SJOQ - PUBLIC REPORT

TSE HE 2018

Eindverslag over de uitvoering van de activiteiten en de resultaten ervan

Title: Slip joint offshore qualification

Abbreviation:	SJOQ
Project number:	TEHE117056
Project period:	04/2018 – 12/2019

Consortium partners:

DOT BV (Penvoerder):	Delft Offshore Turbine B.V., Raam 180, 2611WP Delft, NL
TU Delft:	Faculty of CEG, Section of Offshore Engineering, Stevinweg 1, 2628 CN Delft, NL
Van Oord:	Van Oord Offshore Wind B.V., Jan Blankenweg 2, 4207 HN Gorinchem, NL

Project funding:

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Ministerie van Economische Zaken

TOPSECTOR ENERGIE
Empowering the new economy

1. EXECUTIVE SUMMARY

Background and objectives

To lower the cost price of offshore wind energy this project focussed on the connection between the foundation pile and the turbine. The current state of the art has two solutions: grouting or bolting, see Figure 1. The bolted connection has come into fashion recently, but requires regular inspection and maintenance during its operational lifetime and is not considered as the ultimate offshore proof solution.

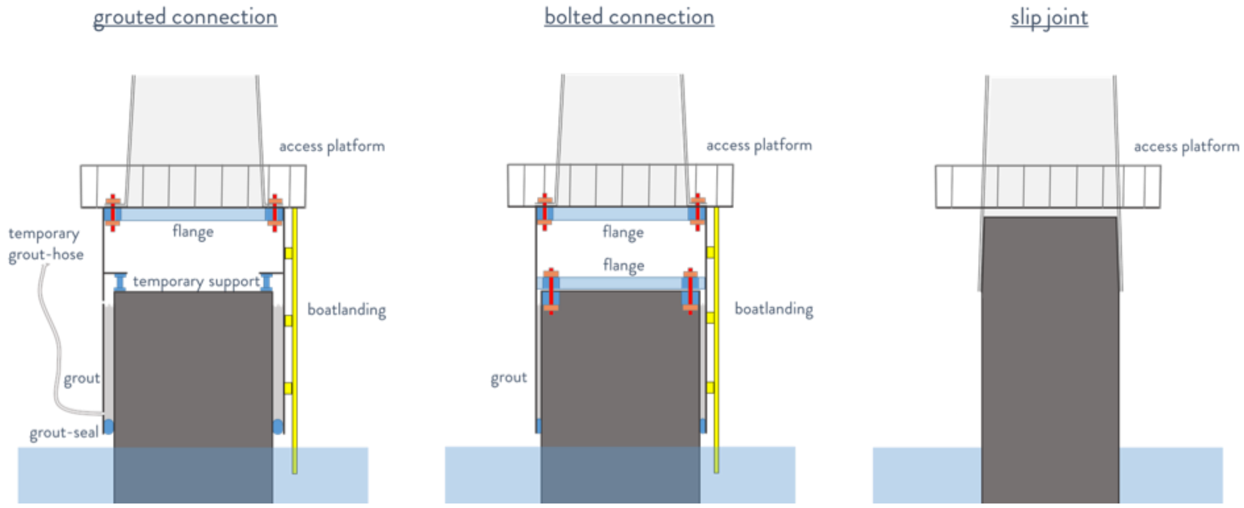

FIGURE 1: SCHEMATIC REPRESENTATION OF A GROUTED, BOLTED AND SLIP JOINT CONNECTION

The slip joint connection is an alternative form of connecting the wind turbine tower to its foundation in which two conical steel tubulars are placed over each other. The connection requires no bolting, grouting, or welding which decreases material costs and valuable installation time offshore. The slip joint principle uses the friction between two conical shapes to create the required structural connection (compare 2 paper coffee cups, upside down, sliding into each other). This project serves as an extension on the SJOR project in which a slip joint was already installed in the Dutch North Sea.

The main objective of the SJOQ project is to increase the TRL and certification level of the slip joint technology at minimal costs. For such an increase in TRL and accompanying certification level the actual installed prototype in the SJOR project should have a longer operational window, allowing the structure to experience more relevant load cases. An increased measurement campaign is required to get a more comprehensive overview of the stress distribution within the joint during these load cases. Finally, an FE model should be created which can be validated with the measured data of the slip joint. The slip joint that is used for the SJOQ project has a diameter of 4.00 [m] with an overlap length of 5.20 [m]. Although smaller in diameter than the foreseen future slip joints (expected to range from 8-12m in diameter), the principal is the same and according to DNV-GL the proposed design tool can therefore be validated using the current set-up.

