Advances in Offshore Wind Technology

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1. Introduction

The new generation of large wind turbines, which is specifically designed for Offshore application, is now in the prototyping phase. The currently largest wind turbine REpower 5M is in operation since autumn 2004. First Offshore prototypes of this type shall be installed in 2006. This paper does focus on the mechanical and structural issues related to large Offshore Wind turbines. Other challenging areas – like electrical engineering, financing or operation and maintenance – are not discussed.

2. Wind turbine technology

Due to the demanding offshore environment with a reduced accessibility, the main emphasis in the development is an economic design of the turbine with a high reliability and a high availability. The REpower 5M is based on proven technology and can be regarded as a logical evolutionary step compared to the smaller turbines. This is a significant difference compared to other large wind turbines which are based on new concepts which don't have a proven track record.

The REpower 5M is equipped with a three-bladed rotor with pitch control. Rated power is 5000 kW (5 MW) with a rotor diameter of 126m. The prototype has been installed on a steel tower with a hub height of 120m. The turbine has been designed for strong wind sites with an annual mean wind speed of 10.5m/s at hub height.

The main technical features of the REpower 5M can be summarized as follows (see also [1]):

- Modular drive train with flanges
- Double drive train bearings (CARB™ and spherical roller bearing)
- On board crane for Operation & Maintenance (Capacity: 3.5t)
- Service friendly design
- Power Electronics and Transformer in the nacelle

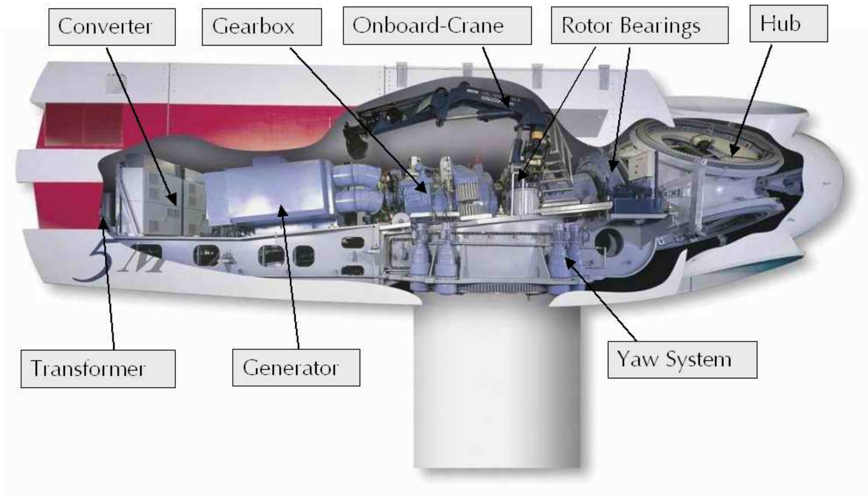

Fig. 1. Arrangement of main components

The rotor blades have been developed in cooperation with LM Glasfiber with the largest rotor diameter ever designed. The blade structure of the LM 61.5 is optimized such that a low blade weight is achieved, in combination with high static permissible stress and high energy yield.

The main, or rotor shaft is supported by means of two bearings. The first, non locating bearing is a so called CARB™-bearing, which can handle much higher dislocations compared to a conventional spherical roller bearing. The second, locating bearing is a spherical roller bearing, which protects the gearbox from external loads (other than the torque) to a large extent. Thus the double bearings will increase the safe life of the gearbox.

The gearbox is a planetary gear with one spur wheel. It is equipped with a refined system for oil filtration and cooling. The oil is filtrated down to 6µm and the cooling system prevents high oil temperatures. Thanks to the double bearing of the main shaft and a robust rotor lock, the gearbox can be disassembled without taking the rotor down.

A double fed inducing generator is used, together with an IGBT inverter. Four water cooled inverters are used with a redundant combination of every pair of two modules. This means, that on failure of one module (or pair), the turbine can still be operated at reduced power (up to 3 MVA).

The GFRP nacelle panel and spinner consist of several parts and are protected by means of a sophisticated lightning protection system.

The simulations of the 5M are extensively compared with measurements. Results so far show a very good agreement between the simulations with Flex 5 and the measurements (see Fig. 2)

