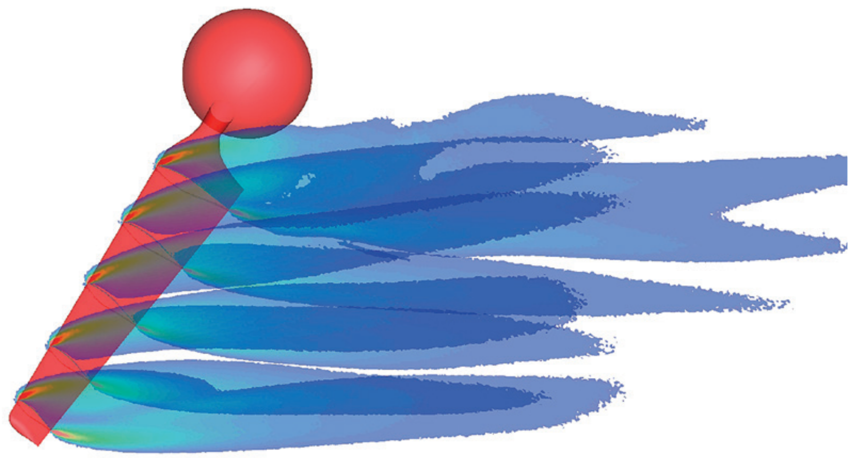


Figure 10: IFE CFD simulation of standstill rotor (above).
Wind tunnel Blind test 3 with unaligned rotors in wind tunnel at NTNU (above). Photo NTNU (top-banner).

HIGHLIGHTS 2013

Commercial use of simulation software developed through NOWITECH

Development of software that can simulate the whole offshore wind turbine's behaviour in the marine environment has had high priority in WP1. MARINTEK develops the SIMO/RIFLEX package and IFE develops 3DFloat. The IEA Offshore Code Comparison Collaboration (OCE/OC4) is perhaps the most important international collaborative platform for those developing and validating integrated models. NTNU, MARINTEK and IFE have been active participants and it has proven very beneficial to participate. Our results have shown themselves to be good when seen in an international research context. We have now come to the stage where we see industrial impact of the efforts. Functionality is migrating into the commercially available versions of MARINTEK's software and they are providing simulation services to their customers. IFE is also providing simulation services to the offshore wind energy industry and the engineering industry have started using 3DFloat for commercial offshore wind projects.

Results from NOWITECH have enabled detailed simulations to qualify alternative sub-structures in offshore wind farms. MARINTEK has prepared such studies for commercial clients resulting in very significant cost savings for realizing the offshore wind farm.

Dr. techn. Olav Olsen is now using 3DFloat for R&D projects and also in commercial projects for a customer in the offshore wind industry. Dr. techn. Olav Olsen is very pleased with the capabilities of 3DFloat and the acceptance of 3DFloat as a tool for commercial industry projects is growing.

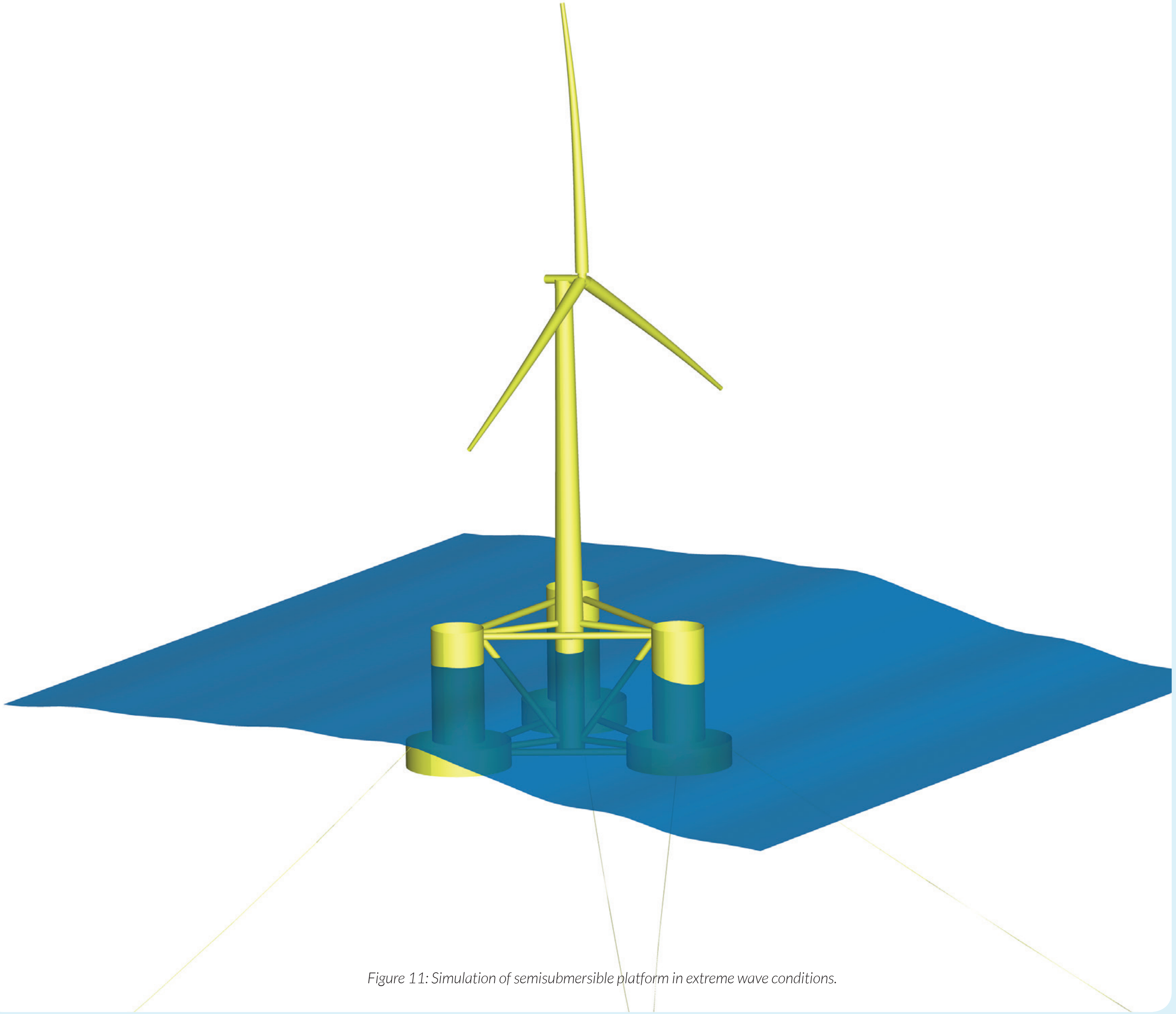


Figure 11: Simulation of semisubmersible platform in extreme wave conditions.

Industry benefits and cooperation

DONG, Statoil and Statkraft are the most active industry partners in WP1 and they contribute with valuable input during the spring and fall industry reference group meetings. We have a new industry partner this year, CD-adapco. We are very happy to have a world leading supplier of CFD software on board.

Result	TRL Level	Impact
Model: IFE - 3DFloat integrate simulation tool	4	Integrated OWT models are essential to research and engineering. The model is in commercial use in the OWT industry.
Model: MARINTEK SIMO-RIFLEX simulation software package	4	Integrated OWT models are essential to research and engineering. The model is in commercial use in the OWT industry.
Model: IFE - 3DWind prototype offshore wind turbine park wake CFD simulation tool. Development finished 2011.	5	Understanding and simulation of the wake effects are essential to park layout, park energy prediction and important to turbine wind loads predictions.
Model: SINTEF ICT & NTNU IFEMCFD 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.
Method: NTNU Dept. of Mathematical Sciences - VMS-based error estimator	(2)	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.
Software: MARINTEK Floatopt spare buoy offshore wind turbine and mooring optimization software tool.	(5)	Can do cost optimized design of spar buoy type OWT substructure and mooring and minimize CAPEX in these areas. Development finished in 2011.
Software: IFE - ALSIM general and offshore wind turbine optimization software tool. Development finished in 2011.	(7)	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 and mooring optimization.
Method: IFE - use of the DLR TAU CFD simulation tool on wind turbine rotor.	(4)	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.
Prototype: Fugro-OCEANOR floating met-ocean buoy with LIDAR for measuring wind speed at different heights above sea level.	(7)	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.

**TRLs in () are indicative only and estimated without any formal assessment. The others are formally assessed.*

Academic achievements

WP1 has three PhDs and one post doc. One PhD finished in 2012 and the remaining two is expected to finish in 2014. The post doc finished in 2013.

WP1 has so far produced approximately 25 publications and given 17 conference presentations in addition to 5 conference posters and 35 project internal technical reports.

We see the most 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).

ENERGY CONVERSION SYSTEM

8.2

Jens Kjær Jørgensen
WP2 leader

The objective of WP2 is to contribute to the development of efficient, low weight and robust blade and generator technology for offshore wind turbines.

The work is divided into three tasks:

2.1 Fatigue properties of composites in rotor blades and rotating machinery
2.2 Ironless generators for direct-drive wind turbines
2.3 Sensor technology for condition monitoring of composite components

Summary of achievements 2013

- PhD student Kevin Cox has submitted his thesis with the title "Lift control of adaptive wind turbine blades with bend-twist coupling".
- An experimental investigation of the fatigue on unbalanced composites has been carried out.

- A progressive damage stiffness reduction fatigue simulation model for composite materials has been implemented and is under validation towards experimental data.
- New equipment for fatigue testing of composite materials has been installed at SINTEF MC to perform fatigue test with optimum control and logging for model input.
- A "spin-off" pre-project "WiVind: wireless sensors for wind turbines" has be established by Kongsberg Maritime and SINTEF ICT and funded 500 kNOK by the Regional Research Foundation of Mid-Norway. The pre-project was established based on experience from the work on the report "Sensors for condition monitoring of different components of (offshore-) wind power plants". The aim of the preproject was to launch an IPN project in EnergiX.
- An application for the full WiWind IPN project has been granted by ENERGIX. Partners: Kongsberg, Sensonor, SINTEF, DTU Wind. Project start April 2014
- Numerical models to simulate slot harmonics and the effect of slot and pole combinations in generators has been implemented and used in design investigations.
- Numerical modal analysis of generator stators has been performed and experimental validation has been initiated, see Figure 12.

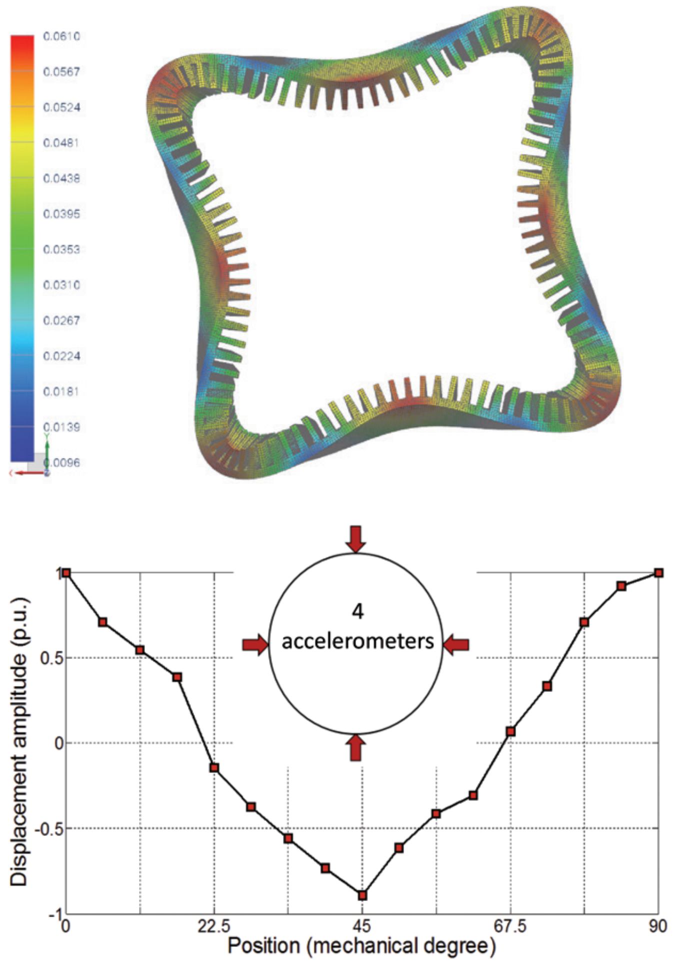


Figure 12: Numerical and experimental modal analysis of the stator of a prototype permanent magnet wind generator.

HIGHLIGHTS 2013

Lift control of adaptive wind turbine blades with bend-twist coupling

Wind turbines are designed to provide high energy production at moderate wind speed. A consequence of this is that the rotor blades are not designed to withstand the maximum catchable force from the wind at high wind speeds. Thus at high wind speed the load from the wind on the rotor needs to be reduced to protect the structure from damage. Today this is done by actively pitching the blade to reduce loads.

The load carrying structure of a wind turbine rotor blade is a large fibre based composite beam. A fascinating feature of such composite beams is that by choosing appropriate unbalanced layups of the fibre directions the beam will twist when subjected to bending. This is the basis for the conceptual idea of wind turbine blades with bend-twist coupling, that twist them self to reduce the lift from the wind at high loads. Compared with pitch control such self-regulation occurs much faster and without the need for motors and control algorithms.

Kevin Cox has been engaged as a PhD student in NOWITECH since 2010. He has now delivered his thesis titled "Lift control of adaptive wind turbine blades with bend-twist coupling" comprising six peer reviewed papers where he investigates a diversity of interesting aspects of self-adaptive rotor blades. Initially Cox contributed to NOWITECH by defining the structural layout of the NOWITECH reference turbine which is used as a baseline for many of his studies.

Several bend twist designs has been investigated with structural simulations and twist at maximum loads of up till 7o resulting in a load reduction of 10-11% has been found. Through a scaling effect study Cox has shown that the bend twist design is applicable for blade lengths between 30 and 90 meters. An additional very interesting finding which has been thoroughly investigated is that unbalanced fibre layups can increase critical buckling loads (up to 7% for the investigated design cases). It is estimated that the investigated design concepts allow for a blade mass reduction of approximately 3%. Finally the critical issue of the effect of unbalanced fibre layup has been addressed in an experimental study, leading to the conclusion that bend-twist coupling had little influence on flexural fatigue of glass-carbon hybrid composites.

NOWITECH thanks Kevin Cox for the good results he has delivered and wishes him good luck with his PhD defense.

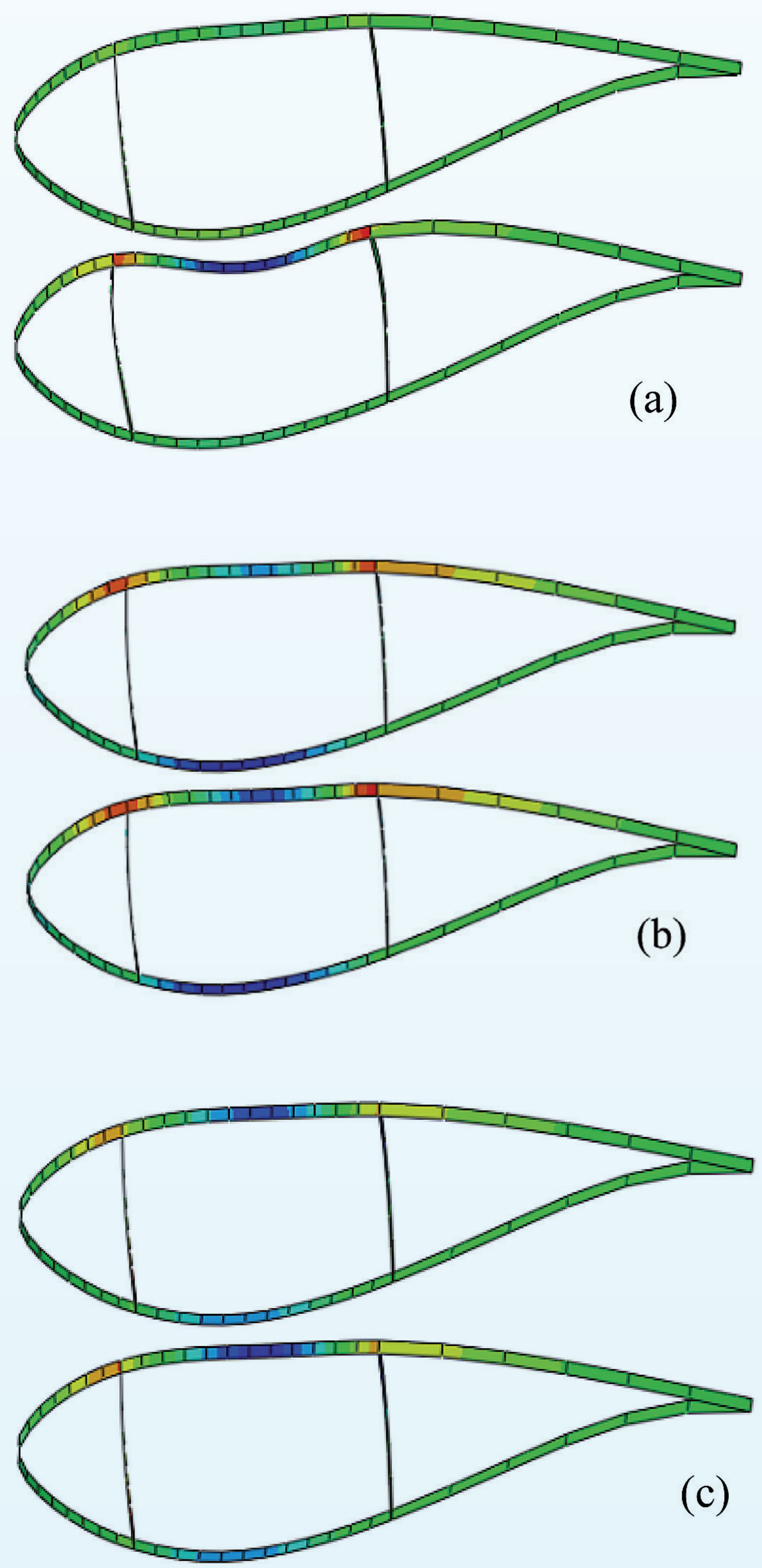


Figure 13: Effect of stability ply orientation on buckling studied in Cox et al. in WP2. Transverse strain at 23m span exhibiting the influence of the Brazier effect (buckling) for the stability ply orientations (a) 0°, (b) +45°, and (c) 90°.

Industry benefits and cooperation

The work in WP2 addresses design and structural integrity of generators and rotor blades. With regards to rotor blades one topic which is addressed is load alleviation through self-adaptive design, as described above. In addition we focus on providing tools that enable better prediction and monitoring of the health and remaining lifetime of rotor blades. This is approached through development of fatigue models for composite materials and through investigation of the use of sensors to monitor structural health. Computer simulations are used to study the effect of design of permanent magnet generators to reduce vibrations induced by magnetic forces. An optimized design with regards to such vibrations will allow valuable reduction of total generator mass. WP2 thanks the industrial partners SmartMotor, Fedem and Kongsberg Maritime for the cooperation in 2013.

Progress in made in alignment with the INNWIND.EU project on developing superconducting generators for wind turbines, see Figure 14. Superconductors carry current densities 100 times higher than copper conductors and enable the generation of strong magnetic fields. In that way the mass and volume of the wind turbine generator can be greatly reduced, and enables design of offshore wind turbines in the 10-20 MW range.

