Disseminating laser wind techniques

Torben Mikkelsen and **Søren Knudsen** from the Technical University of Denmark lead a collaborative approach to develop new research infrastructure for wind generation across Europe

Could you highlight the key attributes of the newly developed WindScanner facility?

The Windscanner is the first-ever remote sensing-based, portable, three-dimensional wind vector measuring system designed to serve the European wind energy research community and the growing wind industry in Europe.

The technology can be ground-based or integrated into the wind turbine hubs, spinners, nacelles and blades to provide detailed and timely prevision of the incoming wind field and wind gusts. The information provided will allow wind turbine manufacturers to match the design and size of a turbine used on a specific site to the local wind conditions, allowing wind energy to be exploited more efficiently.

Mobile WindScanner units will become available for deployment both on- and offshore via regional nodes throughout Europe for monitoring local wind conditions and mitigating frequently encountered problems at existing wind farms. In order to achieve this, a joint, concerted action is needed at European level. The idea is that several WindScanner nodes in Europe will jointly develop this highly advanced and expensive instrumentation and train experts to utilise this technology. The aim is to build highly specialised competence centres in Europe that can continuously develop the technology and host experiments under different climate and terrains conditions, but also serve regional industry. Users not connected to the WindScanner nodes will be granted access based on a common European scheduling and access programme. If realised, this should spur a faster development and dissemination of the technology in a true open innovation process, instead of it being left as a purely national or even institutional effort. This is a new approach to innovation in a technology area strongly interlinked with industry.

How does Windscanner build on exisiting technology?

WindScanner is a step up from state of the art laser-based light detection and ranging (lidars) devices and recent telecom-spurred innovation within fibre-based lasers and electro-optics components. Lidars transmit laser beams into the air, and when they hit particles, they are reflected back to the lidars receivers. Doppler shift information carried with the reflected beams provides information about wind speed aloft. 3D wind scanners consist of three steerable wind lidars systems working together to produce a map of the wind velocity in three dimensions.

By which methods are you hoping to disseminate your technological findings?

Following its forthcoming three-year preparatory phase (2012-15) the WindScanner Research Infrastructure will continue to build on existing national research activities. In Denmark the national Windscanner.dk facility is under construction and being integrated with existing and planned research activities on a national scale. These include testing full-scale turbines at sites at the DTU Risø campus, Høvsøre, Østerild and Horns Rev offshore. We are also making notable contributions overseas via new and ongoing collaboration with the National Renewable Energy Laboratory (NREL) in Colorado, and Sandia in New Mexico, US.

To what extent is the European Strategy Forum on Research Infrastructures (ESFRI) supporting the WindScanner facility?

ESFRI will facilitate the preparatory work on developing a detailed technical design and budget, as well as the necessary discussions with partners and Member States on whether to establish the actual pan-European facility in 2-3 years from now. The exact nature of each of the nodes in the RI still needs to be identified and analysed. At the national level the project is already included in the 2011 Danish Roadmap for Research Infrastructures. All the European Energy Research Alliance (EERA) partner countries have the opportunity to create their own national WindScanner node. Designs and locations are specified nationally and between partners.

Technologically **advancing** wind measurement

While wind power generation is increasingly being used as an alternative energy source, turbulence measurements are still in their infancy. However, a new approach using laser-based wind measurement devices may help the European wind industry develop more efficient turbines

WIND-GENERATED ENERGY requires zero fuel and is increasingly being harnessed as an alternative energy source around the world. Within the EU, figures from the European Wind Energy Association show more than 9,000 MW of wind energy capacity was installed last year, contributing to the nearly 94,000 MW total which supplies 6.3 per cent of the region's electricity. With an average annual increase of 15.6 per cent over the last seven years, the wind energy industry's growth is showing no sign of abating.

Traditionally, the wind energy content in the wind is measured by the local wind field's speed and direction. Anemometers – three cups that capture the wind as it rotates around a vertical axis – record speed, while wind vanes record the direction. Collecting this data is essential to ensuring wind farms are positioned in the most profitable places for generation, where powerful winds are most frequent.

COLLABORATIVE APPROACH

Torben Mikkelsen and Søren Knudsen from the Technical University of Denmark (DTU) are coordinating a new approach to expand existing knowledge about wind and record more accurate measurements, bringing multiple benefits to the wind energy industry as a result. The project was first conceived in 2009 as WindScanner.dk, a national infrastructure activity, before the DTU partnered with other European wind energy research organisations to develop a distributed Research Infrastructure (RI) named the European WindScanner facility. The proposal was included in the European Strategy Forum on Research Infrastructure (ESFRI) Roadmap on Pan-European Research Infrastructures as a top European priority. In order to ensure the technical, organisational and financial maturity the initiative has now received funding from the European Commission for a three-year research infrastructure preparatory phase (RI PP). WindScanner uses a new remote sensing-based wind measurement system to provide more detailed maps of the wind and turbulence conditions around either a single wind turbine or across a farm covering several square kilometres.

The WindScanner infrastructure builds upon recent advancements in remote wind-measuring technology to create measurement techniques called wind lidars (light detection and ranging), which enable the facility to measure wind flow and turbulence across various terrains. The units can be integrated in wind turbine hubs, spinners, nacelles and blades. As well as being deployed onshore, the infrastructure can be operated offshore from stable and floating platforms across regional nodes throughout Europe.