Project plan

The test set-up for the SJOQ tests was the offshore DOT500 wind turbine, which was already installed under the SJOR project [1]. The turbine was situated at the Princess Amaliawindpark (PAWP), offshore IJmuiden. The turbine was a test turbine with a hydraulic drive train operated by DOT B.V. The details of the wind turbine test set-up can be found in Figure 2. The SJOQ measurement campaign was set-up to measure strain at strategic positions in or around the slip joint overlap area, settlement of the turbine tower over the monopile and accelerations in the structure. This data is supported by data gathered from sensors that measure real time environmental data of the wind conditions. In total 132 sensors were installed. The data was all time synchronized and stored locally on a measurement PC. A redundant real-time access to all the operational data, with a local back-up in case of abnormalities was realised. This detailed measurement campaign was created to allow the validation of a FE model of the slip joint, required for certification. For model validation purposes, enough load cases on the slip joint had to be introduced. Also, the magnitude of these load cases had to be high enough to yield results far out of the noise range of the sensors. Two main events were considered that would yield the highest possible load cases:

- Adverse weather conditions in the offshore environment, such as winter storms
- Operational conditions at or around rated wind speed of the turbine, including emergency stops

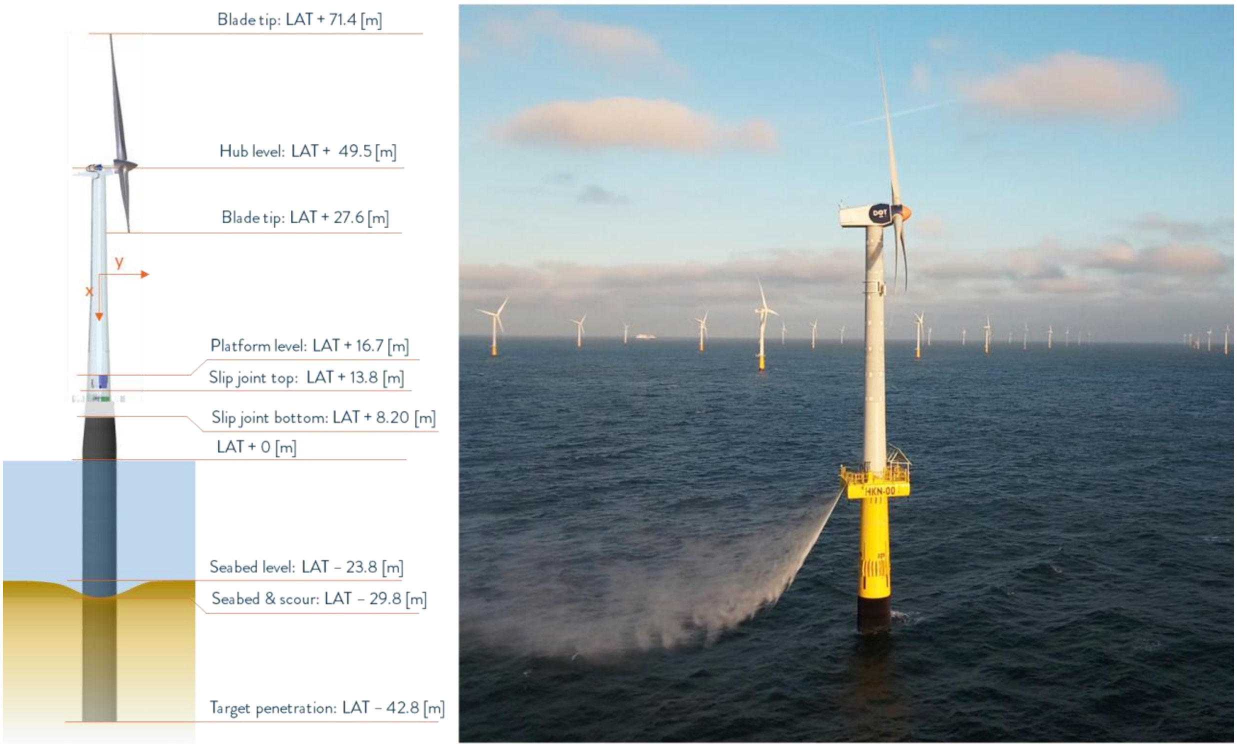

FIGURE 2. DOT500 WIND TURBINE DETAILS AND OVERVIEW

Project results

The WTG commissioning took place from 30 September until 5 October 2018 at the offshore location in PAWP. The turbine was operational within 24 hours after which functional testing and emergency procedure testing was initiated. After the one-week offshore trip the turbine was operating multiple times at rated conditions, already yielding valuable load cases for FE model validations. Table 1 presents a concise overview of all the different offshore trips that were undertaken to maintain operation of the WTG.