Result	TRL Level	Impact
Method to increase buckling resistance in wind turbine blades through unbalanced fibre composite lay ups.	3	The potential for load alleviation and increased critical buckling load through the use of unbalanced fibre layup has been documented for a large number of design cases through simulations and laboratory experiments.
Numerical model of the influence of slot harmonics on magnetic vibrational forces in PM magnet generators	4	The model is highly valuable in order to identify designs with low vibrational forces which will allow valuable reduction in total generator mass
Progressive fatigue damage stiffness reduction simulation model for composite materials	(NA)	This engineering tool can be used to estimate energy production for an offshore wind farm. It can be used together with electrical models in order to optimise offshore wind farm layout.

**The TRL in () is indicative only and estimated without any formal assessment. The other is formally assessed.*

Academic achievements

All three PhD students financed by NOWITECH under WP2 have delivered very good work throughout their engagement. Kevin Cox has delivered his thesis "Lift control of adaptive wind turbine blades with bend-twist coupling" which will be defended in spring 2014. Zhaoqiang Zhangs thesis is under preparation. Mostafa Valavi will continue to work in NOWITECH in 2014 and is very close to have the total results needed for his thesis.

Five conference presentations have been given by researcher and students from WP2 in 2013 and seven papers has been published in peer reviewed journals. In addition an article about the use of superconductors in wind turbine generators has been published in Teknisk Ukeblad.

WP2 has cooperated with partners in EERA Wind structures and Materials on composite materials testing.

Figure 14: Winding of superconducting test coils for wind turbine generators at SINTEF Energy Research. Photo: synlig.no

NOVEL SUPPORT STRUCTURES AND FLOATERS

8.3

Torgeir Moan
Leader WP3

The objective is to develop novel, cost-effective support structures and floaters for deep-sea wind turbines (including surface corrosion protection).

The work is divided into three tasks:

3.1 Bottom-fixed support structures
3.2 Floating support structures
3.3 Surface ("corrosion") protection (coating)

Summary of achievements 2013

The activities have focused on:

- Slamming wave loads and soil-structure modelling for bottom fixed wind turbines. This includes NOWITECH engagement together with NORCOWE in a laboratory experiment WAVESLAM - Wave Slamming Forces on Truss Structures in Shallow Water under the EU HYDRALAB IV framework conducted in 2013 at the Large Wave Flume, GWK in Hannover, see also see Figure 36.

- Design of a novel type of semi-submersible and efficient procedures for time domain and frequency domain analysis for wind turbines with floating support structures, with an emphasis on semi-submersible support structures.

- Development and testing of a novel coating.

- The new knowledge generated for support structures is to a large extent taken into use through implementing it in software for wind turbines. Moreover, the new knowledge also relates to new designs for support structures. The activities on coating might lead to a new product for corrosion protection.

- There has been a close collaboration with other NOWITECH WPs, notably WP1 and WP6 as well as NREL (National Renewable Energy Laboratory, USA)

Industry benefits and cooperation

Result	TRL Level	Impact
Comparison of software codes for analysing semi-sub wind turbines pinpointing accuracy	NA	Several research partners in WP3 have been involved in the OC4 study under the auspices of IEA regarding comparison of software for analysing semi-submersible wind turbines. Figure 15 shows the concept used in the comparative study.
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 WP3 as shown in Figure 16.
Novel protective coating system for offshore wind turbines	3	A maintenance-free coating system comprising thermally sprayed zinc (TSZ) and a top layer of paint, possibly with self-healing properties is in development. Tests show excellent field performance even with a very simple paint system on the top, and give promise of significant cost savings for maintenance of offshore wind turbines.

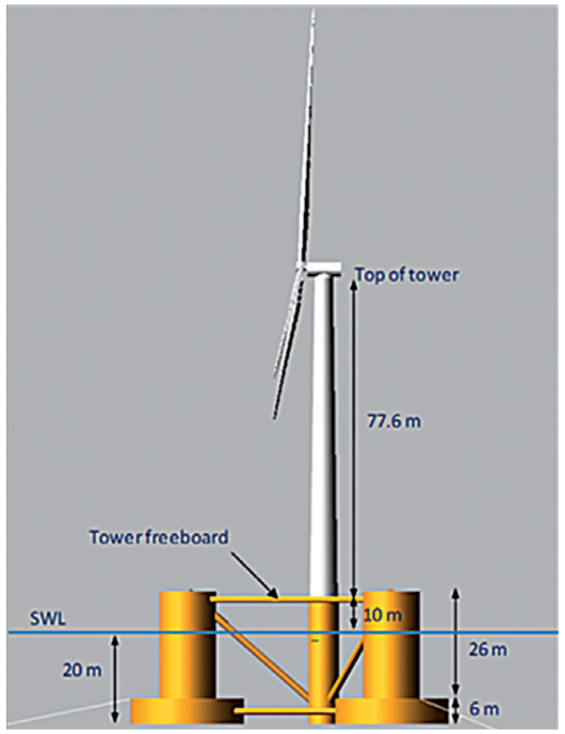


Figure 15: Side view of the OC4 DeepCWind semisubmersible wind turbine.

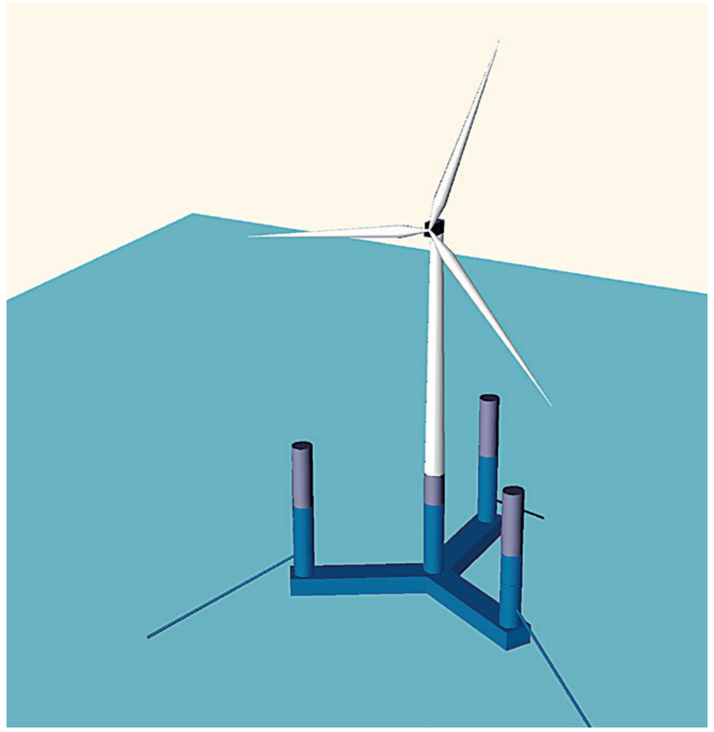


Figure 16: Layout of the 5MW-CSC.

Activities on coatings also comprise investigations into the influence of different reinforcing particle sizes and/or types on the mechanical properties of PU paints and coatings. Erosion test has been used to evaluating the effect of the reinforcing particles, see Figure 17. It was found that:

- Different modification of thermally sprayed PU coatings can enhance the erosion resistance comparable to the performance of commercially available product (3MPU tape) used today for protecting turbine blades.
- Reinforcement with FunzioNanoTM types of modified polyhedral oligomeric silsesquioxane (POSS) provides effective erosion resistance to the PU coatings.
- The addition of nano-ceramic particles (SiC nano-powder) has improved the erosion resistance of the PU coatings even they are reducing the adhesion between the PU particles, causing more brittleness.
- Hydrophobic functionalised silsesquioxane hybrid materials are feasible nano-additives for both thermoset and thermoplastic polymers to relevantly boost their mechanical properties on fracture toughness promoting improved erosion resistance.

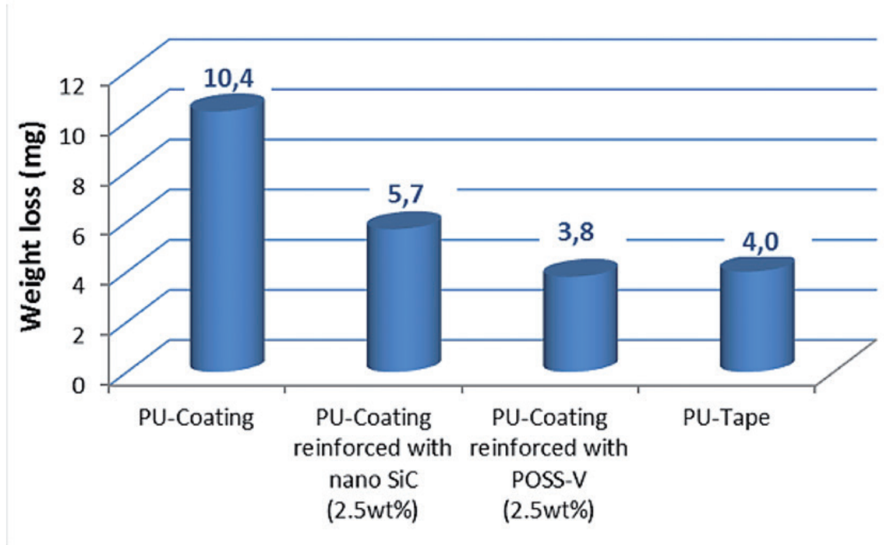


Figure 17: Erosion results as weight loss for thermally sprayed PU coatings reinforced with 2.5 wt% POSS-V and with 2.5 wt% SiC nano-powder, respectively (for comparison: neat thermally sprayed PU coating and commercial PU tape).

Academic achievements

Four PhD students are financed by NOWITECH under WP3. In addition 2 associated candidates are involved. Three of them will finish in 2014. There have been 12 publications in journals and conferences.

HIGHLIGHTS 2013

Exciting results from PhD-students:

Mayilvahanan Alagan Chella

The main objective of the study was to investigate the transformation of waves over a submerged reef numerically. The numerical model is furthermore used to analyze the breaking process and the breaker characteristics over a submerged reef with a slope of 1:10. The behaviour of the waves during breaking was examined using the breaker indices obtained from the numerical simulations and compared with experimental results. The numerical results are in reasonable agreement with the experimental results.

Eric Van Buren

The effect pile soil stiffness formulation on the response of jacket wind turbines has been carried out. Parameters for site conditions and structural geometry are varied, along with selected values assigned in the design standards. The study presents the effects of altering each parameter in terms of the displacement and loading of the piles and support structure, along with a basic look at the predicted potential fatigue of the structure, see Figure 18. The conclusions of the study identify aspects of the common pile design approach for which improvements are needed when used for offshore wind turbine applications.

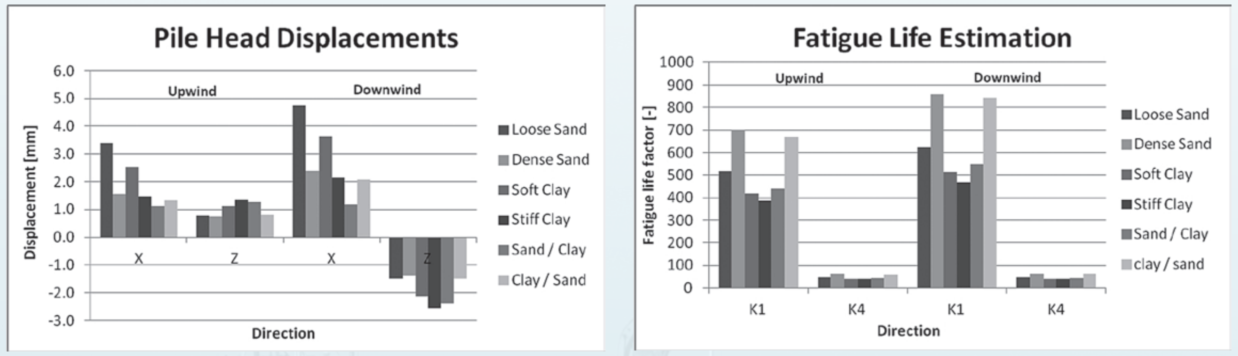


Figure 18: Soil condition impacts on structural fatigue and soil condition impacts on pile displacement.

Daniel Zwick

A study has been carried out, considering the use of a genetic algorithm for the structural design optimization of support structures for offshore wind turbines. Member diameters, thicknesses and locations of nodes are jointly optimized. The approach has been tested with the modified 4-legged UpWind jacket from the OC4 project. These results of the preliminary study using the genetic algorithm demonstrate that automatic optimization of wind turbine support structures is feasible under consideration of a simplified load approach.

Chenyu Luan

Chenyu Luan's activities have been on design of the semisubmersible in Figure 1 as well on developing a modelling method floating wind turbines as multi-body, flexible structure to obtain internal forces in the structure. The method has so far been implemented in conjunction with Simo/Riflex, but can be used on other software with similar features as Simo/Riflex/Aerodyn.

Marit Kvittem

Fatigue and wear are important design criteria for offshore wind turbines due to the seveer cyclic loading. The analysis to determine the fatigue life involves simulating every probable wind and wave condition is a very computationally demanding. Establishing and documenting efficient time domain and linearized frequency domain analysis, have been addressed. A case study where fatigue life estimation for a semi-submersible wind turbine, inspired by the WindFloat concept, was performed.

The results of these analyses were promising with respect to reducing the analysis time for fatigue life estimation, but different platforms have different response characteristics, and thus the conclusions cannot be directly applied to other flowing wind turbine concepts. However, the trends that were observed (which were more thoroughly described in the papers) can be applied as qualitative guidelines.

Erin E. Bachynski

Marine structures with structural periods in the range of 1-5 seconds are known to be susceptible to "ringing" responses in severe seas: a transient response, analogous to the effect of wave slamming that can increase the extreme response. A methodology was established and applied to tension-leg wind turbines. The effect was particularly significant for hulls with larger diameters. An example of the response depending on the hydrodynamic forcing is shown in Figure 19. As shown, the response when second order and ringing forces is significantly increased compared to simulations with only first order wave forces. The maximum response is independent of the turbine operational condition (operating or idling), but the subsequent decay in the tower base bending moment and in the tendon tension depends on the aerodynamic damping.

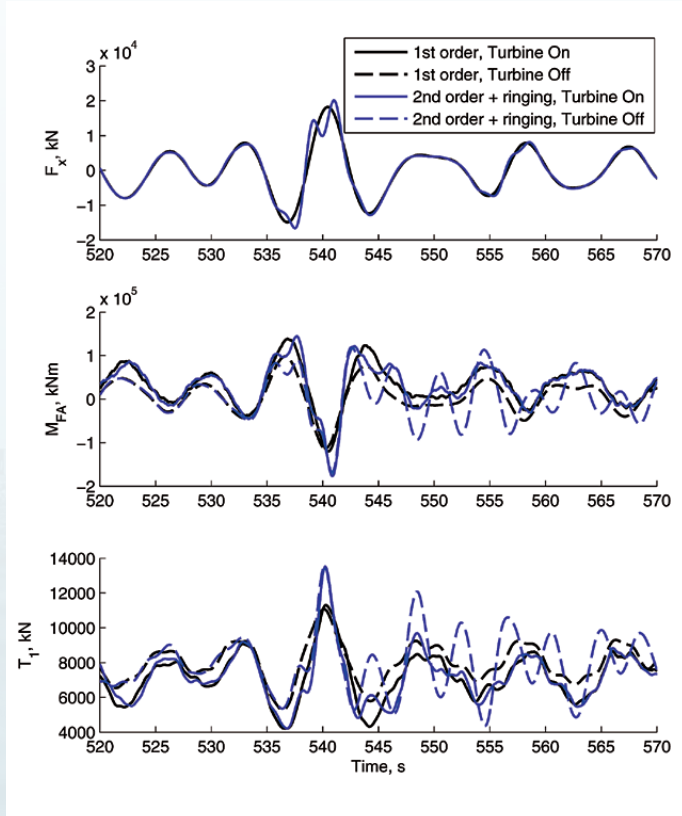


Figure 19: TLPWT responses to first order and higher order loads: Total horizontal wave force (top), tower base bending moment (middle) and downwind tendon tension (bottom). The responses with and without aerodynamic damping are shown.

GRID CONNECTION AND INTEGRATION

8.4

Harald G. Svendsen
WP4 leader

The objective of WP4 is to develop technical and market based solutions for cost effective grid connection and system integration of offshore wind farms.

The work is divided into three tasks:

4.1: Internal electrical infrastructure for offshore wind farms
4.2: Grid connection and control
4.3: Market integration and system operation

Summary of achievements 2013:

This work package has prepared a wealth of new results for improved grid integration solutions for offshore wind energy, with relevance ranging from large power system design and operation to the single wind turbine level.

- Continuing strong international cooperation through EERA (European Energy Research Alliance) on grid connection and offshore wind, and through Nordic and European project
- NTNU/SINTEF's 50 kVA scale laboratory facility with multiple power converters and a wind farm emulator has been established and successfully demonstrated for a case with multi-terminal HVDC offshore grid. The activity includes development of novel control systems for wind farms, including HVDC and enabling converters to operate as virtual synchronous machines for enhanced grid support in compliance with grid codes, see also Figure 35. The latter activity is supported through a newly started internal funded project by SINTEF Energy Research.

- DIPLAB (ETEST) has been procured and delivered to Trondheim with funding from the research infrastructure programme of RCN. DIPLAB is a mobile test laboratory for creating a controlled voltage-dip at the terminals of the generator under test, and by this the grid compliance of the generator can be tested. The grid code sets requirements to the ability of generators to ride-through certain voltage dips, though this influence wind turbine stability, structural loads and lifetime. A first test of DIPLAB is planned to be prepared at Valsneset test station for wind turbines (VIVA AS) by winter/spring 2014.

- New spin-off projects: IRP Wind (EU FP7), BestPaths (EU FP7), Offshore Pumped Storage (IPN) and Smart Grids lab extension (RCN infrastructure).

- Good collaboration with industry partners Statoil, Dong Energy, DNV GL, EDF, Statnett and Statkraft.

- Four PhD studies associated with WP4 (but financed by other sources) have been completed in 2013.

- 8 publications in peer-reviewed scientific journals and 11 publications in international conference proceedings.

Figure 20a: Scaled model of multiple-pole permanent magnet generator. Photo:synlig.no

Figure 20b: Atle Årdal and Atsede Endegnanew operating the lab set-up emulating a North-Sea sea wind farm connected via a multi-terminal HVDC grid. Photo:synlig.no

HIGHLIGHTS 2013

Laboratory demo of a multi-terminal HVDC grid connecting an offshore wind farm

The renewable energy laboratory, also called smart grids lab or wind lab, is owned and operated jointly by SINTEF Energy Research and NTNU. It has been gradually extended over many years and includes today multiple ac/dc converters, a wind power emulator, a load emulator, cable inductances and other equipment that makes it a very suitable scale laboratory for grid integration studies related to offshore wind. The general rating of machinery and converters is 50 kVA and 400 V AC. A milestone in the development of the laboratory was reached in 2013 with successful demonstration of an offshore wind farm connected to an offshore multi-terminal HVDC grid with dc voltage droop control.

The laboratory is an excellent research facility that is a big advantage for grid integration studies in NOWITECH and beyond. There are several reasons that laboratory experiments are important:

- Verification of simulation models
- Analysis of phenomena that cannot be simulated
- Allows tests that cannot be done in the field
- Allows tests of control systems or components in controlled environment
- Providing data for improved modelling or modelling of new components

The multi-terminal HVDC grid case implemented in the laboratory demonstration was a continuation of previous work on offshore grids and robust control concepts for such grids. These are topics that have been a main interest in NOWITECH over several years, and carried out in alignment with other projects, in particular ProOfGrids (RCN KPN) has contributed greatly to the realization of the laboratory. The laboratory demonstration showed that the present facility is indeed a good laboratory for such analyses. The results from the case study showed good agreement between numerical models and laboratory measurements, adding confidence in numerical models and methods.

