PO.ID 095

Corrosion Threats to Offshore Wind Foundations

Isaac Tavares; Petra Ernst, Gareth John; Robin Jacob; Brian Wyatt

Centrica Energy Ltd; Intertek; CP Consultancy Ltd; Corrosion Control Associates Ltd

centrica energy

Abstracts

Although not often appreciated corrosion is a major risk for offshore wind foundations. Its effects could mean costly offshore retrofit work, result in the loss of generation and expose operatives to additional health and safety risks. Corrosion protection is of vital importance to assure the integrity of offshore foundations minimizing exposure to these risks, hence the investigation and analysis of corrosion protection requirements as presented here are of key importance.
Current offshore standards were developed for conditions mostly associated with jacket structures in deeper waters, lower tidal currents and uniform anode distribution. The external protection of most offshore wind farms differs considerably; additionally no suitable guidance exists for internal corrosion protection of monopile foundations.

This work brings together a number of laboratory and full scale trials investigating the behavior and application of internal galvanic anodes and demonstrates that although these can be used successfully to achieve the desired outcomes care needs to be taken in the choice of the main design parameters as current guidance does not adequately reflect observed conditions. Further this work provides the basis to enable certification authorities to reassess existing guidance and upgrade the standards to include the use of galvanic anodes in the internal compartment of monopile foundations.

Figure 1 – General arrangement of monopile foundations

Objectives

The objective of this paper is to address the current gap in knowledge regarding the use of galvanic anodes in the internal compartments of monopile foundations (figure 1 shows a typical arrangement). To this end work was carried out to develop a body of information through a number of laboratory and full scale trials that should enable standards agencies to develop appropriate guidance and designers to effectively assess and design internal protection systems using parameters that are appropriate to the conditions experienced by these structures.

Figure 2 – Monopiles ready for transport – bare steel interior

Methods

This work sets out the results of two independent laboratory studies, a small study which produced unprecedented results leading to developing a larger set of tests looking at different anode materials, cyclic water ingress and egress, different aeration levels and the evolution of gases followed by multiple offshore trial applications which equally provided astonishing results.

The authors reviewed the currently available body of knowledge for the assessment and design of corrosion protection of offshore structures and established that if used at face value may only partially address the external conditions of offshore wind farms due to the way in which anodes are distributed, increasing water depths and importantly the current velocities.
With regards to internal corrosion protection there is no specific guidance available. The authors have used their knowledge of shipping ballast tank cathodic protection design to establish if parallels could be drawn between ballast tank and monopile CP design but found this to again be a different set of circumstances to the internal compartments of monopiles.

Figure 3 – Laboratory trial 1: Coupled and uncoupled tests (NPL)

Figure 4– Laboratory trial 2: Zinc and Aluminium anodes with and without gas membrane and with and without tidal replenishment (Intertek)

Based on the results of this study the use of existing guidance for the design of galvanic anodes for internal corrosion protection would result in a number of issues developing over time and in some cases result in a more aggressive environment ultimately leaving the structures under protected.
This study builds on a progressively larger scale number of laboratory tests to observe the behaviour of galvanic anodes utilised in internal conditions to evaluate the use of different anode materials, the effects of an internal tidal range versus no tidal range, variations to the aeration of the water column and the rates of gas evolution by using potential control mechanisms.
Additionally a number of offshore full scale internal cathodic protection systems were installed to assess the behaviour under real life conditions and provide validation to the laboratory work enabling further understanding of the characteristics that can be expected.