TABLE 1. OVERVIEW OF OFFSHORE TRIPS TO THE WIND TURBINE TEST STRUCTURE IN PAWP

ID	Date out	Date in	Day	Vessel	W2W	Description	Project
1	30/09/2018	05/10/2018	6	Ocean Zephyr (A1 Offshore)	Ampelmann A-type	- Turbine commissioning - First water	SJOQ
2	11/10/2018	11/10/2018	1	DP Galyna (Chevallier)	Ampelmann A-type	- Preparations remote turbine operation - Blockage HP repair 1	SJOQ
3	09/01/2019	12/01/2019	4	Vos Sugar (Vroon)	Ampelmann L-type	- Turbine blackout fix - Blockage HP repair 2	SJOQ
4						Cancelled	
5	06/02/2019	06/02/2019	1	Vos Sugar (Vroon)	Ampelmann L-type	- Junction box nacelle (JB1) fix - High torque WTG bolts - Blockage HP repair testing	SJOQ
6	23/03/2019	30/03/2019	8	DP Galyna (Chevallier)	Ampelmann A-type	- Blockage LP repair - Decom preliminairy preparations	SJOQ
7	23/05/2019	31/05/2019	9	DP Gezina (Chevallier)	Ampelmann A-type	- Decom 24Sea sensor set-up - Decom method testing	SJOQ
8	05/08/2019	06/08/2019	2	DP Galyna (Chevallier)	Ampelmann A-type	Decom final preparations (WTG)	SJOR
9	15/08/2019	16/08/2019	2	Aegir (Heerema)	Ampelmann L-type	DECOM phase 1: removal WTG	SJOR

During the one-year operational period the wind turbine experienced several severe winter storms in the period of December 2018 through March 2019. These winter storms excited the turbine with significant, quasi-static windstorm loading events which yielded interesting load cases for the slip joint. Also, amidst these storms several wave slamming events were monitored which caused significant acceleration and settlement effects. Next to these environmental loading events, operational conditions also resulted in multiple useful load cases. In total 38 relevant load cases were deduced from the operational period data. It can be concluded that the slip joint settlement reaches a stable equilibrium after every sequential higher experienced load case. Also, the hoop strain development corresponds according to expectations with this monitored settlement and was well within yield limits. These conclusions are in line with earlier DOT research [2], [3].

Within the SJOQ project, emphasis was put on the FE modelling of the mechanical behaviour of the slip joint under (extreme) loading. For this reason, both Van Oord and TU Delft put time and effort in creating a FE model and validating it with the offshore measured data of the actual slip joint. The TU Delft focussed on creating and validating a scientific detailed FE model of the slip joint. A full FE model of the whole structure, including the slip joint was developed. Different contact configurations, simulating a reduced contact area and possible ovalization and inclination were assumed and their effect on the first global bending modes was investigated. A comparative analysis between modelled and measured axial strains was performed and a satisfactory match was achieved. The FE model that Van Oord prepared and updated during the SJOQ project serves as a design tool that provides the user with a design envelope for slip joint design purposes. By comparing the physical measurements with the output of the FE model, the applied design philosophy was validated.

All activities performed in the SJOR and SJOQ projects were carefully discussed with DNV-GL as they all served the same goal to increase the TRL of the slip joint at minimal costs. The aim of the projects was to increase the TRL of the technology to TRL 8-9, while at the same time certifying the technology by a third party, more specifically a DNV-GL B-level Provisional Type certificate. This provisional prototype certificate is valid for one year during which the outstanding issues need to be resolved. During the SJOQ project it became clear that there were no outstanding issues defined for the design and test module. This has led to the fact that the certification was raised to A-level for these modules within the SJOQ project.

The project was performed in close collaboration between all project partners, in a constructive manner and in good spirits. Concluding, the consortium is proud to look back on delivering a very successful project.

Dissemination and media coverage

Within the SJOR and SJOQ project multiple knowledge dissemination events and initiatives have been undertaken. In total, six presentations were given, one seminar was organized, and five conference posters and papers were produced. A selection of those can be found in Figure 3. Alongside, thirteen individual media events generated publicity to the project and technology as a whole.

FIGURE 3. SELECTION OF DISSEMINATION EVENTS

Next development steps

Several concrete initiatives were initiated during or after the SJOR and SJOQ project that concerned the commercial application of the slip joint technology. Sif developed an innovative secondary steel concept using a slip joint, omitting the need for a transition piece. Van Oord designed and installed an underwater slip joint, connecting a 9.5 MW turbine to its monopile foundation, that is installed in the Borssele V project by the Twin Towers consortium. As a follow up on the SJOR and SJOQ projects several other new research and development projects have been initiated. A concrete example is the DOT6000 FOX (TEHE119004) project, in which a 3MW+ slip joint is installed by means of a floating vessel. Also, the C-FLO (TEHE118023) project, set up to reduce the uncertainties in the evaluation of the combined degradation mechanisms corrosion and fatigue to derive improved calculation tools for design and maintenance of monopiles.