The laboratory has existed for many years already, but this demonstration marks the beginning of a new phase with vastly increased capability for laboratory experiments relevant for grid connection of offshore wind power. The new grant from RCN to extend the laboratory with more research infrastructure and planned activities in the lab within the new EU FP7 project Best Paths to prepare scaled tests of new multilevel converters for connecting offshore wind farms, give promise of enhanced use of the lab and exiting developments for enabling grid connection of large and far offshore wind farms at reduced costs.

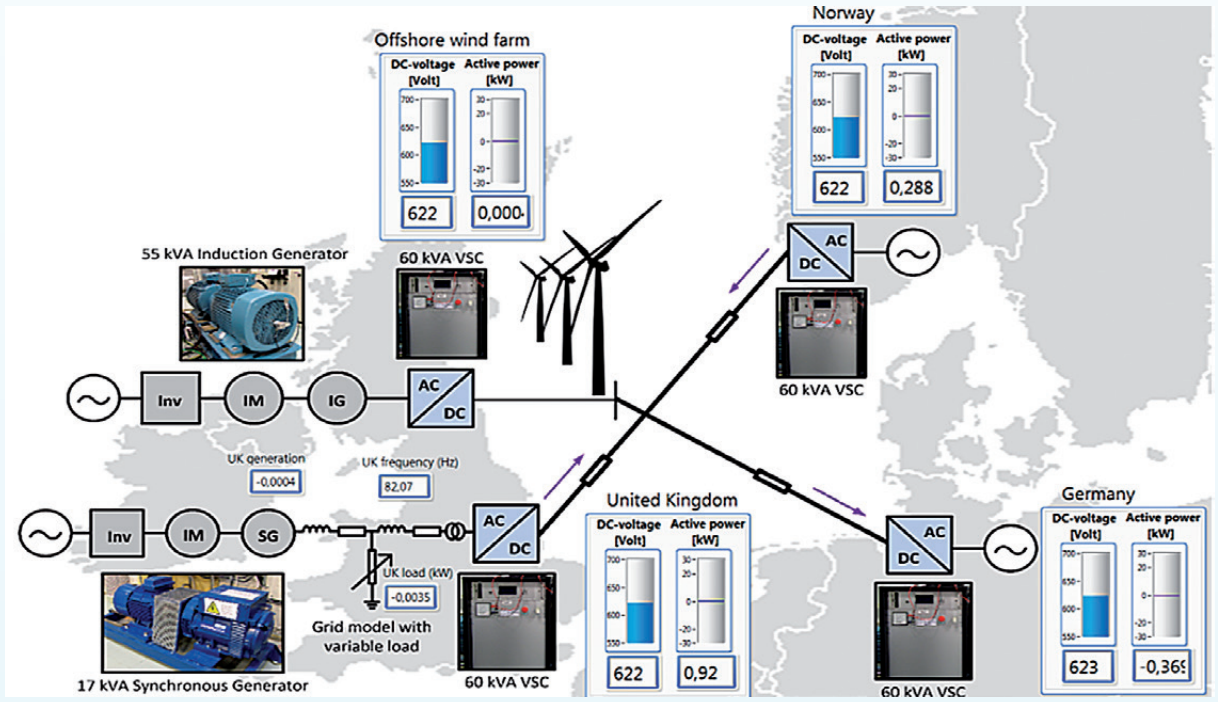


Figure 21: Laboratory setup emulating a North Sea wind farm connected via a multi-terminal HVDC grid to Norway, Germany and the UK.

Industry benefits and cooperation

The industrial benefit of this work package is the development of technical concepts and solutions for the internal electrical design and grid connection of offshore wind farms, and strategies and solutions for power system integration of large amounts of wind power.

Industry partners involved: Statoil, Dong Energy, DNV GL, EDF, Statnett, Statkraft

Result	TRL Level	Impact
Power System Simulation Tool (PSST), software simulation tool	3	The tool optimizes generation dispatch for large power systems, taking into account power flow constraints, variability in renewable energy, demand, and hydro storage dynamics. It can be used with future scenarios to study cost of energy, nodal prices, grid bottlenecks, benefit of grid reinforcements etc.
Net-Op, software simulation tool	3	The tool uses a mixed integer linear programming method to optimise 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
Viper, software engineering tool	(2)	This engineering tool can be used to estimate energy production for an offshore wind farm. It can be used together with electrical models in order to optimise offshore wind farm layout.
50 kVA scale laboratory facility 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
New knowledge about 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.

**The TRL in () is indicative only and estimated without any formal assessment. The other is formally assessed.*

Academic achievements

All three PhD students financed by NOWITECH under WP4 have started. One student has finished his work and expecting to defend his thesis in 2014. The Postdoc period of Steve Völler has ended, and he is continuing offshore wind related research at SINTEF Energy Research. Among the associated PhDs at NTNU four have completed in 2013 and four more are expected to complete in the course of 2014.

In 2013 eight publications in peer-reviewed scientific journals and 11 publications in international conference proceedings have been prepared.

Strong international cooperation has been achieved through participation in the following fora: EERA, 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"; several European research projects, such as EERA-DTOC, DeepWind, Twenties, Marinet, and EuroSunMed; and Nordic research project OffshoreDC.

OPERATION AND MAINTENANCE

8.5

Thomas Welte
Leader WP5

The objective is to develop a scientific foundation for the implementation of cost-effective O&M concepts and strategies for offshore wind farms, taking into account the whole life cycle of the equipment.

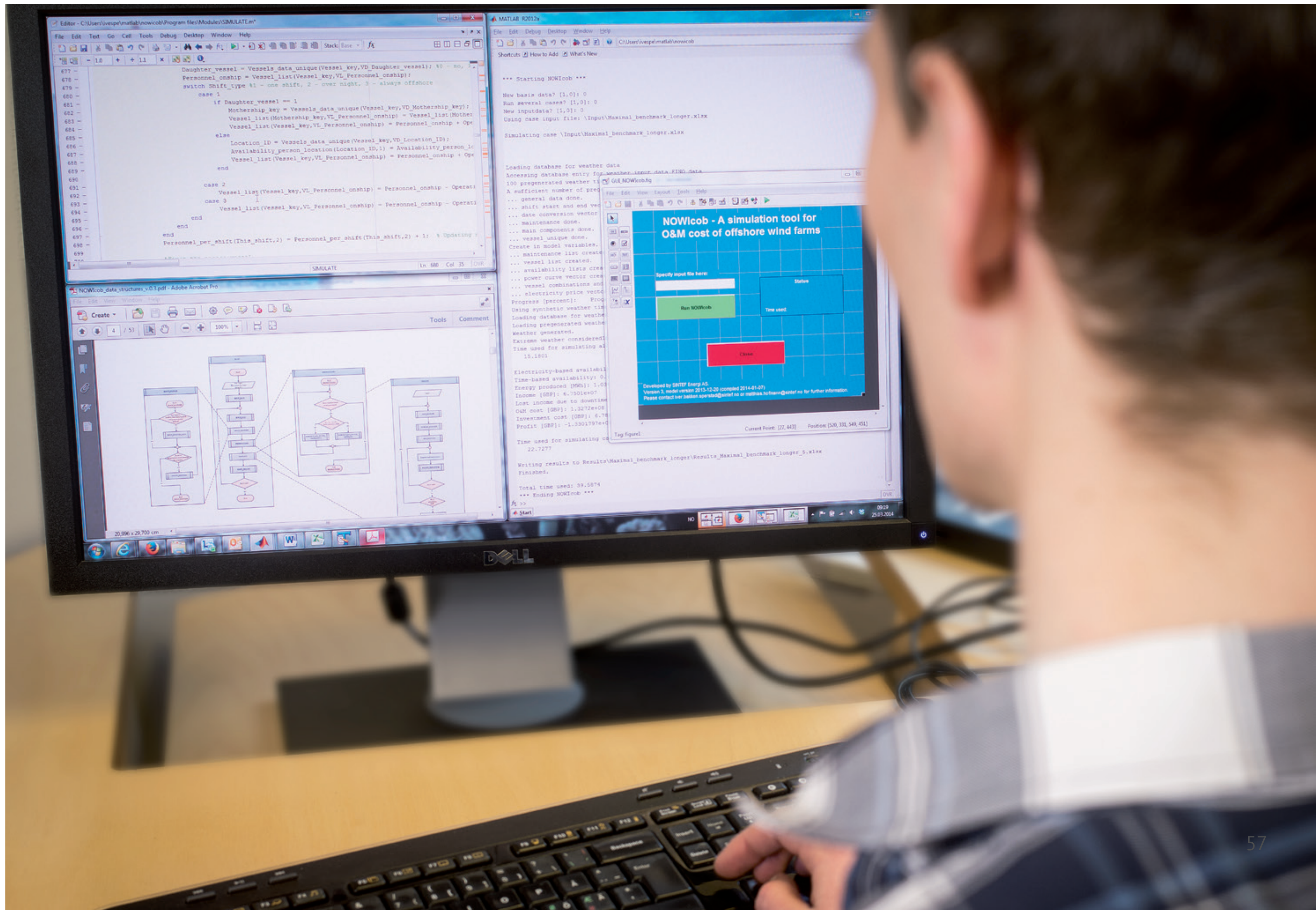
The work is divided into three tasks:

5.1 Maintenance strategies
5.2 Surveillance and condition monitoring
5.3 Access and logistics techniques

Summary of achievements 2013

- The thermally sprayed Silicon Carbide coating has been successfully developed. A patent was granted November 2013 and a industrial development process has been started with three projects funded by FORNY, NTNU Discovery and BRIA. This work is in collaboration with NTNU TTO.
- The third and final version of the NOWIcob life-cycle profit software for offshore wind farms has been developed (in cooperation with the FAROFF project), see Figure 22. A thorough analysis of possibilities to commercialize NOWIcobl has been conducted. As a result of this analysis, a software licence agreement has been prepared.
- The first version of a model and software for routing and scheduling of maintenance fleet for off-shore wind farms has been developed.
- The Remote Presence activity, see Figure 25, will be continued in the new EU FP7 project "Lean-Wind" with Norsk Automatisering supplying a prototype for real-life testing. The NOWITECH partners SINTEF Energy Research, MARINTEK and Kongsberg Maritime participates in LeanWind addressing various aspects related to installation and operation of offshore turbines, and will be carried out in alignment with NOWITECH.
- The milestone "Framework for evaluation of access technology and logistics support" has been reached, and a report with the same title describes the R&D results related to this milestone.

Figure 22: Development of the software NOWICOB – a Software Tool for Estimating operation and maintenance cost of an offshore wind farm. Photo: synlig.no



HIGHLIGHTS 2013

A puzzle solved

Silicon carbide can be sprayed as a coating on machine parts

No one has ever been able to process silicon carbide in such a way that it can be thermally sprayed as a coating on machine parts. That was before NOWITECH PhD student Fahmi Mubarok began his doctoral research.

"You could almost call this alchemy," says Christian Gutvik, project manager at NTNU Technology Transfer (TTO), while we walk a long corridor in search of Fahmi's office. "He has cracked the code that makes it possible to convert the raw material, silicon carbide (SiC), into a material, a coating that can be thermally sprayed onto large machine parts."

Manufacturers that make jet engines and all kinds of turbines – from gas to wind to water – are always on the hunt for technological advantages that can increase performance and improve efficiency. Downtime for repairs and maintenance costs need to be low. The industry has small profit margins and to some extent, manufacturers are all competing for the best equipment. One important aspect is reducing wear in large machines, which is generally done by using extremely hard, wear-resistant ceramic coatings. The coatings make it possible for machines to be less susceptible to corrosion, more durable and withstand higher temperatures.

The best raw material

Silicon carbide is considered to be a miracle material when it comes to ceramic coating because of its unique properties. It is extremely hard, but has low density, which translates into lighter parts, and its characteristics make for very low friction. This combination results in higher performance at reduced cost and with less maintenance time. But, until now, it has been impossible to use SiC as a thermal spray coating, even though everyone would like to. The problem is that the high temperatures generated during thermal spraying transform SiC from a solid to gas. That prevents the material from being used. And that is where Fahmi's story begins.

He has developed a method that protects each SiC particle so that it does not become a gas while it is being thermally sprayed. The technique makes it possible to apply many layers of SiC as a coating on large machine parts. "Many people have tried to achieve this breakthrough," says Christian Gutvik. "Everyone knows this material has potential, many have tried to achieve that potential, but no one has succeeded, so this is ground-breaking." Fahmi has now demonstrated that the patented technology works. From a conceptual standpoint, this is astonishing news.

Finding the solution through play

We have come to the laboratory where Fahmi has spent much of his time in recent years. It is in asmall corner of a large hangar, where many other projects are underway. "The method has actually tried before, but no one has succeeded," says Fahmi. "I spent two years 'playing' with the same ingredients to find the optimal method for making the powder so that it can be applied with a thermal spray gun. It was also important to reduce the time it took. When I started, the process took three days." He can still remember the day in January 2011 when he and his colleagues first produced a good coating. "We realized then that we had a way of making SiC thermal sprayable,"

he says, grinning broadly. Included in the "we" is his mentor, Nuria Espallargas.

Challenges abound

What made Fahmi's breakthrough possible is a chemical process that gives the raw material the characteristics it needs so it can be thermal sprayed. "We're now confident in the overall process. We will probably do some more fine-tuning, but we have other questions to address. One challenge that cropped up during development is the issue of the fineness of the powder. We want to have powder that is as fine as possible, so that it flows like sand in an hourglass."

Fahmi found the solution to that challenge in his own kitchen. "I looked at kitchen ingredients, such as cocoa powder and salt. While salt flows smoothly, cocoa powder is lumpy and uneven. I realized that the secret lies in the structure of each grain". Fahmi solved this problem, and shows us the powder - which flows evenly between his fingers.

Verified in many ways

Finding optimal parameters for both the powder and the thermal spray process are among the critical jobs that remain. The main key parameter is hardness, where the goal is to achieve a hardness that is equal to or better than tungsten carbide. "It's hard to find a clearer verification case than this," says Gutvik. "The research is done; Fahmi and Nuria have demonstrated that their patented process prevents SiC from decomposing during thermal spraying. Now the industry is waiting for further verification, which is where the project stands now." The researchers received a total of NOK 1 million from NTNU Discovery to further develop the promising results they have achieved in the NOWITECH project. Last spring, they were awarded NOK 100 000 in pilot project funds to conduct thermal spray tests to ensure that the results can truly be used in thermal spraying.

Figure 23 PhD student Fahmi Mubarok (top) has together with his mentor Professor Nuria Espallargas (bottom) cracked the code that makes it possible to convert SiC into a material, a coating, that can be thermally sprayed onto large machine parts. Photos by Erik Børseth and NTNU.

"But there is still a gap between us and the industry. Everyone we have been in contact with, whether exit candidates, partners or customers, wants proof that this works and that we are able to provide the market with the properties that people want. We can do that now with the help of the main project funds. We have long lists of questions from potential customers that we will try to answer after we have completed testing and verification."

Secure future

NTNU Discovery have granted 1 mill NOK for verification, and the Norwegian Research counsil has recognised the project by granting 2.9 mill NOK in project funding from the FORNY programme. This is quite a substantial grant, and the gang is very enthusiastic about having a secure future. They already have interest from major industrial partners as well as established players and customers. But what they want first and foremost are pilot customers who are willing to be involved in testing the product. The market is well established with products that already exist.

"Our plans are to establish a company in 2014 and recruit some pilot customers, so that we can show good results by the end of 2015. Then we'll see where things go from there," says Christian Gutvik. Fahmi Mubarok is mainly interested in finishing his doctorate on the topic, and wants to pursue the product further. "But I won't be the one who runs the business," he says with a smile.

Industry benefits and cooperation

WP5 addresses O&M challenges in the development of deep water offshore wind power. WP5 contributes with new solutions regarding O&M strategies, access and logistics, condition monitoring, remote operations, increased reliability of wind turbine components. The overall goal is to reduce costs, and at the same time fulfilling HSE requirements. Results are listed in the table below. These results will contribute to a reduction of maintenance actions needed, to reduced costs per maintenance operation, and to reduced production losses, as illustrated in Figure 24.
The following industry partners have been involved in the work: EDF R&D, Fedem Technology AS, Kongsberg Maritime AS, Statkraft Development AS, Statoil Petroleum AS.

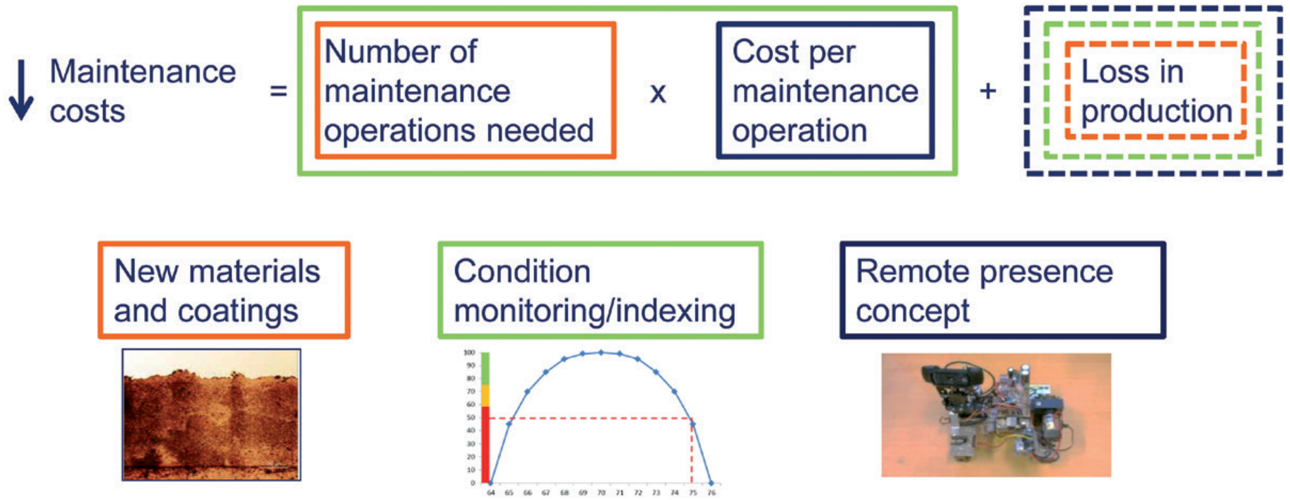


Figure 24: Different cost influencing aspects that NOWITECH WP5 addresses

Result	TRL Level	Impact
NOWIcob tool – A life-cycle profit software for offshore wind farms.	3	NOWIcob can be used as 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.
Fleet optimization tool – An optimization model for making decisions about optimal vessel fleet to support the maintenance operations.	3	Decision support tool for offshore wind farm operators. The model will give output results with regarding (i) location of maintenance bases (onshore/offshore) and (ii) the vessel fleet size and mix i.e. which vessels/ helicopters to invest in and/or charter.
Technology concept formulated for novel drop erosion resistant coatings (for leading edge of blades). Based on this concept, new coatings are currently developed, and the coatings and their properties are tested in the lab.	2	The maintenance of the leading edge of blades is expensive, thus a better drop erosion protective coating will increase useful life and reduce O&M costs.
A remotely controlled robot intended to be installed on a rail inside wind turbine nacelles is developed and tested in lab scale. Further development, including real life testing is planned as part of the new EU (spin-off) project LeanWind.	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.
A thermally sprayed silicon carbide coating (for bearing and gear systems) is successfully developed and tested in lab. The process is patented and in progress for industry implementation (see separate story on WP5 highlight).	3	The coating is mainly intended to increase wear resistance in large main bearings of offshore wind turbines, it can also be applied in outer bearings race way to reduce fretting. The goal is to increase the bearing lifetime, and thus reduce O&M costs.

