TECHNICAL CHALLENGES AND THEIR SOLUTION FOR THE BEATRICE WINDFARM DEMONSTRATOR PROJECT IN 45M WATER DEPTH

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Summary

The REpower 5M wind turbine has been installed in the Moray Firth in Scotland as part of the DOWNVInD Demonstrator Project in summer 2006 in 45m water depth. Numerous technical challenges had to be addressed in order to realize this project. This paper gives an overview about the technologies which have been developed with regards to turbine, substructure and installation.

1 Introduction

The Beatrice Windfarm Demonstrator, part of the DOWNVInD Project under the FP6-Programme of the European Commission, is world wide the first project in which wind turbine generators (WTG) have been installed at water depths around 45 meters.

In addition to that the project posed challenges in many more ways:

- First time use of a jacket as substructure for offshore wind turbines
- Offshore transport and installation of an onshore fully pre-assembled WTG
- Use of a specially designed frame system to soft land and install the WTG from a floating crane barge offshore

to mention just the major ones.

Besides there were also all the adjustments which have been carried out to further optimize the 5M for operation in the hostile marine environment.

2 Turbine technology

The design of the 5M prototype, installed in Brunsbüttel in September 2004, was already with the target to build a wind turbine mainly for offshore use. Nevertheless quite a few changes have been made in the last 2 years to enhance reliability and safety far out in the open Scottish North Sea.

Following actions for marinisation of the wind turbine generator have been carried out:

- Dehumidifiers have been installed in the tower and nacelle. These devices keep the air humidity always on a level of 50% relative humidity that avoids condensation of water on colder surfaces and thus reduces the corrosion risk. The dehumidifier in the tower is combined with a ventilation that distributes the dried air on the full length of the tower.
- Corrosion protection
  All bolts, nuts and washers in the WTG up to grade 8.8 are corrosion protected by hot-dip-galvanisation. Those with grade 10.9 have been coated with a combination of an inorganic base coat and a zinc-lamella top layer.

  All metal surface coatings have to comply with Norsok M 501 standard and proof of compliance has to be provided by external auditors.
- Other than in the prototype, which features a 20kV transformer cooled with external air, a fully enclosed step-up transformer to 33kV has been installed in the offshore turbine. As before, the transformer is situated in the rear of the nacelle, thus reducing the transmission losses and allowing lighter and thinner cables in the tower. The complete encapsulation of the transformer increases the safety and eliminates the potential negative impact of sea air.
- A Palfinger Marine crane has been installed in the nacelle with a maximum lifting capacity of 3.5 tonnes which can also lift equipment up to 1.6 tonnes on the extended boom from the heli-hoist. This allows to handle all equipment for standard service as well as all components that might need to be replaced during service live except the heavy main components. For smaller lifts an additional chain hoist with a capacity of 250kg is situated in the rear of the nacelle.

Fig. 1: Nacelle crane

3 Support structure design process

As the design water depth at site is 44m LAT and 50m design water level, simple solutions like Monopile or gravity foundations were found not to be feasible. Extensive studies have thus been initiated by Talisman Energy to determine the best substructure for this demanding project.

Based on studies performed by Atkins, Kellogg Brown & Root, REpower and OWEC Tower, three substructures were considered for the final selection process: A Center Column Tripod (CCT), a Flat Faced Tripod (FFT) and the OWEC Jacket Quattropod (OJQ), a four-legged jacket solution. A comprehensive substructure selection process was then conducted by AMEC, Talisman, SSE and REpower and finally the OJQ was selected for the project. Some results of the studies performed are given in [2] and [3].

