TECHTALK

R&D monitoring for optimised turbine designs and O&M

Offshore wind energy continues to experience an increasing share of the electricity generation market in Europe. Both the UK and Germany have set up ambitious goals to further expand their offshore wind energy capacity. Relatively smaller countries such as Belgium for example are also stepping up their offshore capacity and are investing in research projects for optimised turbine designs and improved operations and maintenance (O&M) in order to bring down the overall cost associated with offshore wind energy.

At the moment there is a lot of activity in the Belgian sector. The last turbine of the 325MW C-Power wind farm has been installed and full commissioning will be carried out through the summer.

Not far away the 216MW Northwind farm is also busy with installation work at the moment. The monopiles and substation are installed, now the next part of the project is installing the V112 turbines. The 6MW Alstom Haliade turbine is also scheduled for installation soon in the Belwind farm.

Apart from all the installation and operation activities in Belgian waters, there is a lot of research work being carried out by OWI-Lab and their partners, in order to drive new technological improvements.

Costs reduction, a driver to set-up research in the field

In comparison with onshore wind energy, the offshore sector is still low down on the learning curve. Both capital investment costs (CAPEX) and operations and maintenance costs (OPEX) need to be reduced. On the other hand the production output (availability and capacity factor) needs to be increased in order to meet the goals of reaching an LCOE (levelised cost of energy) of €120-125/MWh by 2020. Some developers even aim at an LCOE of €100/MWh.

To meet these ambitious goals new technology developments and innovations throughout the value chain are essential. Improved wind resource assessments, new multi megawatt turbines using different drivetrain topologies, improved installation vessels are some examples of development and innovation. The continuous improvement of existing technology will also help in reaching these goals.

For this reason OWI-Lab has set-up multiple R&D field measurements which have the goal of assessing the health of different wind turbine components. OWI-Lab, working in close collaboration with specialists from the wind farms, now have a greater understanding of the remaining lifetime of components as a result of these measurements. Appropriate measurement strategies for assessing lifetime parameters of the different subcomponents of the wind turbine can bring added value in CAPEX and OPEX cost reduction.

CAPEX cost reduction can be realised by design improvements to reduce material and production costs. Highly accurate, detailed and validated loads at the different turbine and foundation subcomponents can reduce uncertainty and allow for lower levels of redundancy in designs and consequently material reduction.

Loading is dependent on site and changes in time. Special events which are important for lifetime calculations such as emergency shut downs only occur sporadically.

Therefore it is important to conduct long term measurement campaigns to capture all relevant loading conditions. The multi-physics and highly coupled nature of the offshore wind turbine stimulates the use of an integrated approach to achieve maximum efficiency of design changes.

An illustration of this is a weight optimised drivetrain, achieved for example by extra awareness of overall loading conditions, which can significantly impact foundation design.

Focusing on the other hand on the OPEX costs; the long term information about loads on the turbine components can be used for predictive maintenance strategies in order to optimise maintenance tasks. The approach aims to detect problems and take counter action or replace components before failure occurs; but not earlier than is absolutely necessary.

Such a strategy reduces the need for unscheduled repairs and the amount of downtime and lost production related to failures. However, the main challenge in this approach is assessing, not only the current condition but also the remaining lifetime of each specific wind turbine. This means that not only the occurring failure is detected, but also possible future failure is accounted for.

One approach is using the time series of forces, accelerations, and corrosion rates that have actually occurred during the life span of the wind turbine, since loading is site dependent. Monitoring of these parameters during the turbine lifetime can give relevant vital information to wind farm operators.

Since offshore field data of multi-physical parameters can have influence in two ways, in both design optimisation and in improved O&M, OWI-Lab aims at supporting the development of such tools and measurement techniques to assess the lifetime of a wind turbine.

OWI-Lab supporting innovation projects

OWI-Lab, Offshore Wind Infrastructure Application Lab, is a Belgian R&D initiative started in 2008 combining industry, education, and research centres. There are more than 30 partners, including manufacturers, wind farm operators, universities, small and medium enterprises (SME's) and well known companies in the wind industry which participate, in order to create technological improvements which ultimately will lead to reducing the LCOE.