Academic achievements

All four PhD students financed by NOWITECH WP5 have started. One student has submitted his PhD thesis in December 2013 and will defend his work in March 2014. Two other students are expected to finish their theses in 2014. Among the three associated PhD candidates at NTNU, one will not finish his thesis and one candidate has submitted the thesis for defence in March 2014.

In 2013 there have been 9 publications in journals or peer-reviewed conference proceedings. In addition, 2 papers are accepted and 4 are submitted. 1 book chapter has been submitted. Furthermore, 25 reports that document the WP results have been finalized.

There is ongoing collaboration with European research institutes and with international research projects/tasks in several projects:

- EU FP7-ENERGY-2010:
  - LEANWIND (O&M activities)
  - HiPRwind (O&M activities)
- IEA Wind Research Tasks
  - IEA Wind Task 26 on Cost of Wind Energy
  - IEA Wind Task 33 on Reliability Data
- Participation in "Offshore wind O&M modelling group" together with MARINTEK, the University of Strathclyde, the University of Stavanger, NTNU and EDF
- Participation in Nordic wind power O&M network, so far together with Chalmers Univ. of Technology, KTH technical university Stockholm, VTT, DTU, Elforsk and Energi Norge

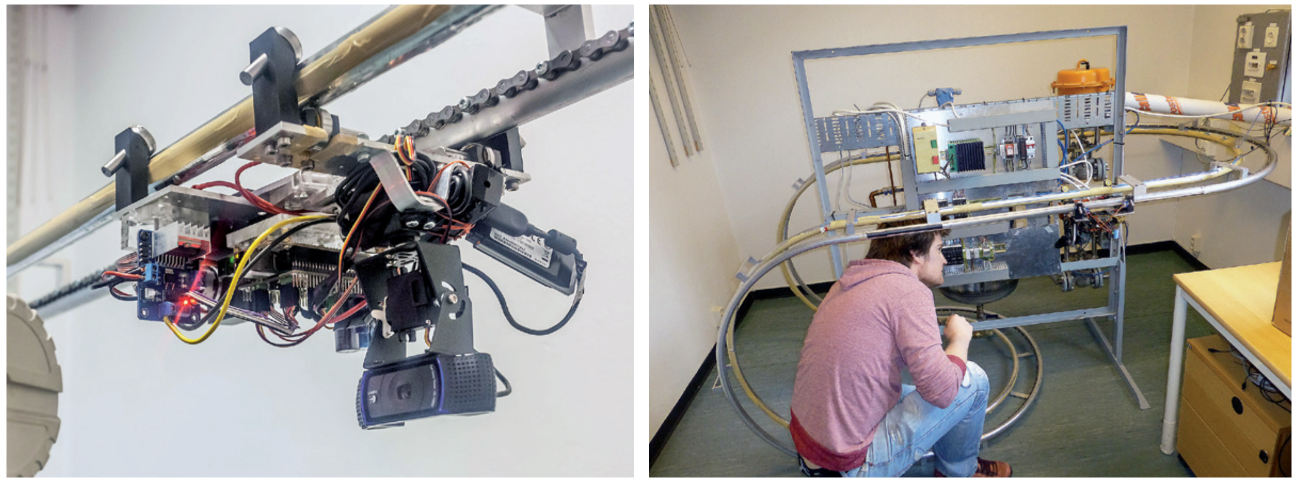


Figure 25: Remote Presence simplified prototype robot (left) in laboratory testing (right).

ASSESSMENT OF ALTERNATIVE DESIGN CONCEPTS

8.6

Ole David Økland, WP6 leader

The objective is to develop and assess novel concepts of deep-sea wind turbines, hereunder developing control systems and combining results from WP1 to WP5. Assessment is by numerical tools and physical experiments in labs and full scale field tests.

The work is divided into three tasks:

6.1 Development of advanced control system
6.2 Assessment of alternative and novel design concepts
6.3 Experiments and demonstration

Summary of achievements 2013

In 2013 there has been good progress in all three tasks in the work package. Results from a number of numerical studies for qualification of novel concepts, including control strategy and behaviour during failure and shutdown, have been published. Model scale experiments have been conducted and reported both for hydrodynamic and aerodynamic loads.

- Research partners have presented results from studies on novel concepts in various conferences and in journals during 2013, i.e.:
    - 10th Deep Sea Offshore Wind R&D Conference, Trondheim, Jan 2013
    - OMAE2013, July
    - 9th PhD Seminar on Wind Energy in Europe, Uppsala University Campus, September 18-20, 2013.
    - EWEA Offshore, Frankfurt, Nov 2013
    - J. Renewable Sustainable Energy
    - WIRE Energy and Environment
    - Journal of Wind Energy
- EU MARINET Wave tank testing of Tension-Leg-Buoy (TLB) offshore wind power platforms has been planned, carried out and reported, see Figure 26.
- An airfoil designed for large scale downwind turbines for offshore application has been tested experimentally and data from these tests have been used to verify the results from calculations.
- FLEXWT infrastructure project has been kicked off in March, 2013
- Strategies for hybrid testing of offshore wind turbines have been an important part of the work in the WP this year. Initial experiments to apply the strategies have been performed and published.
- Results from previous studied on challenges related to scaled tests with combined wind and wave actions have been summarized and reported. Planning and preparation of the milestone test for a floating offshore wind turbine at intermediate water depths in the Marintek Ocean basin in 2014 has been kicked off, and concept for testing has been selected in cooperation with WP3.

HIGHLIGHTS 2013

Real Time Hybrid Model Testing (RTHMT)

Data from scaled model tests where the environmental conditions can be controlled is a key in validation of numerical models for design of novel structures. Traditionally wind force on structures has been tested in wind tunnel tests and wave forces on floating structures in a wave basin. For a floating offshore wind turbine however, the forces from wind and waves interacts and are also influenced by the control system of the turbine. Due to different scaling laws for wind and wave force, a test where these loads are combined and accounted for in a physically correct way is very challenging. A setup where some effects are represented by a scaled physical model, and other effects are represented by numerical models and applied to the physical model by force actuators, is a possible solution. Valentin Chabaud, one of the PhD candidates in WP6, has Real-time hybrid testing of floating wind turbines as the research topic of his thesis. He has tested some simplified models and published his first paper on this topic at OMAE 2013. During 2013 Real Time Hybrid Model Testing has also been selected as the preferred strategy for the NOWITECH milestone test of a floater for intermediate water depths. This test is scheduled for testing in the Marintek Ocean basin in 2014. In RTHMT all of the three tasks in WP6 are combined to provide a good tool for validation of numerical design tools used in assessments of novel floater concepts. A successful model test, where the important physical effects of a floating offshore wind turbine can be captured in a physically correct way, would mean a significant step forward with respect to validation of design tools and assessment of novel concepts for floating offshore wind turbines.

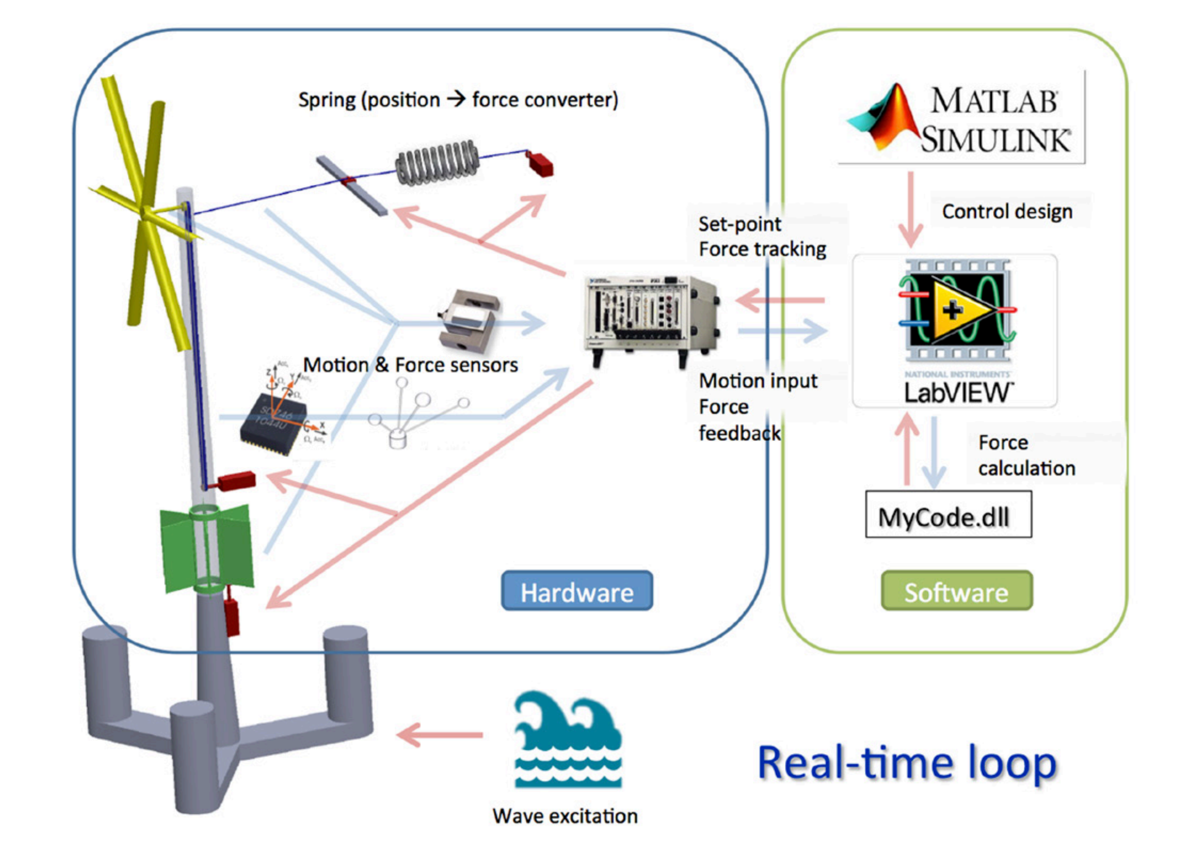


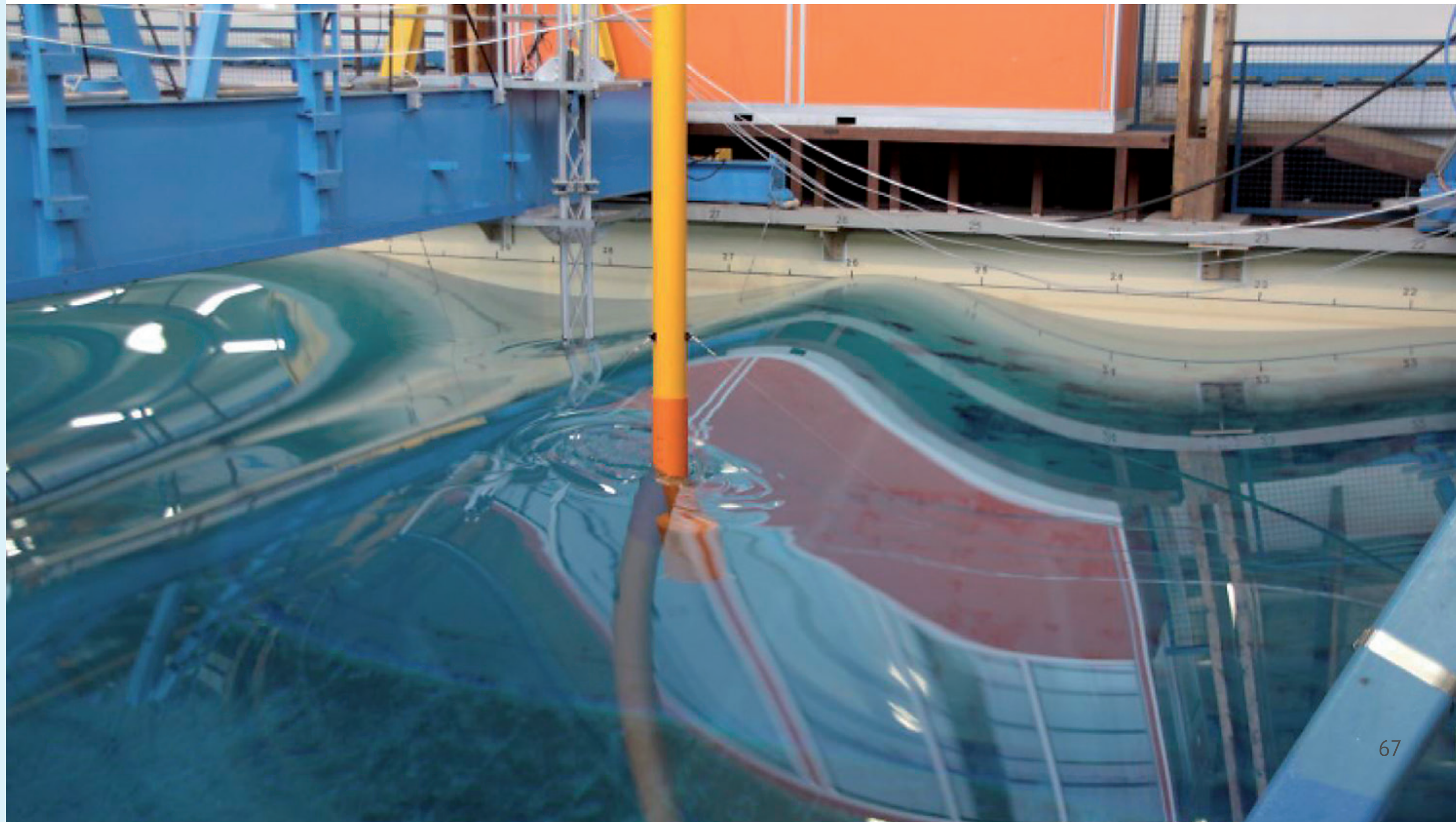
Figure 26: Illustration of RTHMT concept investigated in WP6.

Industry benefits and cooperation

New improved concepts and technologies for offshore wind turbines should be developed by combining wind and offshore oil and gas experience. Robust and reliable technology is of paramount importance in order to keep repair and maintenance costs down. Conceptual design studies, exploring the interaction between the energy conversion, support structure and control system, should be carried out in order to minimize life cycle costs. Therefore, proper tools for these integrated design studies must be developed (WP1) and validated with experiments. Further, applying smart control systems for load mitigation and structural stabilization is also a key for cost reduction.

Result	TRL Level	Impact
Advanced strategies for control of floating offshore wind turbines. Results are reported and control algorithms are implemented in Matlab.	2	Smart control systems for load mitigation and structural stabilization are important for optimal production of power and cost reduction.
Simo-Riflex-DMS simulation tool	3	Computer software for design analysis of floating offshore wind turbines.
Experimental techniques for offshore wind turbines.	2	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.

Figure 27: An experimental study of Tension-Leg-Buoy floaters for offshore wind turbines has been conducted by IFE at IFREMER's wave tank in Brest, France in January 2013 through the EU-funded MARINET initiative.



Academic achievements

All 4 PhD candidates in the WP have completed the course requirements. PhD candidate Tania Bracchi finished her research in 2013 and will defend her thesis early spring 2014. Morten Pedersen is also in the phase of finishing his work. He will be involved in lecturing at NTNU in 2014 and plan to submit his thesis early 2015.

There have been 14 publications from WP6 in 2014: 6 journal/peer review papers, 3 conference publications and 5 reports. The WP has been involved in meetings in the EERA-network, participated in EU-projects under FP7 and spin of projects on relevant topics within the H2020 call has been initiated. The WP has been involved in activities for verification of software tool within the OC4 program lead by NREL, and contributions to the new OC5 program have been planned.

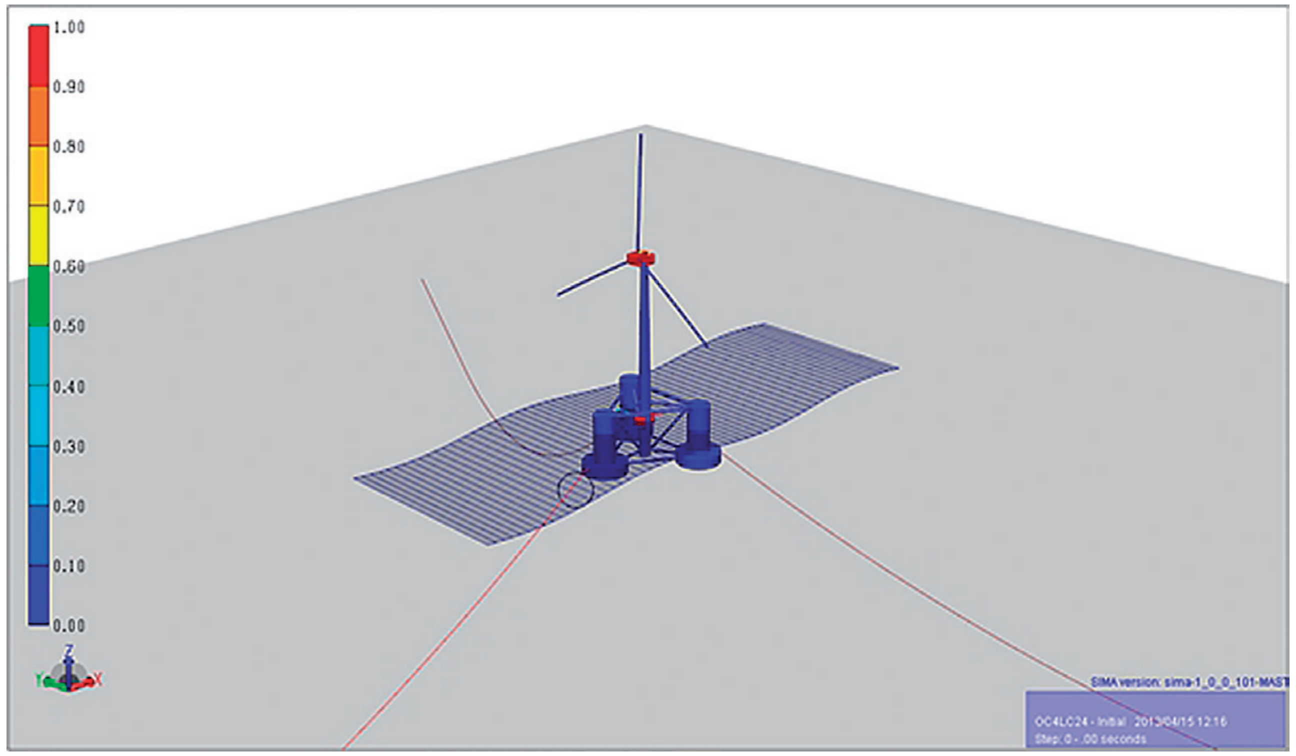


Figure 28 Simo-Riflex model of OC4 semi.

NOWITECH 10 MW REFERENCE TURBINE AND 1200 MW REFERENCE WIND FARM

8.7

Karl Merz,
Head NRT/NRW

NOWITECH has designed a 10 MW offshore wind turbine, and a 1200 MW reference wind farm, as a collaborative effort.

NOWITECH Reference Turbine (NRT)

It is called the NOWITECH Reference Turbine (NRT), Version 0, or NRT0 for short. The NRT0 is the "reference" turbine because its design has been based upon the best-possible application of existing technology;

NRT0 serves as a reference case for further development, such as:

- Obtaining mechanical and electrical design loads for dimensioning of novel components;
- Parameter sensitivity studies and system cost modelling – for example, the influence of the rotor diameter on the cost of energy; and,
- Comparative studies of different topologies, like an upwind versus downwind rotor, a direct versus geared drivetrain, or an AC versus DC wind farm grid.