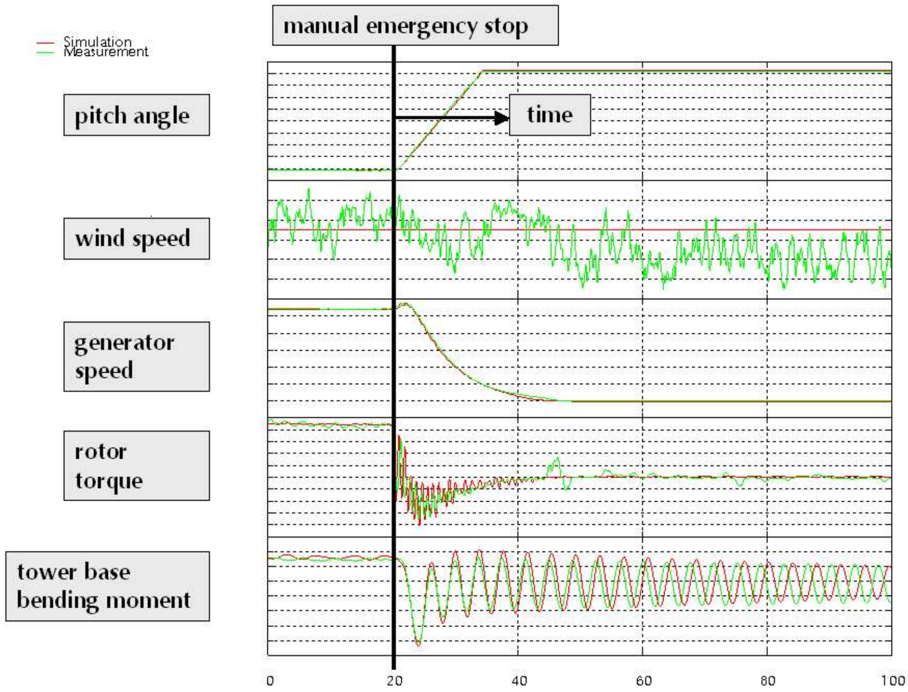

Fig. 2. Comparison between simulation and measurement

3. Substructure technology

One of the main drivers for an economic installation is the substructure design. Many developments on substructure concepts are ongoing and the industry is clearly moving towards more competitive concepts. REpower has worked extensively on design methods for the combined wind and wave loading and several substructures have been evaluated from technical and economical point of view.

3.1. Design methodologies

So far a substitute Monopile is used to represent complex substructures for simulation of the turbines [2]. Although this “semi-integrated” methodology is workable for many substructures, there are some drawbacks:

- Stiffness representation with a Monopile is not good for all kinds of substructures. This leads to significant differences in overall stiffness and thus eigenfrequencies, which are an important parameter in the transient calculations.
- Wave loading is calculated for a straight vertical member, thus the positive effect of distributed members in wave direction is not taken into account. Furthermore, finding equivalent hydrodynamic coefficients to take account of many members proves to be difficult in many cases.
- The use of foundation models in two different programs, which need to be harmonized e.g. in terms of wave loads, creates an additional interface with more possibilities for errors in the process.

The shortcomings of this approach lead to the development of a new solution with a higher degree of integration of the two programs used [3]. The characteristics of this integrated, sequential approach are:

- Two specialized programs – Flex 5 for the wind loads and ASAS(NL) for the wave loads – have been adapted to each other such that they can be used sequentially to obtain a solution for the integrated system.
- The general approach to achieve this has been based on the existing modeling in Flex 5 which uses generalized degrees of freedom to model the substructure. Six generalized degrees of freedom are used.
- Although the methodology is still an approximation, good results can be achieved for many structures. Good knowledge about the methodology and its limitation are required though for safe and efficient design.

A flow chart of the methodology is shown in Fig. 3.

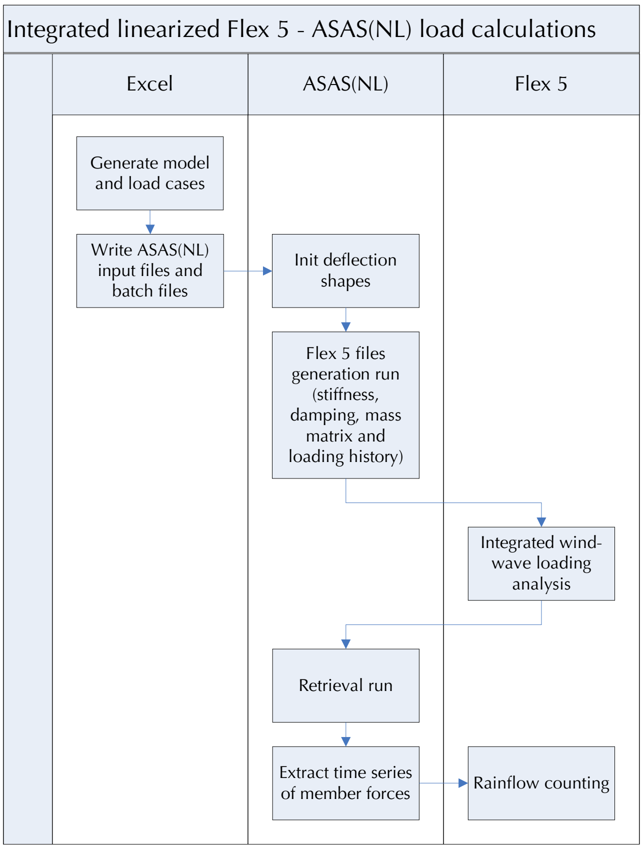

Fig. 3. Overview of calculation process

3.2. Substructure concepts

So far, most of the existing Offshore turbines have been installed with Monopile or gravity base substructures. Due to the size of the 5M and the associated loading, Monopiles are getting quite large and thus other concepts may become more interesting, esp. for water depths in excess of 10m.

Extensive work has been done for the DOWNVInD project which features two turbines for the demonstration phase which will be installed in 45m water depth in 2006. Initially, Tripod foundations which had a weight of over 1000t were foreseen for this project. This selection has been revisited as REpower has worked closely with OWEC Tower – a Norwegian company with a background in Offshore Oil&Gas which is now specializing in Offshore Wind turbines – and it was found that the OWEC Jacket Quattropod (OJQ) offers a much better chance for economic optimization due to lower weight of the substructure. The final design of this structure is currently ongoing and fabrication is expected to commence end of 2005.

Other concepts under evaluation include concrete substructures which are an interesting alternative due to the low material cost. Different concepts are offered on the market, primarily from large building contractors which aim at gaining market shares in this evolving market.

4. Installation methods

Installation concepts are of course closely related to the structural concepts. Installation so far have been executed in a very similar way. Basically the components substructure, tower, nacelle and rotor are installed sequentially, very much in the same way as onshore construction is performed.

The DOWNVInD project will feature significant innovative approaches. Due to the fact that conventional installation is not feasible as jack-ups for 45m water depth are not available for economical conditions, an installation in two pieces is foreseen. The OJQ will be installed and piled first and the full assembly of wind turbine, rotor and tubular tower will be installed as one complete unit as the second piece. The detailed investigation if and how this approach can be made to work is currently underway.

References

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