Pieter Jan Jordaens, who is responsible for Business development & innovation at OWI-Lab explains: "The initiative came in response to a sense of lack of proper public testing and measurement equipment for the fast growing offshore wind market that was still in its infancy." A lot of research projects regarding wind 'field monitoring' have been carried out in real life offshore conditions including the development of a floating LIDAR system (Called FLIDAR) developed by 3E and DEME-OWA.

There is also OWI-Lab's large climatic test chamber that has been installed in a new laboratory in the port of Antwerp. OWI-Lab provides "a unique experience and challenge for the associated researchers who, now, will not need to go offshore as most research can be done in the university or laboratory", Mr Jordaens explains.

OWI-Lab field measurements for R&D purpose at Belwind

One of the early partners of OWI-Lab is Belwind. This offshore wind farm is located in the North Sea on the Bligh Bank, 46km off the Belgian coast. It was one of the first far shore wind farms and it consists of 55

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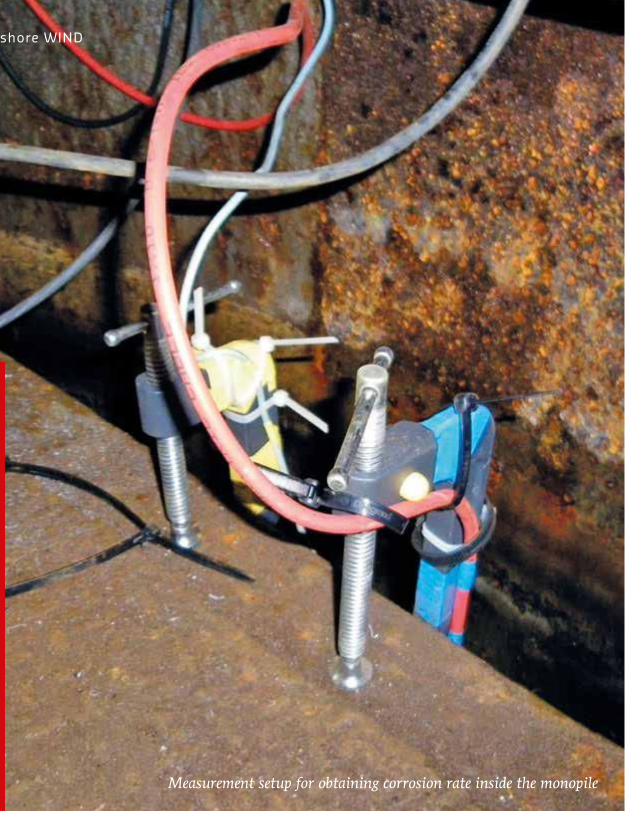


Measurement setup for obtaining corrosion rate inside the monopile

Vestas 3MW wind turbines placed on monopile foundations. Both parties have benefitted from the on-going research monitoring campaigns. The motivation is gaining knowledge and experience that are crucial to minimise construction and installations costs of the future planned wind turbines at the Belwind concession (design optimisation), to extend the lifetime of existing structures, and reduce their operation and maintenance costs (O&M optimisation).

Specific monitoring systems have been installed on one turbine in order to monitor and record the dynamic behaviour of turbine structure, the corrosion rates, the grout integrity and drivetrain loads.

Dynamic monitoring of turbine foundation and tower

“Continuous monitoring of the dynamic behaviour of the foundation and tower by a set of accelerometers has been carried out for more than 18 months to date. The unique dataset is measured and transmitted to an onshore server where we collect the sensor data and additional parameters”, says Professor Christof Devriendt, scientific research coordinator of OWI-Lab. “We use operational modal analyses (OMA) tools used by the aerospace industry to get better insights in the dynamic behaviour of these structures far out at sea.”This monitoring campaign focuses on the continuous measuring of vibration levels, resonant frequencies and damping values of the fundamental modes of the support structure. These parameters can be crucial to minimise O&M costs and to extend the lifetime of offshore wind turbines structures during their operation.