The NRT0 differs from other existing reference wind turbines in two important ways. First, the relative size of the NRT0 rotor is smaller with respect to the generator rating. In other words, the ratio of the rated power Pr to swept area A is high: 640 W/m2, in comparison with 407 W/m2 for the Light Rotor (and NREL 5 MW rotor) and 420 W/m2 for the Sandia rotor. Comparing with commercial designs, the NRT0 is comparable to the Enercon E-126 7.58 MW (598 W/m2), with the Vestas V164 8 MW (379 W/m2) at the other end of the spectrum. The high Pr/A ratio was chosen with a thought towards eventual deepwater (including floating) applications in high-wind climates. It is also planned to develop a variant with a larger rotor, such that Pr/A is near the low end of the range, for cases where interaction with the electrical grid is the dominant cost driver.

The other way in which the NRT0 differs from other reference designs is that its system description includes the electrical components. This provides a baseline that has so far been lacking in the literature.

The design of the NRT0 was initiated in 2011 with a series of workshops, in which technical experts from across NOWITECH brainstormed, discussed, and decided how the turbine should be configured. The workshops culminated in a specification document [1]. Components have been designed based on these specifications. The detailed design has largely been conducted by MSc and PhD students at NTNU.

The rotor/nacelle assembly, not including the blades, is shown in Figure 29. The drivetrain is direct-drive, with the generator and rotor on the same side of the tower. The nacelle structure – what would be the bedplate on a traditional wind turbine design – consists of two parts: a turret mounted atop the yaw bearing, and a cylindrical nose, bolted to the turret. The generator stator is mounted on the nose. The generator design is somewhat atypical, in that the rotor is external to the stator. The rotor housing is bolted at one side to the end of the main shaft, where it reacts to the torque from the aerodynamic rotor. At the other side, the rotor housing is supported by a bearing mounted on the nose, inboard of the stator. The main shaft is then mounted inside the nose, supported by two bearings.

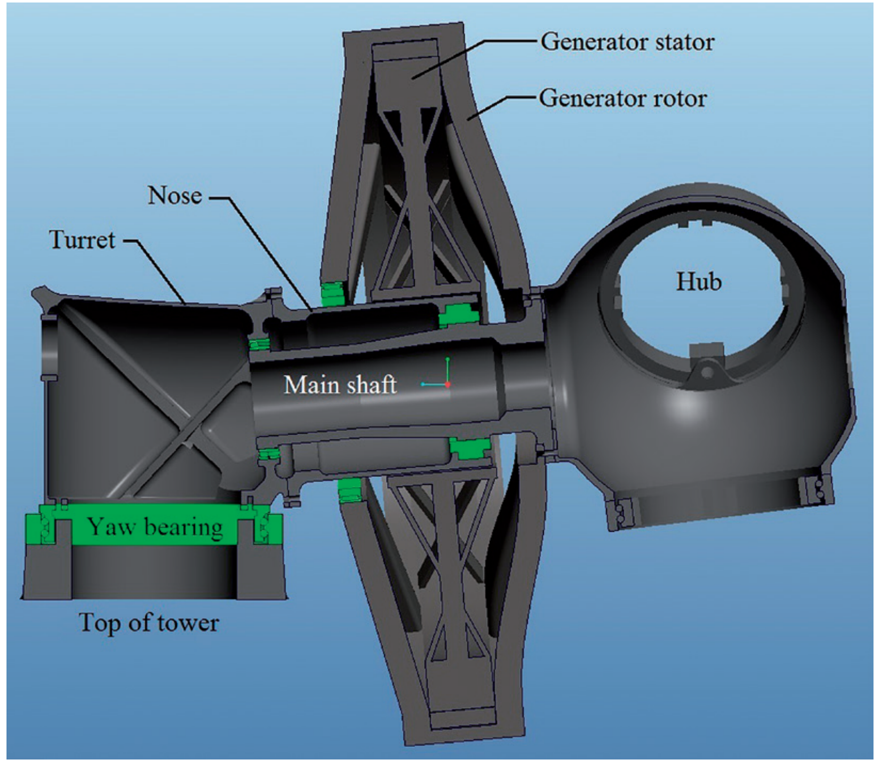


Figure 29: A cutaway view of the nacelle, main shaft, hub, and generator

Figure 30 lists some global specifications of the NRT0. The rated power of 10 MW is reached, under ideal, uniform wind conditions, at the rated wind speed of 13.25 m/s, with a rotational speed of 12.2 rpm (1.28 rad/s). The hub height of 93.5 m leaves 23 m of clearance between the blade tips and the undisturbed sea level, which is sufficient for a maximum wave height (trough to crest) of 30 m. The Dutch weather forecast station K13-Alpha in the North Sea has been selected as the reference site.

The rotor-nacelle assembly is supported by a full-height lattice tower. Muskulus [2] discusses the reasons for selecting a full-height lattice tower, as opposed to a monopile or a hybrid cylinder/lattice tower.

Publications in 2013 include MS theses by D'Arco [3] and Singh Klair [4].

Rated electrical power	10 MW
Rated windspeed	13.25 m/s
Design tip speed ratio	7.3
Maximum tip speed	90 m/s
Rotational speed range	5.0-12.2 rpm
Rotor diameter	141 m
Blade cone angle	2°
Main shaft tilt angle	5°
Hub height	93.5 m
Upwind rotor	
Direct-drive PM generator	
Medium-voltage AC wind farm grid	
Collective blade pitch control	
IEC 61400-3 design class	IC
Full-height lattice tower	
Water depth	60 m
Maximum wave height	30 m
Reference wind and wave site	K13-Alpha

Figure 30: Specifications for the NOWITECH 10 MW Reference Turbine

[1] Dahlhaug OG, et al.; "Specification of the NOWITECH 10 MW Reference Wind Turbine"; NOWITECH Report, January 2012

[2] Muskulus M; "The full-height lattice tower concept"; Energy Procedia 24 (2012) 371-377

[3] D'Arco LM; Modeling and Analysis of the Displacements for the Main Shaft of a 10 MW Offshore Wind Turbine in the Most Severe Operating Conditions; MS Thesis, Department of Mechanical Engineering, University of Naples, Italy, 2013.

[4] Singh Klair S; Design of Nacelle and Rotor Hub for NOWITECH 10 MW Reference Turbine; MS Thesis, Department of Mechanical Engineering, NTNU, 2013.

NOWITECH reference wind farm (NRW)

Work on defining a NOWITECH reference wind farm (NRW) was started in 2013. The governing idea is as for the NOWITECH reference wind turbine, i.e. to serve as a reference case for research and benchmarking. NRW is a 1200 MW offshore wind farm similar to a UK round 3 wind farm located far offshore. The turbine used in the wind farm is the DTU Light rotor, with the electrical system of the NOWITECH reference turbine (NRT). The wind farm location and environmental data is taken from Dogger Bank, more specifically the planned Creyke Beck A wind farm. Studies have been performed to determine the turbine placement in the wind farm and to define the electrical system including voltage levels, collector grid lay out and configuration, substation rating and placement, transmission system, and converter station configuration.

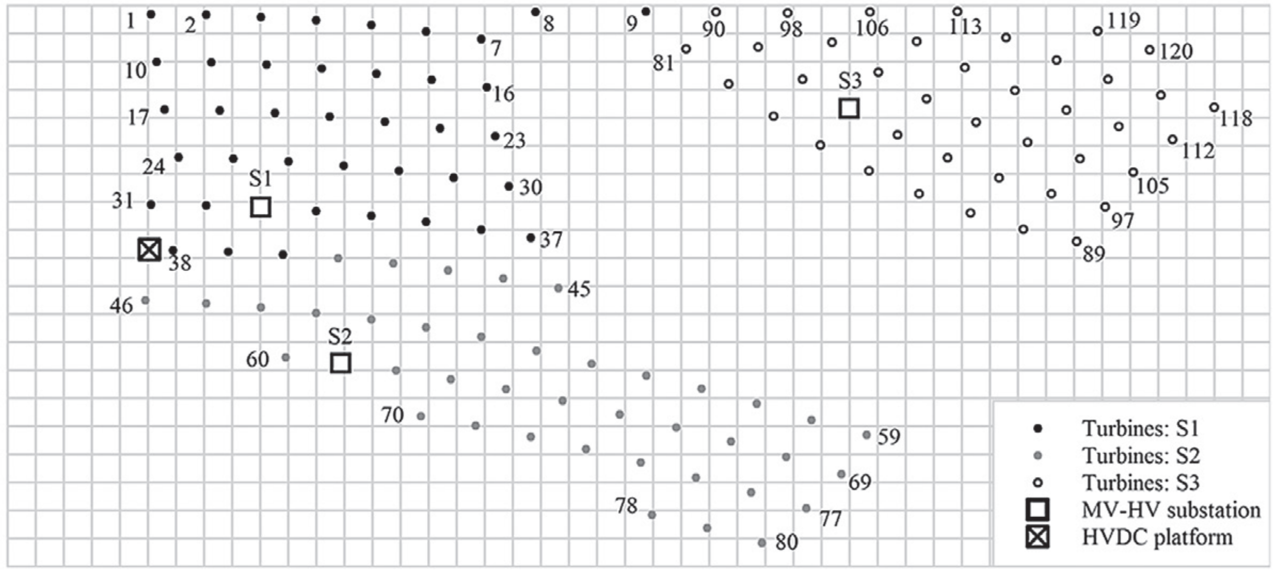


Figure 31: Layout of the NOWITECH 1200 MW Reference Wind Farm

Based on bathymetry and wake losses, a first layout of the NRW is suggested as shown in Figure 31. The total area is 515 km2, but some parts of this area have been avoided due to larger water depths, a cable that goes through the area, and two old oil production wells. The design has a turbine distance of approximately 10 D, where the rotor diameter D = 178 m. There are three clusters of wind turbines, each with a transformer substation (S1, S2, and S3) that connects to the HVDC platform in the western part of the wind farm. The design work is ongoing and further details including suggestions for wind farm control is expected to be published during 2014. Cooperation with NORCOWE and others are anticipated.

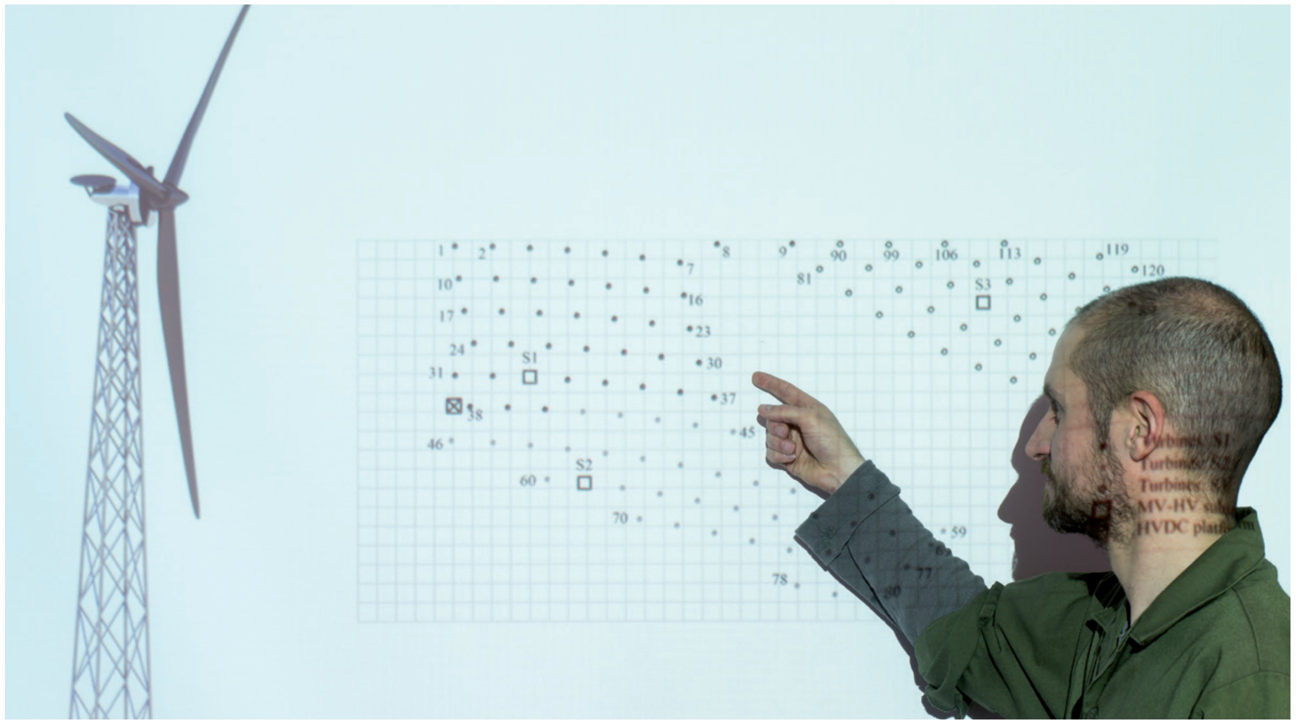


Figure 32: Karl Merz explaining calculation parameters for the reference wind farm. Photo: Erik Børseth

8.8 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 section 9.

An application to develop the SmartGrid lab was granted by RCN by the end of 2013. Thanks to this, a very significant upgrade of the lab will take place during the next few years 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, ref WP 4 highlight story in section 8.4.

Further infrastructure are being developed with funding from RCN, namely DIPLAB (8 MVA short-circuit emulator, named ETEST in the application) for NOWITECH and NOWERI (offshore met-ocean measurement station and floating 225 kW research turbine) jointly between NOWITECH and NORCOWE.

DIPLAB[3] 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 is planned to be prepared at Valsneset test station for wind turbines (VIVA AS) by winter/spring 2014. The aim of the test is to get aquatinted with the equipment, but also to gain knowledge about the response of wind turbines subject to voltage dips. Both electrical and mechanical loads will be measured during the test, and may provide a basis for validating numerical simulation models.

NOWERI is still in preparation. NTNU is the contract partner with RCN for the floating test turbine and UiB for the met-ocean measurements, but with a joint consortium agreement including also IFE, SINTEF and CMR. The plan is to have the floating research turbine installed off the coast of Mid-Norway, originally indicated within 2014, but unfortunately some delay is expected.

An EU infrastructure project was also started in 2013 with participation from NOWITECH. This is WindScanner.eu being 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.
The research infrastructures are developed with separate contracts external to NOWITECH, but prepared in alignment with NOWITECH.

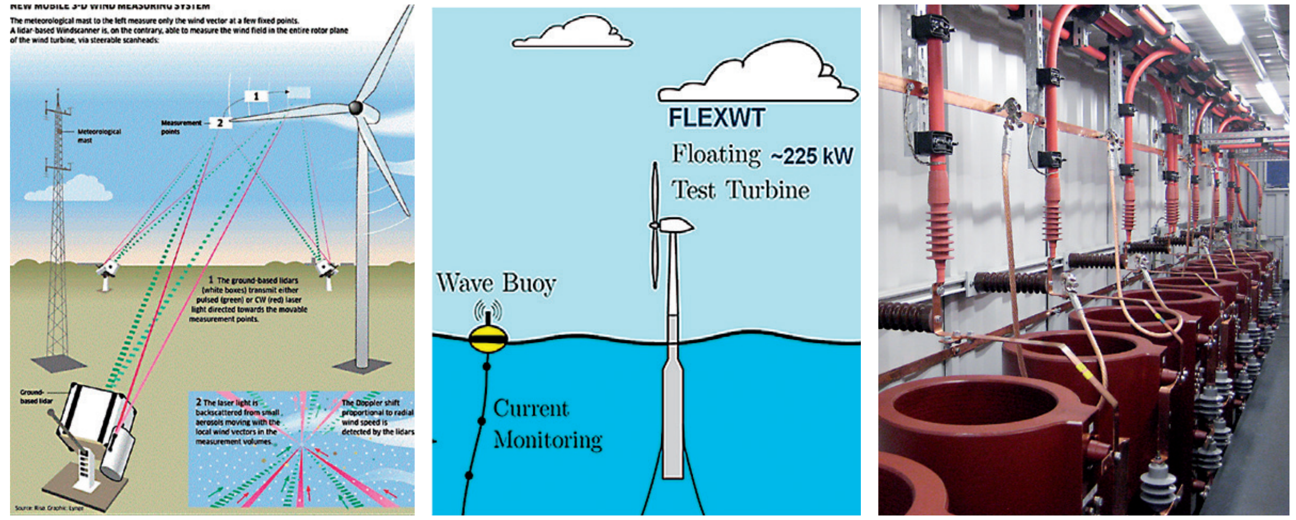


Figure 33 Research infrastructure in preparation, from left: WindScanner.eu, NOWERI floating test turbine and DIPLAB.

Figure 34: The first DIPLAB test will be prepared during winter/spring 2014 at Valsneset test station for wind turbines. Photo: synlig.no . Insert: An enthusiastic scientific staff from SINTEF Energy Research and NTNU in front of the mobile test lab, now DIPLAB. The lead for procurement and operation of the lab, research scientist Helge Seljeseth is number one from left. Photos by Helge Seljeseth / SINTEF.

8.9 SPIN-OFF PROJECTS

The NOWITECH research partners are attractive: A total of five Research Council of Norway projects were started in 2013 with participation of one or more of the research partners in NOWITECH. Since start-up the count is 55 new projects with an accumulated budget of over 1 Billion NOK. The projects are with EU (22) or Nordic funding, or by the Research Council of Norway (RCN) divided into competence building projects (KPN, KMB etc. 24), industry driven (IPN, BIP 9). Research infrastructure counts 3 projects from these. A selection of the projects is listed in Table 1. A number of bilateral projects directly for industry come in addition. The projects are with separate contracts external to NOWITECH, but carried out in alignment with NOWITECH.

Table 1 Selection of projects (granted, started, on-going or finished in 2013) with participation of one or more of the research partners in NOWITECH.

