2760

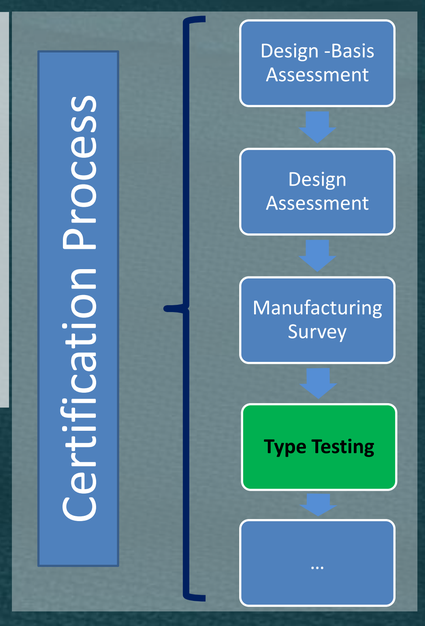
Measurement Concept for Floating Offshore Wind Turbines

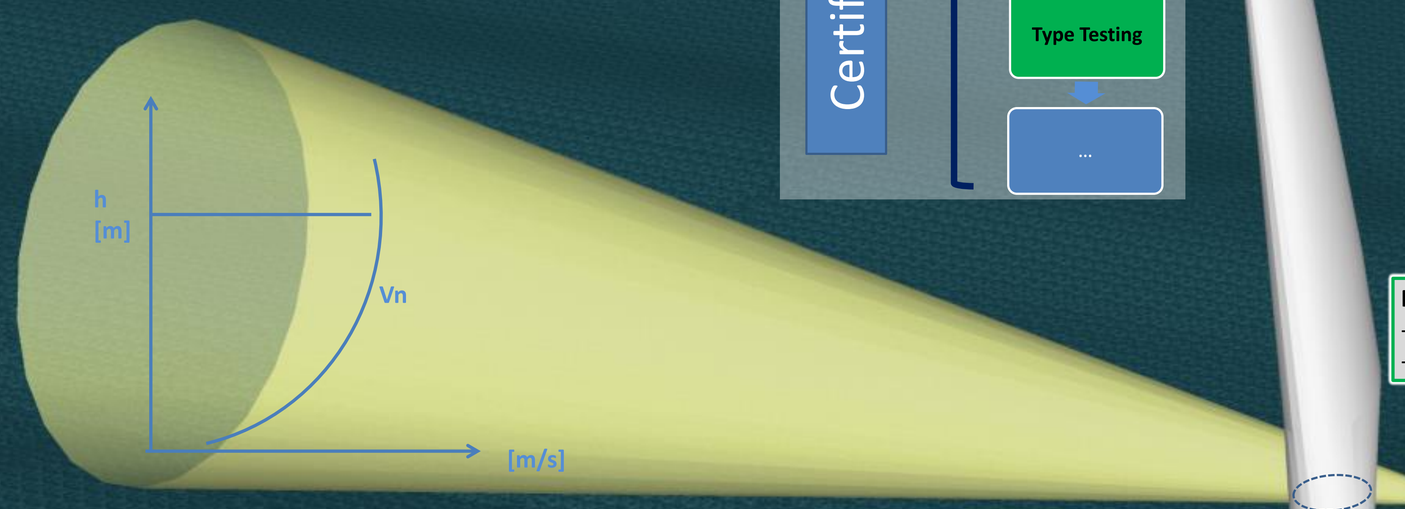
Dipl.-Ing. (FH) Patrik Jübermann, Dipl.-Ing. (FH) Hans-Peter Link
DNV GL ENERGY

KEYWORDS: *structural loads, FOWT, type testing, IEC 61400-13*

Introduction

While the offshore wind industry for turbines on solid foundations is growing rapidly, suitable solutions for deep water sites still remain a rare sight. Currently, there are more than 30 different types of floating offshore wind turbines (FOWT) being developed, and the demand for this technology is increasing. However, all developers share a common problem: the lack of standards and practices to guide their products through the certification process. One important step of the certification are the load measurements, which are used to verify the design parameters and load assumptions. Since 2011 we have been involved in a structural load measurement campaign on the Windfloat™prototype in Portugal.
Using our experience with the windfloat measurement campaign and some fine tuning with DNVGL Certification, we have developed the measurement concept which is presented in the green-framed boxes on the right half of this poster.