The design responsibility was split among the parties as follows:

OWEC Tower:
- Basic design for the OJQ

REpower:
- Load calculations for the integrated system [1]: Fatigue loads were handed over for every member of the substructure, extreme loads were only determined for tower bottom. These were then superimposed with deterministic extreme waves by AMEC. This approach was chosen due to practical limits (i.e. calculation effort required) when deriving member forces for the full model from the integrated model. It was found to be a very workable solution, though.
- Tower design

AMEC:
- Basis of Design
- Detailed design incl. boat landings (Fig. 2), J-tubes, transition node detailing, pile sleeves, etc.
- FLS assessment based on fatigue (stress) spectra supplied by REpower
- ULS assessment based on extreme tower bottom loads

This split in design responsibility turned out to be a very workable setup. It allowed the participating companies to take a leading role in their areas of expertise without the need to share confidential information. REpower has developed sophisticated calculation techniques both for load calculations and further processing for fatigue assessment using stress time series which facilitated an economic design.

Fig. 2: Boat landing

4 Substructure fabrication and installation

The jacket was fabricated in Scotland by Burntisland Fabrications Ltd. As only two demonstrator units were foreseen at this stage, no special fabrication aids were designed and used. The fabrication was hence relatively complicated, making it more expensive than foreseen for serial production. As the structure is fairly simple, fabrication was completed without major difficulties.

Special items for fabrication were:

- Pile sleeves had a heavy wall section (130mm) as swaging had been selected for the connection between pile and pile sleeve.

- Boat landings were quite complicated with many members (Fig. 2). This was due to the fact that a very safe design was chosen which required to accommodate several vertical and horizontal members.

- Grinding was required at some of the K-joints due to high fatigue usage. This was not foreseen in the basic design but proved to be necessary as out-of-plane vibrations of the bracings were predicted which increased fatigue loads [3].

Fig. 3: Fabrication of the jackets

Fig. 4: Fabrication of the transition node

Jacket installation was performed by the Rambiz with a standard installation sequence:

- The jackets were first placed on the seabed, being secured by the mud mats.
- Piles (72'' diameter, one in each corner) were then placed into the pile sleeves, aided by video supervision from an ROV.
- The piles were then driven to target depth with an IHC S-500 hammer.
- The jacket was finally levelled and the permanent connection to the jacket established by swaging. Swaging is a metal forming technique in which the metal is plastically deformed to its final shape using high pressures. The pile diameter inside the pile sleeve is increased and a permanent connection to the pile sleeve established (see http://www.oilstates.com/ for details).

Fig. 5: Jacket on barge prior to installation

The last part of the substructure installation was installation of the boat landings and the insert module inside the transition node which contains the emergency refuge and the switchgear. These items were installed separately as they would have been interfering for the main jacket installation.

Installation of the turbine was prepared by installation of the JIF arms (see following section).

Fig. 6: Jacket installed

5 Turbine Installation

The REpower 5M turbine was pre-installed as a complete system, consisting of tower, nacelle and blades in the base harbour of Nigg in the Cromarty Firth. This installation took part on the TIF, acronym for “tower interface frame”, the upper part of the soft landing offshore installation equipment (designed by The Engineering Business Ltd). Thus, the TIF also acted as a wide base or interim gravity foundation. Once this was completed, the TIF was then also used to lift the entire system with the crane barge Rambiz.

Fig. 7: WT-A installed on the TIF in Nigg

After a 12 hours transfer to the site in the Beatrice Oilfield in the outer Moray Firth, supported by an offshore tug, the offshore installation was started. The TIF and its matching counterpart, the JIF, short for “jacket interface frame”, make up a soft landing device. This allows to compensate the crane barge’s movement caused by waves and swell up to around 1.0m sea level movement.

Following the successful first time landing of this kind, the WTG could get positioned with hydraulic actuators to match the bolt holes circles of the tower and substructure flanges. After completion of the bolting the spreader beam was lowered and the structure released from the hooks of the Rambiz.

As all these operations have never been carried out before, the major difficulty with it was to determine the limiting factors and agree with all partners on an acceptable level of risk mitigation.

Confidence, as with all first time projects of such magnitude, will increase with the level of experience. This could allow to change from conservative limits for wind speed and wave height to higher figures, which will widen the operational window for this installation methodology and in turn could make it an alternative too existing installation methods for deep sea wind farms.

Fig. 7: Transit to site

Fig. 8: Turbine landed on jacket

Fig. 9: Installed turbine in the Beatrice Field

6 References

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