Project title	Type	Partners	Status
Best Path	EU FP7	Red Electrica , Iberdrola, SINTEF Energy	Granted
IRPWIND	EU FP7	DTU, SINTEF Energy, MARINTEK, NTNU, Fh IWES +	Granted
Wind farm Energy storage	Industrial	SINTEF Energy, Iberdrola, Gamesa	Granted
SmartGrids lab	RCN infra-structure	NTNU, SINTEF Energy Research	Granted
Kon-Wake	IPN	Kongsberg, SINTEF MK	Started
WiWind	IPN	Kongsberg, SINTEF IKT	Started
Offshore Energy Storage system	IPN	Sub Hydro SINTEF Energy	Started
Nettintegrasjon	NFR	Sogn og Fjordane Energi, SINTEF Energy	Started

Project title	Type	Partners	Status
DIMSELO	regional RCN KPN	IFE, DTU, STATOIL, STATKRAFT, NTNU	Started
TP WIND	NFR	SINTEF Energy	On-going
EERA JPWIND	NFR	SINTEF Energy	On-going
WindScanner.eu	EU ESFRI	DTU, Fh IWES, ECN, ForWind, CENER, SINTEF ENERGY, LNEG, University of Porto and CRES	On-going
DIPLAB (ETEST, 8 MVA short-circuit emulator) - procured	RCN infra-structure	SINTEF ENERGY	On-going
NOWERI - offshore met-ocean measurements and floating wind turbine (in preparation)	RCN infra-structure	CMR, UiB, NTNU, SINTEF, IFE etc.	On-going
EWEM: European Energy Master (Erasmus Mundus programme)	EU	TU Delft, DTU, NTNU, Universität Oldenburg	On-going
FAROFF: Far offshore operation and maintenance vessel concept development and optimization	RCN IPN	Statkraft, MARINTEK, Fred Olsen, Odfell, SINTEF ENERGY	On-going
WINDSENSE: Add-on instrumentation system for wind turbines	RCN IPN	Kongsberg Maritime, Statoil, NTE, SINTEF ENERGY, Marintek, NTNU, WCMN	On-going
ProOfGrids: Protection and Fault Handling in Offshore HVDC Grids	RCN KPN	SINTEF ENERGY, 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	NTNU, Marintek	On-going
InnWind: Innovative wind conversion systems (10-20MW) for offshore applications	EU FP7	Risø DTU, SINTEF ENERGY, etc.	On-going

Project title	Type	Partners	Status
EERA-DTOC: EERA Design Tools for Offshore Wind Farm	EU FP7	DTU Risø, SINTEF ENERGY, etc	On-going
MARINET: Marine Research Infrastructures Network for Energy Technologies	EU FP7	HMRC University College Cork, Risø DTU, NTNU, Universityof Strathclyde, Fraunhofer IWES, SINTEF ENERGY, 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. SINTEF ENERGY, NTNU etc.	On-going
Offshore DC: DC grids for integration of large scale wind power	Nordic	Risø DTU, AAU, Chalmers, SINTEF Energy, VTT, Dong, Vestas, ABB, Energinet.dk, NTNU,	On-going
Offwind: Prediction tools for offshore wind electricity generation	Nordic	IRIS, SINTEF, FFI, WindSim, Storm Geo etc.	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, VTT, Vindforsk, Chalmers, Risø DTU	On-going
RAWi: Radio Acoustic Wind Sensor	RCN BIP	Triad, IFE, UIB, Kjeller Vindteknikk, NORBIT	On-going
Twenties (www.twenties-project.eu)	EU FP7	Red Electrica, SINTEF ENERGY etc	Finished
DeepWind: Future Deep Sea Wind Turbine Technologies	EU FP7	Risø DTU, Statoil, SINTEF ENERGY, MARINTEK etc.	Finished

9 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 IRP-WIND project being awarded in 2013 with coordination by DTU and objectives closely aligned with EERA JP wind. IRPWIND, www.irpwind.eu will kick off in March 2014.

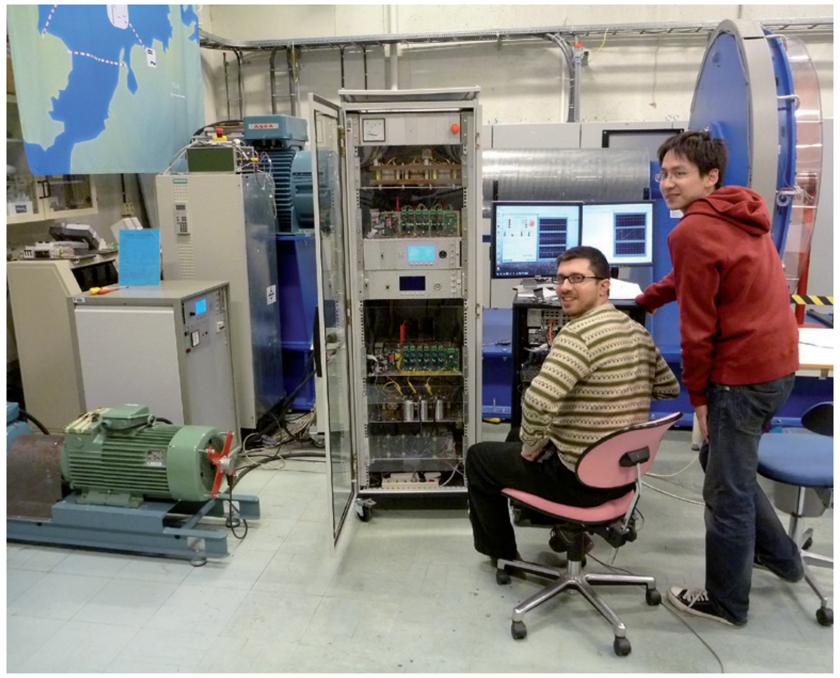


Figure 35: A team of researchers led by Olimpo Anaya-Lara all from University of Strathclyde, visited SINTEF Energy in April and June 2013 to carry out experiments in the renewable energy smart grids lab. The picture shows Salvatore D'Arco (left, SINTEF Energy) and Fan Zhang (right, University of Strathclyde) working with the OPAL-RT setup for controlling a lab scale converter to provide synthetic inertia. The aim was to observe and assess the impact of different control loops for provision of synthetic inertia from wind turbines. Photo by: Kjell Ljøkelsøy

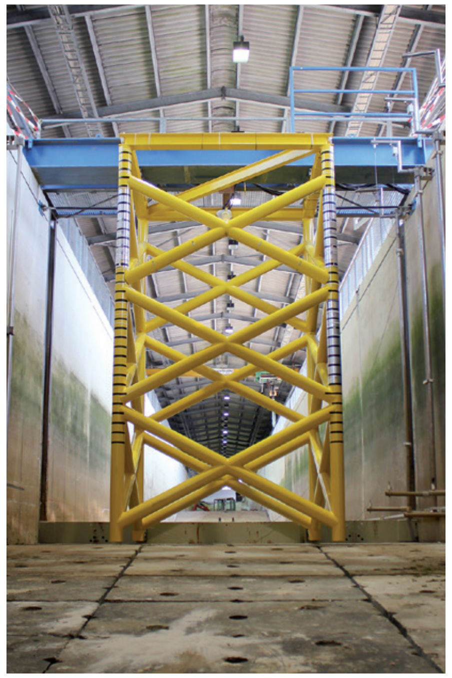


Figure 36: As part of HYDRALAB IV the WAVESLAM - Wave Slamming Forces on Truss Structures in Shallow Water laboratory experiment was carried out in cooperation between NOWITECH and NORCOWE during a 5 week period in 2013 at the Large Wave Flume, GWK in Hannover. Picture by Forschungzentrum Küste (FZK)

- 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. Work in 2013 has focused on preparing a new strategic research agenda (SRA) to be launched during EWEA'2014 in March 2014.

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

- Erasmus Mundus European Wind Energy Master (EWEM), www.windenergymaster.eu. NTNU has together with three other European universities (TU Delft, DTU and University of Oldenburg) jointly been awarded an Erasmus Mundus European Wind Energy Master (EWEM) programme that started September 2012. TU Delft and DTU are also associate research partners to NOWITECH. The programme aims to educate 120-150 MSc graduates per year in Wind Energy technology.

- IEA Wind, www.ieawind.org; The research partners of NOWITECH are active in all relevant tasks of IEA Wind, including:
    - o IEA Wind Task 25: System operation (grid integration)
    - o IEA Wind Task 26: Cost of wind energy
    - o IEA Wind Task 29: Mexnext: Analysis of wind turbine measurements
    - o 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, e.g. PT 61400-3 developing a technical specification for the design requirements for floating 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 2013 the research parties in NOWITECH participated in 15 projects with EU or Nordic funding providing for very substantial international collaboration. Through the MARINET and HYDRALAB IV programmes for transnational laboratory access the research partners of NOWITECH have both welcomed guests to own laboratories, see Figure 35, and been using laboratories abroad in Hannover at the Large Flume Tank, see Figure 36 and at IFREMER's wave tank in Brest, see Figure 27.

10 RECRUITMENT

The Centre includes a strong PhD and Postdoc programme. One new Post Doc started in 2013 with funding from NOWITECH, leading to an overall number since start of NOWITECH of 27 PhD scholars and two Postdoc at NTNU fully funded by the Centre. In addition, another 28 PhD and Postdoc students were associated to the Centre in 2013. 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 list of all PhD students and Postdocs financed through NOWITECH or by other sources can be found in the Appendix.

Six NOWITECH associated PhD students successfully defended their doctoral work in 2013. These were:

NAME	THESIS TITLE
Tobias Aigner	System Impacts from Large Scale Wind Power
Anders Arvesen	Understanding the environmental implications of energy transitions: A case study for wind power. PhD thesis. Norwegian University of Science and Technology
Wenbin Dong	Time-domain fatigue response and reliability analysis of offshore wind turbines with emphasis on welded tubular joints and gear components
Sverre Gjerde	Analysis and Control of a Modular Series Connected Converter for a Transformerless Offshore Wind Turbine
Muhammad Jafar	Transformer-Less Series Compensation of Line-Commutated Converters for Integration of Offshore Wind Power
Raymundo Torres Olguin	Grid Integration of Offshore Wind Farms using Hybrid HVDC Transmission Control and Operational Characteristics

The majority of the PhD and postdocs financed by NOWITECH are due to finish in 2015. The first PhD student graduated in 2012, and more than 10 PhD students are expected to conclude their study in 2014. Thus, to keep up the momentum, significant additional funds for a next wave of PhD students are needed. This is high on the agenda in the management of NOWITECH and in the SC in particular. A solution is sought in dialogue with the Board and the RCN.

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 thesis. 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 2013, professors and scientific staff at NTNU, with relations to NOWITECH, were supervisors for 24 Master Degree theses specializing in offshore wind energy (see Appendix A.1.7). 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.

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.

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.

From a recruitment and gender perspective it is notable that around half of the Master of Technology Students at NTNU within wind in 2013 was women. For specific topics related to offshore wind there is even a majority registered. This promises well for the future gender equality in the sector. NOWITECH is very pleased with this development and will continue to promote offshore wind energy studies to female students and in relation to recruitment to PhD studies.

Figure 37: A new Post Doc started in 2013, Ali Nematbaksh. His topic of research is Alternative floating wind turbine concepts for moderate water depths. Supervisors are Prof. Torgeir Moan and Adj. Ass. Prof. Zhen Gao

Figure 38: Hanne Vefsnmo is one of many MSc students that completed their thesis related to offshore wind energy in 2013. Her thesis was "Determining the Optimal Vessel Fleet for Maintenance of Offshore Wind Farms". Here in discussion with Researcher Iver Sperstad Bakken regarding the tool "Nowicob". She now works as a researcher at SINTEF Energy Research. Photo: synlig.no

11 COMMUNICATION AND DISSEMINATION

The scientific results of the Centre are disseminated efficiently and achieving international recognition. Publications since start-up include 101 peer-reviewed papers, 107 reports, 61 media contributions and 146 conference presentations of which 20 were invited keynotes. NOWITECH publications in 2013 include a total of 86, whereof 25 journal papers or peer-reviewed papers, 18 conference papers, 5 Books/PhD Thesis', 23 reports and 15 media contributions. More details are listed in the appendices.

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

- 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 professional. New of this year is twitter feed for relevant news to users.
- Popular articles, adverts, media contributions and interviews are generally important means for raising public education and opinion.
- The NOWITECH newsletters give short teasers of results. The newsletters are distributed through e-mail and public web; they are open and shall be understandable also for the educated non-expert. Links for further reading are however to the NOWITECH e-room that is for partners only. Four newsletters were produced in 2013.
- In 2013 the seminar series "Industry meets Science" was continued in cooperation with Access Mid-Norway and Wind cluster Mid-Norway. The aim of the seminar is facilitate an improved interaction between the research in NOWITECH and relevant industry, also to those that are not partner in NOWITECH. The community program Access Mid-Norway is discontinued after 2013, so the cooperation will continue with Wind Cluster Mid-Norway to arrange these events in 2014. http://www.sintef.no/Projectweb/Industry-meets-science/
- The annual offshore wind R&D conference in Trondheim has developed into an international event with call for papers, peer-review and publication in the open access journal Energy Procedia (Elsevier). EERA DeepWind'2013 had about 140 delegates from 14 countries and a total of 50 oral and 24 posters, see Figure 39.
- The NOWITECH Day is an annual event bringing together all NOWITECH partners to share information, discuss and enjoy research on offshore wind technology. This year the event was not only to present NOWITECH results, but also highlight a selection of external projects with association to NOWITECH. The programme was a mix of oral presentations and posters with ample time for discussions and mingling, see Figure 40.

NOWITECH partners have access to a project e-room, where all internal information and project results are presented.

Figure 39, previous page: DeepWind 2013 22nd -24th January in Trondheim was accomplished in excellent manner with 140 delegates from 14 countries, and with about 50 oral presentations and 24 posters. Pictures are from the poster session(1st from the left), the poster award (2nd from the left) and from the opening session (3rd from the left)

Figure 40: The NOWITECH Day 2013 was well accomplished in Trondheim 11 June bringing together all NOWITECH partners to share information, discuss and enjoy research on offshore wind technology The 4th picture from the left shows the NOWITECH day 2013 poster award committee and award winners from left: Per Arne Wilson (secretary NOWITECH CIC), John Olav Tande (NOWITECH director), professor Michael Muskulus (vice chair NOWITECH Scientific Committee), PhD student Øyvind Netland, NTNU and research scientist Atsede Endegnanew, SINTEF Energy Research. The last picture from the left shows Iver Bakken Sperstad, SINTEF, in engaged dialogue with Wei He, Statoil and Vincent De Laleu, Edf.

A.1 PERSONNEL

Current Centre Management and Committees

John Olav G. Tande, Centre Director | Hans Christian Bolstad, Centre Manager | Roy Stenbro, Head WP1 | Jens Kjær Jørgensen Head WP2 | Torgeir Moan, Head WP3 | Harald Svendsen, Head WP4

Thomas Welte, Head WP5 | Ole David Økland, Head WP6 | Trond Kvamsdal, Chair SC | Michael Muskulus, Vice-chair SC | Johan Sandberg Chair CIC | Per Arne Wilson, Secretary CIC

Karl Merz, Head Reference Turbine | Debbie Koreman, Higher Executive Officer | Randi Aukan, Centre Secretary

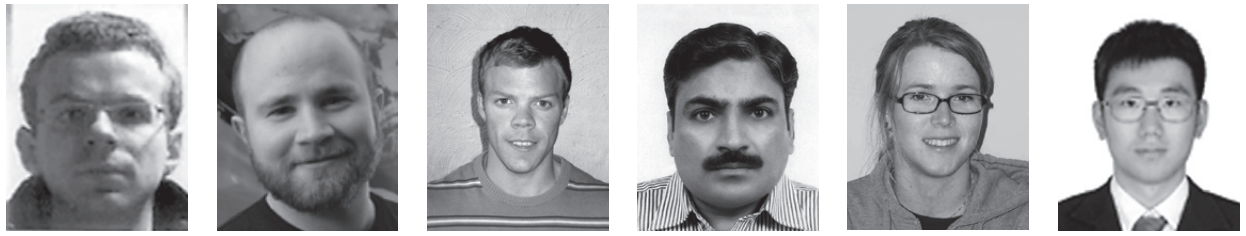
Key researchers are listed in A.1.1.

NOWITECH would like to thank the following for their contributions in 2013

Kjetil Uhlen Head WP4 until 31.12.13 | Kjell Eriksson Chair CIC until 01.06.13 | Matthias Hofmann Head WP5 until 31.12.13 | Nils Arild Ringheim Centre Manager until 01.04.13 | Tobias Aigner Centre Manager 01.04-15.07.13 | Bernd Schmid Head WP2 until 16.08.13

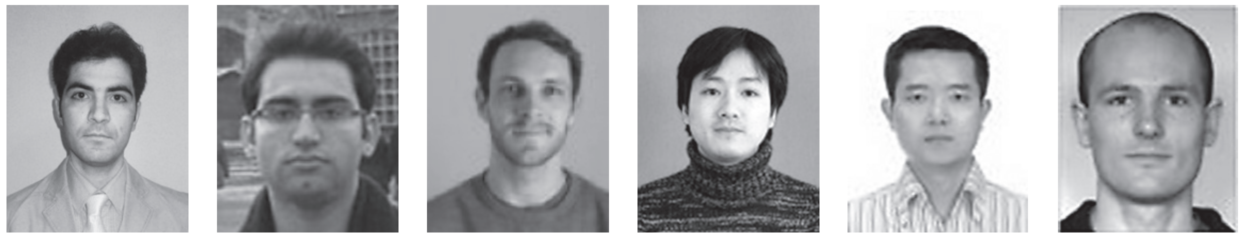
NOWITECH PhD students

Tania Bracchi | Lars Morten Bardal | René Alexander Cárdenas | Valentin Chabaud | Mayilvahanan Chella | Kevin Cox



Emmanuel Dombre | Pål Egil Eriksen | Lars Frøyd Completed 2012 | Zafar Hameed | Marit Irene Kvittem | Chenyu Luan

Mubarok, Fahmi | 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

NOWITECH Postdoctoral Researchers in 2013

Mukesh Kumar
Post-Doc

Nematbakhsh, Ali
Post-Doc

Details of topics and further list of associated postdoctoral researchers and PhD students are listed in A.1.3-A.1.6. Master students are listed in A.1.7.

A.1.1 Key Researchers

#	Name	Institution	Main Research Area / Role
1	Albrechtsen, Eirik	SINTEF TS	WP5
2	Armada, Sergio	SINTEF MC	WP3, WP5
3	Berthelsen, Petter Andreas	Marintek	WP1,WP3, WP6, Management
4	Bjørgum, Astrid	SINTEF MC	WP3, WP5
5	Bolstad, Hans Christian	SINTEF Energy Research	Centre Manager
6	Dahlhaug, Ole Gunnar	NTNU	Management (including SC), WP1
7	Delhaye, Virgile	SINTEF MC	WP2
8	Echtermeyer, Andreas	NTNU	WP2
9	Endegnanew, Atsede	SINTEF Energy Research	WP4
10	Equey, Sebastian	SINTEF MC	WP5
11	Foques, Sebastien	Marintek	WP1, WP3
12	Fossen, Thor Inge	NTNU	WP6
13	Fosso, Olav	NTNU	WP4, Board
14	Fylling, Ivar	Marintek	WP1, WP6
15	Gaarder, Rune Harald	SINTEF MC	WP2
16	Gao, Zhen	NTNU	WP3
17	Grytten, Frode	SINTEF MC	WP2
18	Hals, Jørgen	Marintek	WP1
19	Halvorsen-Weare	Marintek	WP5
20	Hinrichsen, Einar	SINTEF MC	WP2
21	Hofmann, Matthias	SINTEF Energy Research	WP5
23	Holdahl, Runar	SINTEF ICT	WP1
24	Høidalen, Hans Kristian	NTNU	WP2
25	Johnsen, Heidi	SINTEF MC	WP3
26	Johnsen, Roy	NTNU	WP3
27	Jørgensen, Jens Kiær	SINTEF MC	WP2, Management
28	Karimirad, Madjid	Marintek	WP6
29	Krasilnikov,Vladimir	Marintek	WP6
30	Krogstad, Per Åge	NTNU	WP1,WP6
31	Kvamsdal, Trond	NTNU	SC
32	Lars Sætran	NTNU	WP1
33	Mateusz.Graczyk	Marintek	WP1
34	Maus, Karl Jacob	IFE	WP1
35	Moan, Torgeir	NTNU	WP3, WP6, Management (incl SC)
36	Muk Chen Ong	Marintek	WP3
37	Muskulus, Michael	NTNU	Management, SC, WP3
38	Muthanna, Chittiappa	Marintek	WP6
39	Niklas Magnusson	SINTEF Energy Research	WP2
40	Nilssen, Robert	NTNU	WP2
41	Nonås, Lars Magne	Marintek	WP5
42	Nygaard Tor Anders	IFE	WP1, WP2, WP3, WP6
43	Nysveen, Arne	NTNU	SC, WP4
44	Oggiano, Luca	IFE	WP1
45	Ormberg, Harald	Marintek	WP1, WP3
46	Passano, Elizabeth	Marintek	WP3
47	Rødseth, Harald	Marintek	WP5
48	Sauder, Thomas	Marintek	WP6
49	Simon, Christian	SINTEF MC	WP3
50	Skavhaug, Amund	NTNU	WP5
51	Skjetne, Roger	NTNU	WP6
52	Soloot, Amir	NTNU	WP4
53	Sperstad, Iver	SINTEF Energy Research	WP5
54	Stansberg, Carl Trygve	Marintek	WP3, WP6
55	Stenbro Roy	IFE	WP1, WP2, WP3, WP6, Management
56	Svendsen, Harald	SINTEF Energy Research	WP4, WP6
57	Tande, John Olav Giæver	SINTEF Energy Research	Centre Director
58	Uhlen, Kjetil	NTNU / SINTEF Energy Research	WP4, WP6, Management
59	Valland, Anders	Marintek	WP5
60	Vatn, Jørn	NTNU	WP5
61	Vogl Andreas	SINTEF ICT	WP2
62	Völler, Steve	NTNU	WP4
63	Welte, Thomas	SINTEF Energy Research	WP5
64	Økland, Ole D.	Marintek	WP3, WP6, Management
65	Østbø, Niels Peter	SINTEF ICT	WP2
66	Årdal, Atle	SINTEF Energy Research	WP4