For example when it comes to monopile foundations, scouring and reduction in foundation integrity over time can be problematic because they reduce the fundamental structural resonance of the support structure. This results in aligning that resonance more closely to the lower frequencies at which much of the broadband wave and gust energy is contained.

Thus the lower the natural frequency becomes results in more wave energy that can create resonant behaviour, which, in turn, increases fatigue damage.

Continuous monitoring of the effect of scour on the dynamics of the wind turbine will therefore help to make a better decision on when to plan scour protection system maintenance activities.

Corrosion rates of the support structure

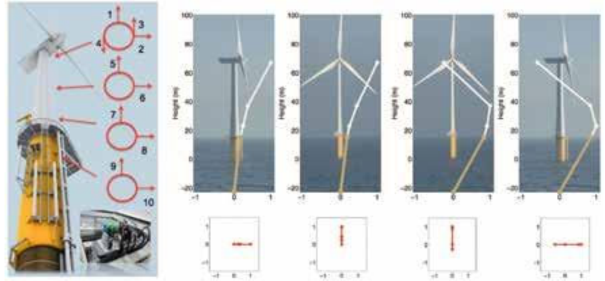
Corrosion represents a specific challenge for offshore foundations, as the foundation steel will spend at least 20 years of it functional life in submerged conditions. The remote locations together with the underwater conditions make corrosion inspections an intricate task. ‘Zensor’, a spin-off of the Vrije Universiteit Brussel (VUB), developed an innovative solution capable of continuously measuring corrosion rates at a remote location and transmitting the results to an onshore database. OWI-Lab supported Zensor in setting up the offshore field measurements. Prof. Yves Van Ingelgem explains: “Measurement electrodes have been placed on the inside of the monopile structure. The corrosion rate is continuously monitored at multiple depths using these electrodes.” A detailed knowledge of the corrosion state of the foundation allows for a significant cost reduction:

- Repairs can be conducted before serious damage has occurred.
- Avoiding specific and costly inspections.
- Corrosion-related maintenance can be condition-based, including improved planning of operations.
- Prevention of unforeseen corrosion-related failure before the projected lifetime.
- Deducing relevant information allowing for cost-reduction in future wind farms.

Grout integrity

Recently a third measurement campaign was initiated that focuses on the grout connection. The grout is designed to act as an adhesive between the pile foundation and the transition piece of the turbine. This campaign is needed to check if the grout is failing which could cause the turbine to slip. There will never be a safety issue as supporting brackets prevent the turbine towers from slipping completely. Between these brackets and the monopile structure elastomeric bearings have been fitted combined with load cells and displacement sensors.

The data from these sensors is currently also being analysed by researchers. From this data monthly reports are created allowing the continuous monitoring of the grout connection. Also a more detailed measurement campaign using innovative fibre optic sensors is currently being considered to get an even better insight in the long-term behaviour of grout-connections.



Measurement setup for obtaining vibration levels and vibration modes of tower and foundation

Drivetrain load identification measurement campaign

This measurement campaign has the goal to identify internal loads at critical subcomponents within the gearbox. “The aim is to develop the instrumentation technology to visualise and track over time the most important internal gearbox parameters needed in the remaining life time calculations,” says Dr. Ir. Jan Helsen.

By keeping the instrumentation complexity as low as possible it is envisaged to allow the instrumentation of all turbines in a wind park in a cost effective way. By partnering with either or both a gearbox and generator supplier it should then be possible to use the resulting time series to get a valid remaining life estimate for each subcomponent in the drive train. The wind farm O&M manager can then use this information to optimise maintenance schedules and logistic plans.

This approach is complementary to the different techniques currently available to assess whether failure is initiating or already further developed. The most commonly used approaches to assess current condition of wind turbine drive trains are: oil analysis, vibration analysis and acoustic analysis. However it is less straightforward to use them in a predictive way. The main goal is to develop and provide proof of concept of the appropriate instrumentation methodology for this purpose and then set the first steps for analysing the time series resulting from the measurement campaign.

Thanks to OWI-lab