At the Danish test site, Mikkelsen and Knudsen – alongside collaborators Mikael Sjöholm, Nikolas Angelou and Anders Tegtmeier – have tested three short-range and three long-range WindScanners. The short-range devices are flexible and can be easily configured for specific measurement campaigns. They have already seen full development during the scanning of wind flow over buildings and small hills, marking the first time turbulence has been measured remotely across such complex terrains. Additionally, during the early tests, the team successfully performed a detailed two-dimensional mapping of downwash wakes from low hovering helicopters. The long-range WindScanners have so far been used to measure wind speed and direction of up to 6 km at the DTU Risø Campus, while wind profiles were measured at heights of 100-1,600 m.

Which strategies or approaches are being employed by the team in order to achieve detailed and accurate results?

The lidars' spatial and temporal resolutions are modelled and theoretically calculated. The instruments are designed and their performances evaluated experimentally during full-scale test measurements in the lab and at the wind energy test sites. Secondly, the scanners' pointing accuracy with both the short- and long-range systems are evaluated both statically and during scanning. Their uncertainty and backlash features are meticulously monitored, evaluated and improved upon as necessary.

We also compare the remote sensing instruments' wind vector measurements with corresponding measurements points obtained from precision instrumentation installed in tall meteorological masts.

What enhancements have been made to existing wind tunnel testing?

Wind tunnels capable of generating wind speeds up to 100 m/s are advantageous for providing detailed information for design and flow over a blade segment with high Reynolds numbers. By contrast, WindScanners measure wind conditions around entire wind turbines and wind parks within fully developed turbulence with all natural atmospheric scales embedded (eg. large-scale meander) and with the significant atmospheric stratification effects also present. WindScanners can measure wind and turbulence structures affecting huge wind turbines and their interaction more realistically than is possible in a limited-scale wind tunnel.

THE EUROPEAN WINDSCANNER FACILITY

OBJECTIVES

- Develop 6 to 8 new partner nodes at existing or planned test facilities across Europe. The nodes will be national/regional competence centres responsible for the continuous development of WindScanner technology and training of experts
- Undertake a coordinated experimental research programme for large European-level wind energy measurement campaigns based on key contributions from WindScanner
- Establish a central facility/hub to disseminate and service the instrumentation; handle data flow and management; host servers; and train experts and users

PARTNERS

DTU Wind Energy; **IPU**, Denmark • **CENER**, Spain • **ECN**, The Netherlands • **CRES**, Greece • **Fraunhofer IWES**; **ForWind**, Germany • **SINTEF**, Norway • **LNEG**; **University of Porto**, Portugal

CONTACT

Torben Mikkelsen
Responsible for Technology and Innovation
Professor in Remote Sensing for Wind Energy

T +45 4677 5009
E tomi@dtu.dk

Søren Knudsen
Project Coordinator

Technical University of Denmark
DTU Wind Energy
Risø Campus
Frederiksborgvej 399
Building 125
4000 Roskilde, Denmark

T +45 2070 4621
E sknu@dtu.dk

TORBEN MIKKELSEN leads a group at DTU Wind Energy engaged in innovation and dissemination of remote sensing-based WindScanners for experimental research and measurements of atmospheric flow and turbulence.

SØREN KNUDSEN is employed at DTU Wind Energy in the Management and Administration Unit, where he is responsible for strategic planning and international affairs.

Technical University of Denmark

DTU

EUROPEAN EXPANSION

Following its three-year preparatory phase (PP) the WindScanner facility will begin to be constructed in late 2015 and disseminated across Europe thereafter. Promotional material such as website branding, publications, papers delivered at the European Strategy Forum on Research Infrastructures (ESFRI) conferences; annual project workshops with participation from stakeholders will be used to raise awareness of the new RI PP. Additionally, over the course of the three years, the European Energy Research Alliance (EERA) project partners will present and discuss the RI PP's ongoing results at major wind and renewable energy events.

ESFRI is supporting the WindScanner team led by DTU to develop an in-depth technical and design budget, examining different financing models to propose and prepare discussions with other EU Member States. Further collaboration is planned with the RI facility's many EERA partners (such as German ForWind) for activities including offshore testing, eg. at Krieger's Flag, and wind turbine control.

While Denmark and Germany already have national wind energy infrastructure activities, implementation in other European countries will depend on national funding for each of the nodes, as well as the running costs for each facility. Other issues such as choice of governance model, handling of intellectual property rights (IPR) and open access may present obstacles to deployment, but Mikkelsen and Knudsen believe the RI PP is well-equipped to overcome them.

Once the construction phase commences in 2015-16, the WindScanner facility will play a pivotal role in upgrading the anticipated European partner nodes with modern lidar technology and helping each of the EERA partner countries build their own national node facilities. A coordinated experimental research programme is also expected to take place to develop a comprehensive database that will gather all of the wind data and provide site-specific information on wind conditions before on- and offshore wind turbines are created and installed. From this information, the facility hopes to improve the modelling of local flow conditions, streamline wind turbines and reduce the costs of wind production. Additionally, from 2016, the facility will set up a WindScanner.eu hub to manage the data from across all the European nodes, as well as train researchers and technicians.

Mikkelsen and Knudsen hope the RI PP will enable wind manufacturers to more accurately match the design and size of a turbine at a specific location, according to local wind conditions, and complement wind tunnel scale testing. Additionally, they believe that WindScanner will not only benefit the European wind industry but will also, for instance, enable the aviation industry to detect wind shear and turbulence on runways, which will make flying and landing more safe. The construction industry is also thought to benefit from the information provided by the WindScanners as the lidars will be able to assess wind loads on tall buildings.

> As well as being deployed onshore, the infrastructure can be operated offshore from stable and floating platforms across regional nodes throughout Europe

Looking ahead, Mikkelsen outlines the next stage for WindScanner: "Helped by the ESFRI process, the consortium is excited about reporting new WindScanner prototype equipment through wind energy-orientated research conferences and publications".