A.1.2 Visiting Researchers

#	Name	Affiliation	Nationality	Sex	Duration	Topic
1	Olimpo Anaya-Lara	NTNU / Strath-clyde University	British	M	2 months	Impact of different control loops for provision of synthetic inertia in the Doubly-fed Induction Generator
2	Zhang, Fan	Univ StrathClyde	British	M	2 months	Impact of different control loops for provision of synthetic inertia in the Doubly-fed Induction Generator
3	Kluge Georg	Berufsakademi, Sachsen	German	M	1 year	Grid integration of Offshore Wind farms

A.1.3 Postdoctoral Researchers with financial support from the Centre

	Name	Nationality	Period	Sex	Topic
1	Kumar, Mukesh	Indian	2011-2013	M	Adaptive methods for accurate CFD-simulations of aerodynamic loads of offshore wind turbines (WP1)
2	Nematbakhsh, Ali	Iran	2013-2015	M	Alternative floating wind turbine concepts for moderate water depths

A.1.4 PhD-students with financial support from the Centre

#	Name	Nationality	Period	Sex	Topic
1	Knut Nordanger	Norwegian	2010-2013	M	Coupled fluid-structure interaction simulation of offshore wind turbines (WP1)
2	Pål Egil Eriksen	Norwegian	2010-2014	M	Rotor wake turbulence (WP1)
3	Kevin Cox	American	2010-2013	M	Lift control of wind turbine blades by using smart composite materials manipulating aero-dynamics rotor properties (WP2)
4	Mostafa Valavi	Iranian	2010-2013	M	Magnetic forces and vibrations in wind power generators (WP2)
5	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 (WP2)
6	Daniel Zwick	German	2009-2013	M	Design and production of offshore jacket struc-tures (WP3)
7	Eric Van Buren	American	2009-2012	M	Bottom-fixed support structure for wind tur-bine in 30-70 m water depth (WP3)
8	Marit Irene Kvit-tem	Norwegian	2009-2013	F	Life cycle criteria and optimization of floating structures and mooring systems (WP3)
9	Mayilvahanan Chella	Indian	2010-2013	M	Wave forces on wind turbine structures (WP3)
10	Amir Hayati Soloot	Iranian	2009-2013	M	Analysis of switching transients in wind parks with focus on prevention of destructive effects (WP4)
11	Fahmi Mubarok	Indonesian	2010-2013	M	Novel coating and surface treatment for im-proved wear resistance (WP5)
12	Zafar Hameed	Pakistani	2009-2013	M	Maintenance optimization of wind farms from design to operation (models, methods, frame-work) (WP5)
13	Øyvind Netland	Norwegian	2010-2013	M	Cost-effective monitoring for remote environ-mental friendly O&M of offshore wind turbines (WP5)
14	Tania Bracchi	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 (WP6)
15	Kai Wang	Chinese	2010-2013	M	Comparative studies of floating concepts (WP6)
16	Morten Dinhoff Pedersen	Norwegian	2010-2013	M	Design of control systems for load mitigation and stabilization of floating wind turbines (WP6)
17	René Alexander Barrera Cárdenas	Columbian	2011–2014	M	Multi-domain optimization model for the eval-uation of power density and efficiency of wind energy conversion systems
18	Valentin Chabaud	French	2011–2014	M	Experimental investigation of coupled hydro-dynamic and aerodynamic performance of floating wind turbines
19	Chenyu Luan	Chinese	2011-2015	M	Efficient stochastic dynamic response analysis for design of offshore wind turbines
20	Stanislav Shche-betov	Czech	2011-2015	M	Influence of material and process parameters on fatigue of wind turbine blades in a marine environment
21	Dombre Emma-nuel	Frankrike	2011-2015	M	Hydrodynamic modeling and analysis of float-ing wind turbines
22	See; Phen Chiak (Bryan)	Malaysia	2012-2015	M	Development of market models incorporating offshore wind farms and offshore grids
23	Nejad; Amir Rasekhi	Iran	2012-2015	M	Condition monitoring of the mechanical system of a windfarm
24	Bardal; Lars Morten	Norway	2012-2015	M	Design wind and sea loads for offshore wind turbines

A.1.5 Postdoctoral Researchers working on projects aligned with the Centre with financial support from other sources

#	Name	Nationality	Period	Sex	Topic
1	Hui Li	Chinese	2011-2013	M	Dynamic analysis of offshore monopile wind turbine including the effect of scour
2	Karl Merz	American	2011-2013	M	Offshore wind turbines in EU projects
3	Muk Chen Ong	Malaysian	2011-2013	M	Dynamic analysis of offshore monopile wind turbine including the effect of scour

A.1.6 PhD-students working on projects aligned with the Centre with financial support from other sources

(Only those active in 2013 are shown.)

#	Name	Financing	Nationality	Period	Sex	Topic
1	Aigner, Tobias	Elkraft	Germany	2008-2013	M	System impacts of large scale wind power
2	Arvesen, Anders	Indecol	Norway	2008-2013	M	Assessment of environmental benefits and costs of a large-scale introduction of wind energy
3	Bartl, Jan	EPT	Germany	2013-2017	M	Wind Turbine Wake Interactions
4	Dai, Lijuan	Dept of Marine Technology	China	2009-2013	F	RAMS engineering and management in the development and operation of offshore wind turbines
5	Dombre, Emmanuel	St. Venant-lab-EDF, Paris	France	2012-2015	M	Hydrodynamic modeling and analysis of floatinf wind turbines
6	Dong, Wenbin	CeSOS	China	2008-2013	M	Offshore wind energy in Norway: setting the basis
7	Gjerde, Sverre	Elkraft	Norway	2009-2013	M	Integrated converter design with generator for weight reduction of offshore wind turbines
8	Hansen, Thomas Henrik Hertzfelder	EPT (Industry)	Norway	2013-2016	M	Design and analysis of wind turbine rotor blades for offshore applications
9	Hansen-Bauer, Øyvind Waage	EPT	Norway	2013-2017	M	Investigation of the structure of turbulent wakes formed behind wind turbines
10	Heidenreich, Sara	KULT	Germany	2010-2014	F	Public engagement in offshore wind energy
11	Holtsmark, Nathalie	Elkraft	Norway	2010-2014	F	Wind Energy Conversion using high frequency transformation and DC collection
12	Jafar, Muhammad	Elkraft	Pakistan	2008-2013	M	HVDC-transmission for offshore wind power from the generator tot the onshore grid
13	Langhamer, Olivia	Biology	Germany	2010-2013	F	Renewable offshore energy and the marine environment: biofouling and artificial reefs
14	Olsen, Pål Keim	Elkraft	Norway	2011-2014	M	Electrical Degradation phenomena in insulation materials exposed to combined DC and AC voltage
15	Ong, Muk Chen	Dept of Marine Technology	Malaysia	2011-2013	M	Dynamic analysis of offshore monopile wind turbine including the effect of scour
16	Pierella, Fabio	EPT	Italy	2008-2013	M	Wind energy: Full scal and wind tunnel simulated measurements; consequential wind turbine design optimization, model construction and experimental testing
17	Reiso, Marit	BAT	Norway	2009-2013	F	Design and analysis of downwind rotor for WT with jacket tower
18	Schafhirt, Sebastian	BAT	Germany	2013-2017	M	The modeling of support structure dynamics for offshore wind turbines
19	Slimacek, Vaclav	IMF	Czechia	2011-2015	M	Reliability analysis of offshore wind turbines/plants and their connection to Smart Grids
20	Steen, Markus	Geography	Norway	2010-2014	M	Commercialization of new technology and industrial development in new renewable energy - the case of offshore wind
21	Tasar, Gürsü	EPT	Turkey	2009-2013	M	Full Scale Measurements of Wind Conditions Relevant for Offshore Wind Turbines
22	Torres Olguin, Raymundo	Elkraft	Mexico	2008-2013	M	Offshore Wind Farms Electrical System and Grid Integration
23	Valibeiglou, Mahmoud	IPK	Iran	2008-2013	M	Area in Operation and Maintenance in online monitoring and use of online data for maintenance decision for offshore wind farms
24	Vrana, Til Kristian	Elkraft	Norway	2009-2013	M	Development and Operation of the North Sea super Grid
25	Øverås, Ingrid	KULT	Norway	2005-2013	F	The nature politics of wind power

A.1.7 Master Degrees during 2013 affiliated with NOWITECH

#	Name	Sex	Topic
1	Aase, Anne Guri	F	A new approach towards comparing environmental impacts from small-scale hydropower, large-scale hydropower and wind power
2	Andresen, Birgitte	F	Wake behind a wind turbine operating in yaw
3	Bjørnland, Karl Hermann Mathias	M	Wind-induced Dynamic Response of High Rise Buildings
4	Brandal, Andre	M	Optimal Operation of Wind Farms
5	Gilje, Kristian Malde	M	Airborne Wind Turbines for Ship Propulsion
6	Gressetvold, Marit	F	Identifying Conservative Criteria for (environmental) Assessments of Vulnerability;: Seabirds and Offshore Wind Farms as a Case Study
7	Hagen, Brede Andre Larsen	M	Sensitivity Analysis of O&M Costs for Offshore Wind Farms
8	Kirkeby, Henrik	M	Control of VSC During Unsymmetrical AC Faults in Offshore Wind Farms
9	Kjørlaug, Remi André	M	Seismic Response of Wind Turbines: Dynamic Analysis of a Wind Turbine in Horizontal and Vertical Direction - Subject to Earthquake, Wind & SSI
10	Kolstad, Magne Lorentzen	M	Integrating Offshore Wind Power and Multiple Oil and Gas Platforms to the Onshore Power Grid using VSC-HVDC Technology
11	Lunde, Knut-Ola Gjervold	M	Hydrodynamic analysis and structural design of the Concrete Star Wind Floater
12	Lynum, Susanne	F	Wind turbine wake meandering
13	Meisingset, Kristine Kiplesund	F	Influence of Offshore Wind Farm on Shore CrabCarcinus maenas Population Dynamics
14	Mikkelsen, Kristine	F	Effect of free stream turbulence on wind turbine performance
15	Navaratnam, Christy Ushanth	F	Wave slamming forces on truss structures for wind turbines
16	Neuenkirchen Godø, Sjur	M	Dynamic Response of Floating Wind Turbines
17	Nielsen, Magnus Sand	M	Monte Carlo Simulation of Power Systems with Wind Power
18	Oehninger-Storvoll, Karen-Christine	F	Stress influence of offshore wind farms on the reproduction of the viviparous eelpout (Zoarces viviparus)
19	Rosenlund, Even	M	Nonlinear Hydrodynamic Effects for Bottom-Fixed Wind Turbines
20	Rosenlund, Gjert Hovland	M	Optimal Production Balance with Wind Power
21	Solberg, Mikkel	M	MPC of Variable Speed Wind Turbines
22	Vefsnmo, Hanne Merete	F	Determining the Optimal Vessel Fleet for Maintenance of Offshore Wind Farms
23	Veila, Siri	F	Impacts of Interconnecting the Wind Farm Projects within the Dogger Bank Zone: A Technical-Economical Evaluation of the Impact of Increased Wind Farm Connection Reliability
24	Zhang, Rui	M	Comparative Study On Dynamic Responses of a Semi-submersible Wind Turbine Using a Simplified Aerodynamic Model and a BEM Model

Master students are all registered in Diva Research Portal.

A.2 STATMENT OF ACCOUNTS 2013

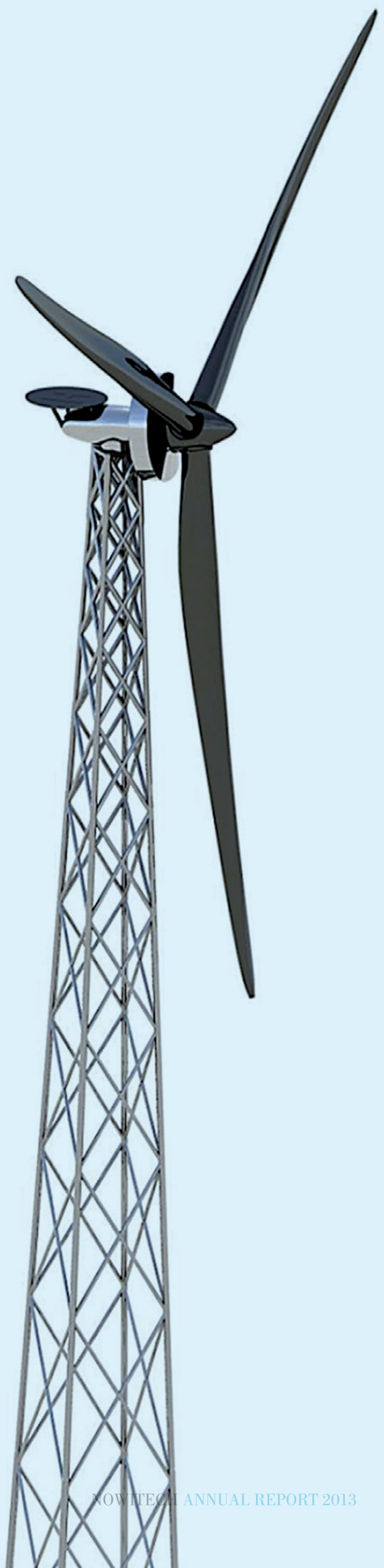
(All figures in NOK 1000)

FUNDING

Name	Amount	Amount
NFR		20 000
SINTEF Energi AS		2 346
NTNU		8 656
IFE		1 103
MARINTEK		1 824
SINTEF		799
CD-adapco	313	
DNV	500	
DONG Energy Power AS	500	
EDF R&D	1 341	
Fedem Technology AS	341	
Kongsberg	503	
NTE Holding AS	1 000	
SmartMotor AS	606	
Statkraft Development AS	1 500	
Statnett SF	500	
Statoil Petroleum AS	1 150	
Subtotal Industry Partners		8 253
Public Partners		0
Total		42 981

COSTS

Name		Amount	Amount
SINTEF Energi AS	(Host Institution)		9 383
NTNU	(Research Partner)		16 091
IFE	(Research Partner)		4 414
MARINTEK	(Research Partner)		7 295
SINTEF	(Research Partner)		3 194
Kongsberg		503	
CD-adapco		313	
EDF R&D		841	
Fedem Technology		341	
Smart Motor		606	
Subtotal Industry Partners			2 603
Public Partners			0
Total			42 981



A.3 PUBLICATIONS

Journal and Peer Review Papers

[1] Barrera-Cardenas, R.; Molinas, M.; Multi-objective Design of a Modular Power Converter based on Medium Frequency AC-link for Offshore DC Wind Park; DeepWind 2013; Energy Procedia; Volume 35; 2013

[2] Bachynski, E.; Etamaddar, M.; Kvittem, M.; Luan, C.; Moan, T.; Dynamic Analysis of Floating Wind Turbines During Pitch Actuator Fault, Grid Loss, and Shutdown; DeepWind 2013; Energy Procedia; Volume 35; 2013

[3] Nejad, A.; Gao, Z.; Moan, T.; Long-term Analysis of Gear Loads in Fixed Offshore Wind Turbines Considering Ultimate Operational Loadings; DeepWind 2013; Energy Procedia; Volume 35; 2013

[4] Hofmann, M.; Bakken Sperstad, I.; NOWIcob – A Tool for Reducing the Maintenance Costs of Offshore Wind Farms; DeepWind 2013; Energy Procedia, Volume 35; 2013

[5] Halvorsen-Weare, E.; Gundegjerde, C.; Halvorsen, I.B.; Hvattum, L.M.; Nonås, L.M.; Vessel Fleet Analysis for Maintenance Operations at Offshore Wind Farms; DeepWind 2013; Energy Procedia; Volume 35; 2013

[6] Marvik, J.I.; Svendsen, H.G.; Analysis of Grid Faults in Offshore Wind Farm with HVDC Connection; DeepWind 2013; Energy Procedia; Volume 35; 2013

[7] Endegnanew, A.; Farahmand, H.; Huertas-Hernando, D.; Frequency Quality in the Nordic Power System: Wind Variability, Hydro Power Pump Storage and Usage of HVDC Links; DeepWind 2013; Energy Procedia; Volume 35; 2013

[8] Svendsen, H.; Merz, K.; Control System for Start-up and Shut-down of a Floating Vertical Axis Wind Turbine; DeepWind 2013; Energy Procedia; Volume 35; 2013

[9] Gjerde, S.; Ljøkelsøy, K.; Undeland, T.; Laboratory Verification of the Modular Converter for a 100 kV DC Transformerless Offshore Wind Turbine Solution; DeepWind 2013; Energy Procedia; Volume 35; 2013

[10] Cox K.; Echtermeyer A.; Geometric scaling effects of bend-twist coupling in rotor blades; DeepWind 2013; Energy Procedia; Volume 35, 2013

[11] F. Pierella, L. Sætran, P.A . Krogstad; Blind Test 2 calculations for two wind turbines in tandem arrangement; SCI journal; ICOWES 2013 Conference 17-19 June 2013, Lyngby

[12] Netland, Ø.; Skavhaug, A.; Software Module Real-Time Target: Improving Development of Embedded Control System by Including Simulink Generated Code into Existing Code; 39th EUROMICRO Conference on Software Engineering and Advanced Applications 2013; Santander; Spain; September 4-6, 2013

[13] Netland, Ø.; Jenssen, G.; Schade, H.M.; Skavhaug, A.; An Experiment on the Effectiveness of Remote, Robotic Inspection Compared to Manned; IEEE Systems; Man and Cybernetics 2013; Manchester; UK; October 13 - 16, 2013

[14] He, W.; Uhlen, K.; Hadiya, M.; Chen, Z.; Shi, G.; del Rio, E.; Case Study of Integrating an Offshore Wind Farm with Offshore Oil and Gas Platforms and with an Onshore Electrical Grid; Journal of Renewable Energy; Volume 2013; 2013

[15] Korpås, M.; Trötscher, T.; Völler, S.; Tande, J.O.; Balancing of Wind Power Variations using Norwegian Hydro Power; Wind Engineering; Volume 37; 2013

[16] Krogstad, P.Å.; Eriksen, P.E.; "Blind test" calculations of the performance and wake development for a model wind turbine; Renewable Energy; Volume 50; 2013

[17] Svendsen, H.G.; Planning Tool for Clustering and Optimised Grid Connection of Offshore Wind Farms; DeepWind 2013, Energy Procedia; Volume 35; 2013