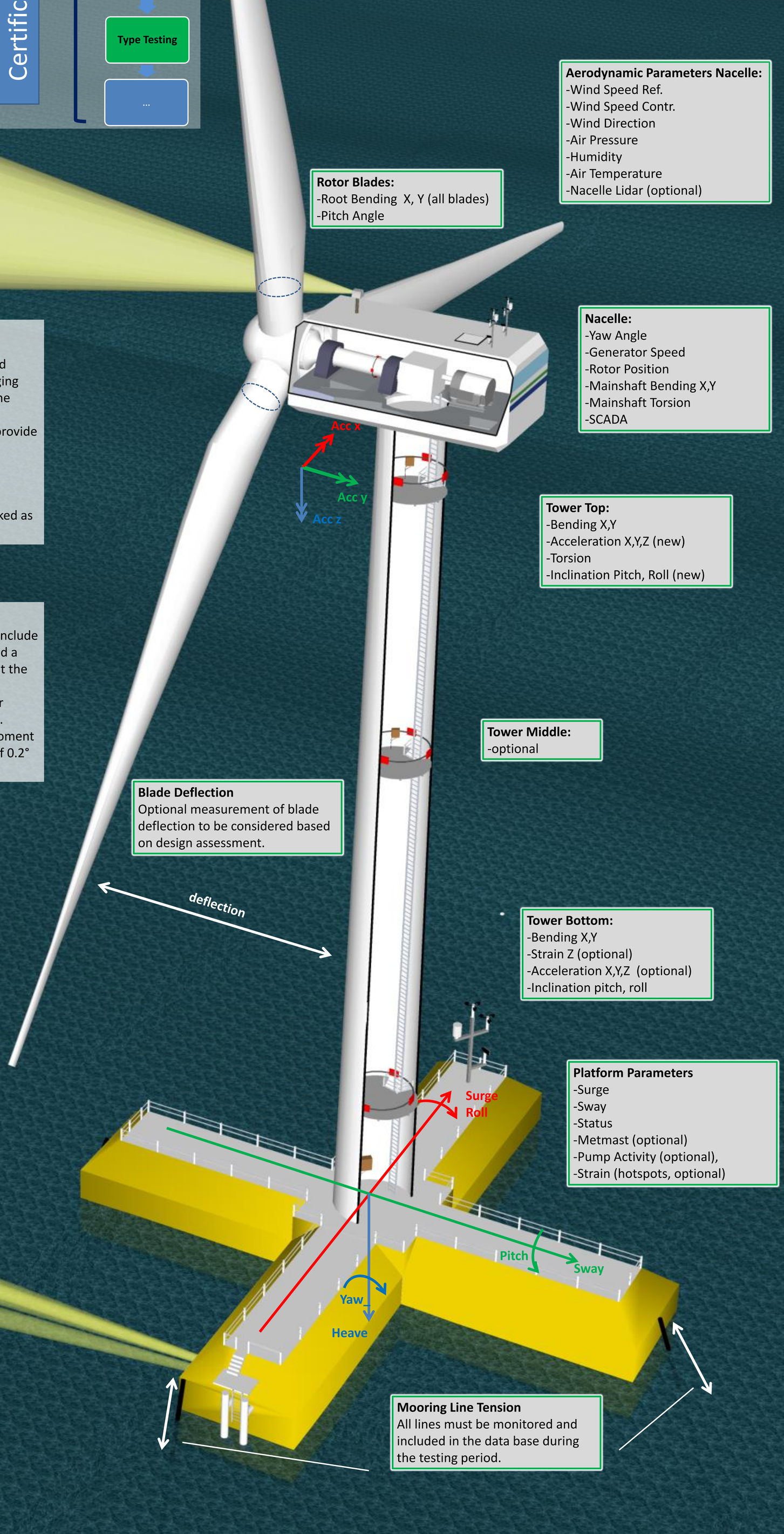


Global Coordinate System
Measurement results shall refer to a stationary coordinate system which is fixed to the platform geometry. In reference to geographic coordinates the X-Axis points north, the Y-Axis points east and the Z-Axis points downwards. The right-hand-rule should be followed to determine axis- and rotational directions. The yaw angle between platform north and true north should be monitored.

Aerodynamic Parameters Nacelle:
-Wind Speed Ref.
-Wind Speed Contr.
-Wind Direction
-Air Pressure
-Humidity
-Air Temperature
-Nacelle Lidar (optional)

Rotor Blades:
-Root Bending X, Y (all blades)
-Pitch Angle

Nacelle:
-Yaw Angle
-Generator Speed
-Rotor Position
-Mainshaft Bending X,Y
-Mainshaft Torsion
-SCADA



Tower Top:
-Bending X,Y
-Acceleration X,Y,Z (new)
-Torsion
-Inclination Pitch, Roll (new)

Tower Middle:
-optional

Blade Deflection
Optional measurement of blade deflection to be considered based on design assessment.

Tower Bottom:
-Bending X,Y
-Strain Z (optional)
-Acceleration X,Y,Z (optional)
-Inclination pitch, roll

Platform Parameters
-Surge
-Sway
-Status
-Metmast (optional)
-Pump Activity (optional),
-Strain (hotspots, optional)

Sea Condition Parameters
-Wave Height
-Wave Direction
-Swell
-Current Speed
-Current Direction

Mooring Line Tension
All lines must be monitored and included in the data base during the testing period.

Key Considerations

Whereas the codes of wind turbine models with **solid foundations** have been often verified and optimized, the simulation and verification of turbines on **floating foundations** is still a challenging subject. New aspects are the higher level of complexity due to the floating motion as well as the hydrodynamic forces which interact with the structure.
A measurement concept for floating wind turbines should therefore address these issues and provide results that can be used to verify codes and improve designs.
Our approach is based on following principles:

- All external and internal forces must be represented
- The base of the concept is IEC 61400-13 with deviations and extensions
