Grouted Connections – Offshore Standards Driven by the Wind Industry

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ABSTRACT

Grouted connections are commonly used to connect towers for offshore wind turbines to monopile foundations. These connections in contrast to similar grouted pile-sleeve-connections used for oil & gas jacket structures are characterized by large diameters, predominant bending moment, and a high degree of fatigue loading.

Starting in 2009, sliding damage has been reported at a number of offshore wind farms with plain cylindrical grouted joints. Since 2007, the research project 'Grouted Joints for Offshore Wind Turbine Structures' (GROW) has investigated improving the strength of hybrid connections by applying shear keys.

Germanischer Lloyd (GL) has been involved together with other industry partners and led by the University of Hannover (Germany) [see Klose et al (2008)]. Due to the aforementioned occurrences of damage and the results of the research work, existing standards and guidelines such as GL (2005), DNJ OS J101 and NORSOK N 004 have been reviewed and existing design approaches and calculation tools have been modified. It should be noted that this will also have an impact on the design procedures for oil & gas structures.

The lessons learned from the reported damage incidents are presented in this paper. Also included is an overview about the updated GL Guideline for the Certification of Offshore Wind Turbines to be published during 2012 as well as a presentation of recommended design procedures. Furthermore, an outlook on the follow-up research project “GROWup” will be presented.

KEY WORDS: Grouted connections; Wind turbines; Offshore; Foundations; Shear Keys.

INTRODUCTION

Within the last decade, a significant number of offshore wind farms have been installed in Central and Northern Europe. Offshore wind energy is gaining a leading role in the energy supply of tomorrow, especially when reduction of CO₂ emissions remains on the political agenda and nuclear power is considered to be less of an option since the Fukushima accident.

The support structures for these wind turbines consist of either structural steel or reinforced concrete. One of the commonly used foundation types is the so-called monopile (see Fig. 1), which is installed by a pile driving hammer. In order to accommodate inclinations from the vertical axis due to driving, the transition piece between the tower and foundation pile will be connected using a grouted connection, thus allowing the transition piece to be installed plumb.

Fig.1: Offshore wind turbine on monopile (schematic; Source: GROW Final Report) and transition piece during installation (Source: Densita/s)

In most cases, the connection between the transition piece and the monopile was made only by the cylindrical grout material, without any additional connectors. This technique had been adapted from the oil & gas industry where grouted connections have been used for jacket structures since the 1970s.

In 2009, slippage of the transition pieces was detected in a number of wind farms in the North Sea. Wind farm operators, utilities and certification agents investigated this phenomenon and came to the conclusion that the design rules applied thus far had over-estimated the axial capacity of the grouted connections.