[18] Fossum, Peter K.; Frøyd, Lars; Dahlhaug, Ole G.; Design and Fatigue Performance of Large Utility-Scale Wind Turbine Blades; J. Sol. Energy Eng; ISSN 0199-6231; Voume 135, Issue 3

[19] Smith, J.; Osborn, D.; Tande, J.O.; Korpås, M. et al Transmission planning for wind energy in the United States and Europe: status and prospects; Wiley Interdisciplinary Reviews: Energy and Environment; ISSN 2041-840X; 2013

[20] Wang, K.; Hansen, M.O.L.; Moan, T: Model improvements for evaluating the effect of tower tilting on the aerodynamics of a vertical axiswind turbine; Wind Energy Online Library

[21] Haileselassie, T.M. ; Uhlen, K.; Power System Security in a Meshed North Sea HVDC Grid; Proceedings of the IEEE; Volume 101, Issue 4

[22] Taxt,H.; Magnusson, N.; Runde, M.; Apparatus for Calorimetric Measurements of Losses in MgB2 Superconductors Exposed to Alternating Currents and External Magnetic Fields, Cryogenics Vol. 54, pp. 44-49, 2013

[23] Taxt, H.; Magnusson, N.; Runde, M.; Brisigotti, S.; AC Loss Measurements on Multi-filamentary MgB2 Wires with Non-magnetic Sheath Materials; IEEE Trans. Appl. Supercond. Vol. 23; No 3, 8200204, 2013

[24] Cox, Kevin; Echtermeyer, Andreas Effects of composite fiber orientation on wind turbine blade buckling resistance; Wind Energy; DOI: 10.1002/we.1681; October 2013

[25] Merz, K.; Svendsen, H.G.; A Baseline Control Algorithm for the Deepwind Floating Vertical-Axis Wind Turbine; J. Renewable Sustainable Energy; Volume 5; Issue 063136

Published Conference papers

[1] Pål Egil Eriksen, Per-Åge Krogstad; Phase-locked averaging of mean velocity and turbulent quantities in a wind turbine wake; Wind Energy Science and Technology, RUZGEM 2013, October 3-4, 2013, Ankara, TURKEY

[2] Eriksen, P.E.; Krogstad, P.Å.; A multi component hot-wire probe and its application and feasibility in wind turbine wake measurements; Proceedings of 9th PhD Seminar on Wind Energy in Europe September 18-20, 2013, Uppsala University Campus Gotland, Sweden

[3] Netland, Ø.; Skavhaug, A.; Two Pilot Experiments on the Feasibility of Telerobotic Inspection of Offshore Wind Turbines, EUROMICRO / IEEE Workshop on Embedded and Cyber-Physical Systems 2013; June 19; Hotel "Slovenska Plaza"; Budva; Montenegro

[4] Marvik, J.I.; Svendsen, H.G.; Stability in offshore wind farm with HVDC connection to mainland grid; 10th Deep Sea Offshore Wind R&D Conference, Trondheim, Jan 2013

[5] Mubarok, F.; Armada, S.; Espallargas, N.; Tribological Characterization of Thermally Sprayed Silicon Carbide Coatings; World Tribology Congress 2013; Torino; Italy; September 8 – 13, 2013

[6] Hofmann, M; Sperstad, I.B.; Analysis of sensitivities in maintenance strategies for offshore wind farms using a simulation model; EWEA OFFSHORE 2013: Frankfurt; 19 November - 21 November 2013

[7] Endegnanew; A.; Svendsen, H.; Grid code compliance of the DeepWind floating vertical axis wind turbine; EWEA Offshore 2013; Frankfurt

[8] Yasuda, Y.; Årdal, A.R.; Hernando, D.H. et al; Flexibility chart. Evaluation on Diversity of Flexibility in Various areas; 3th International Workshop on Large-Scale Integration of Wind Power into Power Systems; London; 20 - 22 October 2013

[9] Holttinen, H.; Robitaille, A.; Orths, A.; Pineda, I.; Lange, B.; Carlini, E.M.; O'Malley, M.; Dillon, J.; Tande, J.O. et al; Summary of experiences and studies for Wind Integration - IEA Wind Task 25; 13th International Workshop on Large-Scale Integration of Wind Power into Power Systems; London; 20 - 22 October 2013

[10] Årdal, A.R.; D'Arco, S.; Sharifabadi, K.; Grid integration of Offshore Wind Power Plants with Oil and Gas Installations; 13th International Workshop on Large-Scale Integration of Wind Power into Power Systems; London; 22 - 24 October 2013

[11] Endegnanew, A.; Svendsen, H.; Automated grid connection design process for offshore wind farm cluster; EWEA Offshore; Frankfurt; Nov 2013

[12] See, C.S.; Fosso, O.B. ; Molinas, M. ; Foosnas, J.A.; A method for optimizing the offer price of collaborative power generators; IEEE PowerTech; Grenoble; 2013

[13] A. Robertson, J. Jonkman, and W. Musial et al; Offshore Code Comparison Collaboration, Continuation: Phase II Results of a Floating Semisubmersible Wind System; EWEA Offshore 2013, Frankfurt, Germany November 19–21 2013
[14] Garces, Alejandro ; Barrera-Cardenas, Rene; Molinas, Marta; Optimal Control for an HVDC System with Series; IEEE ECCE 2013; Denver; USA
[15] Soloot , A.H.; Høidalen, H.K.; Gustavsen, B; Internal Resonant Overvoltage in Wind Turbine Transformers-Sensitivity Analysis of Measurement Techniques; ICEMS 2013; Busan, Korea; Oct. 2013
[16] Soloot, A. H.; Høidalen, H. K.; Gustavsen, B.; Modeling of Wind Turbine Transformers for the Analysis of Resonant Overvoltages; IPST2013; Vancouver, Canada; July 2013
[17] Soloot, A.H.; Høidalen,H.K.; Gustavsen, B.; Upon the improvement of the winding design of wind turbine transformers for safer performance within resonant overvoltages; CIGRE SC A2 & C4 joint colloquium 2013; Zurich; 2013
[18] Wang, K.; Moan, T.; Laver Hansen, M.O.; A METHOD FOR MODELING OF FLOATING VERTICAL AXIS WIND TURBINE; Proceedings of the 32th International Conference on Ocean, Offshore and Arctic Engineering; OMAE 2013; June 9 - 14, 2013; Nantes; France

Books / Theses

[1] Nodeland, A.M.; Rotor and wake modeling with an actuator line Open FOAM CFD model; (Master Thesis); NTNU

[2] Gjerde, S.S.; PhD - Analysis and Control of a Modular Series Connected Converter for a Transformerless Offshore Wind Turbine; 978-82-471-4688-0

[3] Aigner, T.; System impact from large scale wind power - Degree of Philosophiae Doctor; ISBN: 978-82-471-4508-1

[4] Torres-Olguin, R.; Grid Integration of Offshore Wind Farms using Hybrid HVDC Transmission: Control and Operational Characteristics - Thesis for the degree of Philosophiae Doctor; ISBN: 978-82-471-4300-1

[5] Jafar, M.; Transformer-Less Series Compensation of Line-Commutated Converters for Integration of Offshore Wind Power: Thesis for the degree of Philosophiae Doctor; ISBN 978-82-471-4355-1

Reports

[1] Martin,Rebecca.; State of the art of reliability and availability data; EDF

[2] Kühn, P.; Welte, T.; et al.; IEA Wind Task 33 - Reliability data standardization of data collection for wind turbine reliability and operation & maintenance analyses; Fraunhofer Institute for Wind Energy and Energy System Technology IWES; SINTEF Energi AS et al

[3] Hernando, D.H.; Aigner, T..; Wind Power and PV data and simulation of production times series; SINTEF Energi AS

[4] Støylen, H.; Svendsen, H.; Electrical design of a 1200 MW offshore wind farm; Project Memo; SINTEF Energi AS

[5] Tande, J.O.; TR A7307 Deep Sea offshore Wind R&D Conference 24 - 25 January 2013; SINTEF Energi AS

[6] Tande, J.O.; NOWITECH Day 2013 – 11 June, SINTEF Energi AS

[7] Rødseth, H.; Valland, A.; Brurok, T.; Technical condition indexing of an offshore wind farm; MARINTEK

[8] Tande, J.O.; NOWITECH Annual Report 2012; SINTEF Energi AS

[9] Hofmann, M.; Sperstad, I.B.; Input to the NOWIcob model from other tools and models; SINTEF Energi AS

[10] Wilson, P.A.; Idea generation & development of Ideas, NTNU

[11] Muskulus, M.; Design of new cost-effective bottom-fixed structure for use at 30-70 m water depths. NOWITECH Milestone no 7; NTNU

[12] Økland, O.D.; Control scheme for load mitigation and minimization of motions of floating wind turbine. Milestone delivery no 15; MARINTEK

[13] Uhlen, K.; Svendsen, H.G.; Marvik, J.; Hernando, D.H.; Numerical simulation models of offshore wind farms and electrical infrastructure for assessment of power system operation and grid stability; Project Memo; SINTEF; NTNU

[14] Anaya-Lara, O.; Tande, J.O.; Uhlen, K.; Adaramola, M.; Control Challenges and Possibilities for Offshore Wind Farms; Strathclyde Univ.; SINTEF Energi AS; NTNU

[15] Holttinen, Robitaille, A.; J.; Tande, J.O. et al.; Design and operation of power systems with large amounts of wind power. IEA Wind Task 25; VTT; Hydro Quebec; SINTEF Energi AS
[16] Valland, A; Brembo, J C.; Pre-study on expected degradation mechanisms and failures in offshore wind turbines; MARINTEK
[17] Svendsen, Harald G.; Endegnanew, Atsede G.; DeepWind - Description of control concepts for grid code compliance; SINTEF Energi AS
[18] Marvik, J.I.; Dynamic analyses of three-terminal HVDC grid connected wind farm; Project Memo; SINTEF Energi AS
[19] Schmid, B.; Matveev, A.; Zhang, Z.; NOWITECH WP2 – Generator technology Milestone report 2013 Status of milestone first half of NOWITECH project period; SINTEF Materials & Chemistry
[20] Schmid, B.; Echtermeyer, A.; Cox, K.; NOWITECH WP2 – Blade technology Milestone report 2013 Status of milestone first half of NOWITECH project period; SINTEF Materials & Chemistry
[21] Stenbro, R.; Overview of the work done on the NOWITECH WP1 milestone named "Design tool for cost optimization of floating support structure and mooring system", IFE
[22] Stenbro, R.; Overview of work done on the NOWITECH milestone named "Characterisation of micro scaled wind", IFE
[23] Welte, T.; Slimacek, V.; Degradation of failure models for offshore wind turbines; TR F7323; SINTEF Energi AS

Media contribution

[1] Abelsen, A.; Tande, J.O.; 100 000 klimajobber i sikte; Energiteknikk; no6; 2013

[2] Jakobsen, H.Ø.; Tande, J.O.; Betaler hundretusener for omtale av prosjekter; Forskning.no; SINTEF Energi

[3] Benjaminsen, C.; Tande, J.O.; Etterlyser satsing på vindkraft; Gemini; Forsknings.no; SINTEF Energi AS

[4] Benjaminsen, C.; Tande, J.O.; Vindkraft i flytsonen; Gemini; SINTEF Energi AS

[5] Haigh, L.; Tande, J.O.; Winds of change: NOWITECH in International Innovation; Research Media Ltd; SINTEF Energi AS

[6] Lankhorst, S.; Muskulus, M.; Academia and industry - an essential combination; Offshore Wind Magazine; NTNU

[7] Lie, Ø.; Tande, J.O.; Finansdepartementet fratar Norge muligheten til å ta en posisjon på havvindteknologi; Teknisk Ukeblad; SINTEF Energi AS

[8] Abelsen, A.; Tande, J.O.; Enkelt grep for flytende vindkraft, Xergi; nr 1; 2013

[9] Høi Rühne, F.; Tande, J.O.; Amerikanere: Vores turbine sætter nye standarder for vindkraft; Ingeniøren; SINTEF Energi AS

[10] Sundlisæter, T.; Tande, J.O..; Sheerwind Invelox - Ny vindturbin produserer seks ganger så mye kraft; Teknisk Ukeblad; SINTEF Energi AS

[11] Seehusen, J.; Ramsdal, R.; Tande, J.O.; Ewicon vindkraft: Lager strøm av vind uten en eneste bevegelig del; Teknisk Ukeblad; SINTEF Energi AS

[12]Pumpekraft fra havdypet; Abelsen media; SINTEF Energi; Energiteknikk; nr 2; 2013

[13]Seehusen, J.; Tande, J.O.; NOWERI - Dette blir verdens første havvindturbin for åpen forskning; Teknisk Ukeblad; SINTEF Energi AS

[14]Nilsen, J.; Tande, J.O.; Verdens største havvindturbin - Havvindgigantene kniver om å ha verdens største havvindturbin; TU

[15]Lie, Ø.; Ny superleder kan gi billigere havvind; Teknisk Ukeblad; 29. april 2013

Conference presentations

[1] Tande, J.O.; Invited speaker related to WP0 and WP6. "To what extent can floating foundations match the needs and expectations of the market?; Future Offshore Foundations 2013; Bremen; 23 - 25 October 2013

[2] Uhlen, K.; Wind integration studies - Results from IEA Wind Task 25 - Future need of transnational R&D; ERA-NET plus workshop; Stavanger; 9th October 2013

[3] Cox, K.; A Parametric study of unbalanced composites on the structural response of a 70m adaptive wind turbine blade; ICRACM 2013, International Conference on Recent Advances in Composite Materials, Goa, India. 20 February 2013

[4] Radheed, A.; Kvamsdal, T.; Tande, J.O.; Norwegian Research for Offshore Windtechnology (NOWITECH); Renewable Energy Respecting Nature; Mumbai; India; 7 - 8 May 2013

[5] Huertas Hernando, D.; Optimal offshore grid developments in the North Sea towards 2030; DeepWind 2013; Trondheim; 24 - 25 January 2013

[6] Tande, J.O.; Innovations in Offshore Wind Technology through R&D; DeepWind 2013; Trondheim; 24 - 25 January 2013

[7] Eriksen, P.E.; 3D hot-wire measurements of a wind turbine wake; DeepWind 2013; Trondheim; 24 - 25 January 2013

[8] Sperstad, I.B.; Hofmann, M.; NOWIcob – A tool for reducing the maintenance costs of offshore wind farms; DeepWind 2013; Trondheim; 24 - 25 January 2013

[9] Nejad, A.R .; Long-Term analysis of Gear Loads in Fixed Offshore Wind Turbines Considering Ultimate Operational Loadings; DeepWind 2013; Trondheim; 24 - 25 January 2013

[10]Wolfgang, O.; Skjelbred, H.I.; Korpås, M.; Evaluating North Sea grid alternatives under EU's RES-E targets for 2020; DeepWind 2013; Trondheim; 24 - 25 January 2013

[11]Wolfgang, O.; Skjelbred, H.I.; Korpås, M.; Evaluating North Sea grid alternatives under EU's RES-E targets for 2020; DeepWind 2013; Trondheim; 24 - 25 January 2013

[12]Svendsen, H.G.; Planning Tool for Clustering and Optimised Grid Connection of Offshore Wind Farms, DeepWind 2013; Trondheim; 24 - 25 January 2013

[13]Kielland-Haug, J.J.; The role of the North Sea power transmission in realising the 2020 renewable energy targets - Planning and permitting challenges; DeepWind 2013; Trondheim; 24 - 25 January 2013

[14]Soloot, A.H.; Høidalen,H.K.; Gustavsen, B.; Upon the Improvement of the Winding Design of Wind Turbine Transformers for Safer Performance within Resonance Overvoltages; DeepWind 2013; Trondheim; 24 - 25 January 2013

[15]Endegnanew, A.G.; Farahmand, H.; Huertas-Hernando, D.; Frequency Quality in the Nordic system: Offshore Wind variability, Hydro Power Pump Storage and usage of HVDC Links; DeepWind 2013; Trondheim; 24 - 25 January 2013

[16]Zhang, Z.; Nilssen, R.; Nysveen, A.; Chen, A.; Matveev, A.; High-power generators for offshore wind turbines; DeepWind 2013; Trondheim; 24 - 25 January 2013

[17]Gjerde, S.; Ljøkelsøy, K.; Undeland, T.; Laboratory Verification of the Modular Converter for a 100 kV DC Transformerless Offshore Wind Turbine Solution; DeepWind 2013; Trondheim; 24 - 25 January 2013

[18]Barrera-Cardenas, R.; Molinas, M. ; Multi-objective Optimization of a Modular Power Converter Based on Medium Frequency AC-Link for Offshore DC Wind Park; DeepWind 2013; Trondheim; 24 - 25 January 2013

[19]Svendsen, H.; Merz, K.; Operational Control of a Floating Vertical Axis Wind Turbine – start-up and shut-down; DeepWind 2013; Trondheim; 24 - 25 January 2013

[20]Cox, K.; Echtermeyer, A.; Geometric scaling effects of bend-twist coupling in rotor blades; DeepWind 2013; Trondheim; 24 - 25 January 2013

[21]Hofmann, M.; NOWITECH WP5, Operation & Maintenance, Presentation for GA, Trondheim 12 November 2013

[22]Jørgensen, J.K.; NOWITECH WP2 Energy Conversion System, Presentation for GA, Trondheim, 12 November 2013

[23]Stenbro, R.; NOWITECH WP1, Presentation for GA, Trondheim, 12 November 2013

[24]Moan, T.; NOWITECH WP3, Support structures, Presentation for GA, 12 November 2013

[25]Tande, J.O.; NOWITECH Status & Outlook, Presentation for GA, 12 November 2013

[26]Bakken, I.S.; Hofmann, M.; Analysis of sensitivities in maintenance strategies for offshore wind farms using a simulation model; EWEA OFFSHORE 2013: Frankfurt; 19 November - 21 November 2013

[27]Zhang, Z.; Matveev, A.; Nilssen, R.; Nysveen, A.; Ironless multi-stage axialflux permanent magnet generator for offshore wind power application; 12th Joint MMM/Intermag Conf.; USA; 2013

[28]Magnusson, N.; B. Jensen, B.B.; Abrahamsen, A.B.; Nysveen, A.; Superconducting Generator Technology for Large Offshore Wind Turbines; DeepWind'2013 Conference; Trondheim; January 2013

[29]Lindau, S.; Magnusson, N.; Taxt, H.; A Method to Estimate the necessary Twist Pitch in Multi-filamentary Superconductors; European Conference on Applied Superconductivity, Genoa, Italy, September 2013

NOWITECH Annual Report 2013

April 2014

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Design: synlig.no
Trykk: K-print

NOWITECH (Norwegian Research Centre for Offshore Wind Technology) is a centre for environment-friendly energy research started in 2009 co-funded by the Research Council of Norway, industry and research partners.

The objective of NOWITECH is pre-competitive 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. Work is focused on technical challenges including a strong PhD and post doc programme:

- Integrated numerical design tools for novel offshore wind energy concepts.
- Energy conversion systems using new materials for blades and generators.
- Novel substructures (bottom-fixed and floaters) for offshore wind turbines.
- Grid connection and system integration of large offshore wind farms.
- Operation and maintenance strategies and technologies.
- Assessment of novel concepts by numerical tools and physical experiments.

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Research partners
- SINTEF Energy Research (host)
- Institute for Energy Technology (IFE)
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- Technology (NTNU)
- Norwegian Marine Technology Research
- Institute (MARINTEK)
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- Technical University of Denmark (DTU Wind Energy)
- TU Delft

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The Centres for Environment-friendly Energy Research (CEERs) scheme is an initiative to establish time-limited research centres which conduct concentrated, focused and long-term research of high international calibre in order to solve specific challenges in the field of energy and the environment.