- To reduce costs, the sensor list resembles the required minimum, additional signals are marked as „optional“.

Calibration Procedures

Conventional calibration methods for bending moment signals in tower, mainshaft and blades include the determination of a signal offset. This is usually done by the rotation of a steady mass around a defined axis. The average of the maxima/minima values of the signal response should represent the offset.
As the floating capabilities of the platform never allow a steady state within necessary limits for calibration, the obtained offsets vary every time the calibration maneuver has been performed.
At tower tilt angles of less than 2° this can already influence the offset of the tower bending moment signals of more than 10% of the maximum values. Inertial-sensors with an roll/pitch accuracy of 0.2° or better could be used for offset correction.

Conclusions

The measurement concept for a structural load measurement campaign on a Floating Wind Turbine includes core elements of the IEC 61400-13 as well as additional quantities.

- Quantities concerning the turbine are accelerations in all three directions in tower top and inclination in tower top and tower bottom.
- Wind speed measurements can be conducted with nacelle anemometry or the use a LidaR device.
- Regarding the floating platform, the position and orientation must be monitored with adequate accuracy. Load measurements of the support structure have to be defined by the certification body.
- The mooring line tension must be recorded on all lines (direct or indirect measuring methods possible).
- To evaluate the hydrodynamic forces, various sea condition parameters must be included in the database: wave height, wave direction, swell, current speed and current direction.
- Calibration procedures for load signals must be revised as well as the uncertainty calculations.

As for power performance measurements, a much more detailed knowledge of the wind field is required. This concept only applies to load measurements.

Acknowledgements

The development of the concept has been funded by DNV GL. We thank DNV GL Renewables Certification for its valuable input.