Results

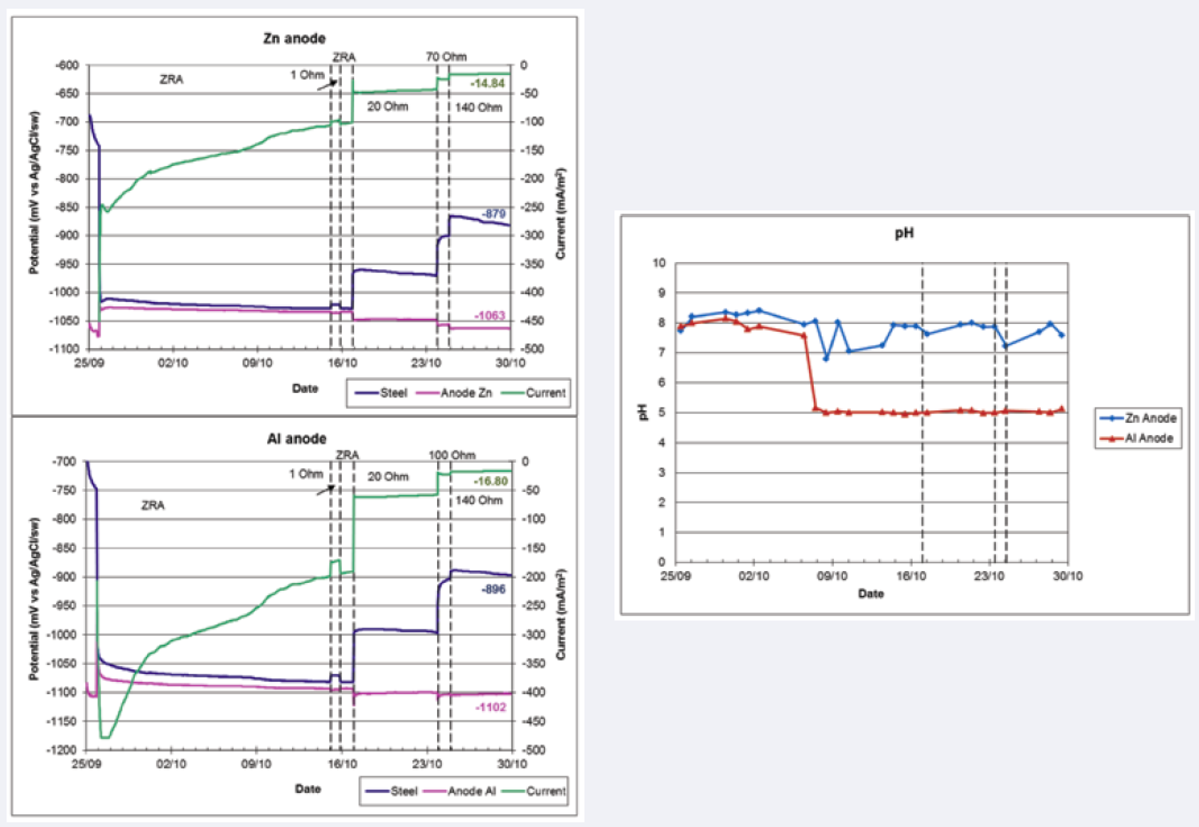

Figure 5– Laboratory trial 2: Potential and pH readings

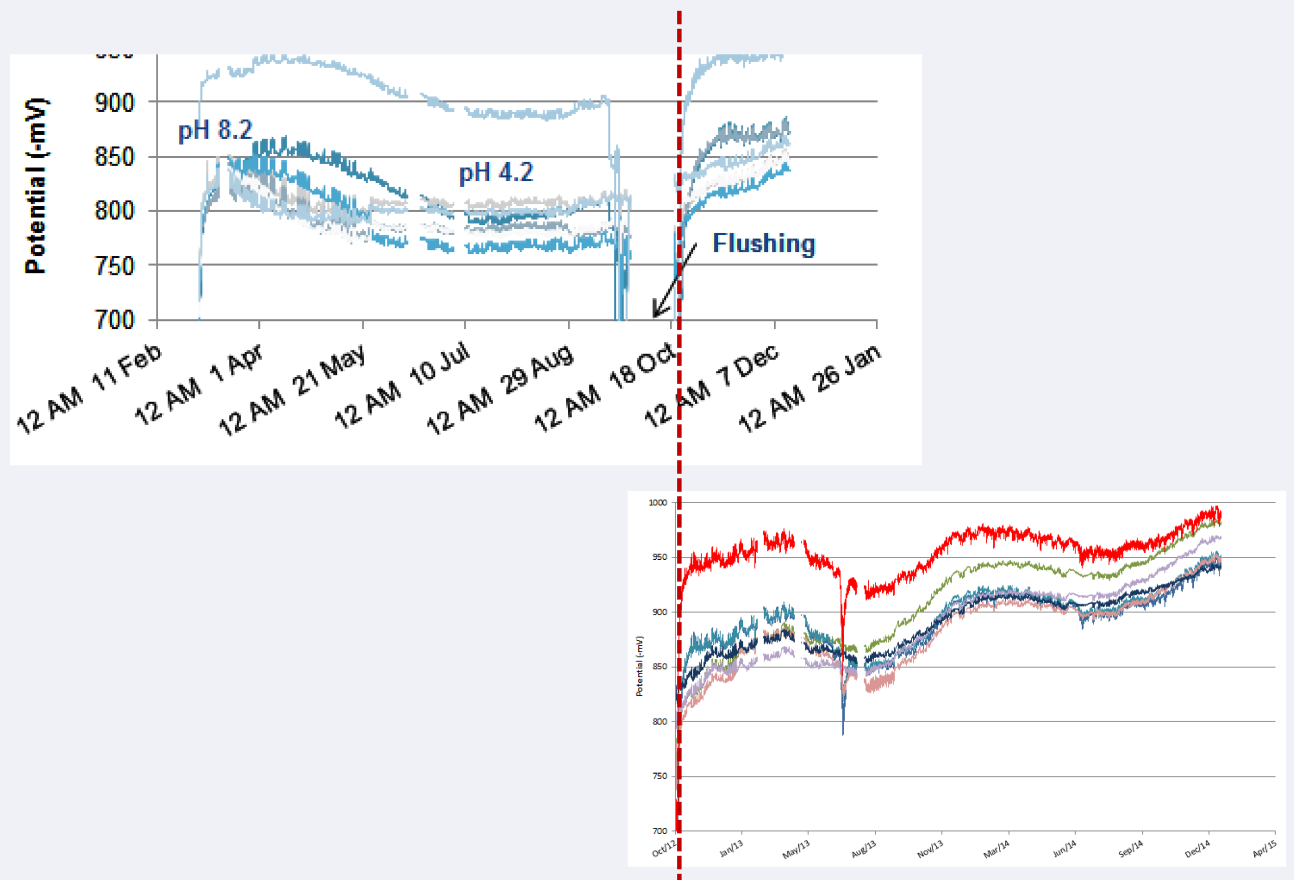

Figure 6– Full scale trials showing effect of flushing in potential levels (March 2012 to Dec 2014)

Conclusions

Corrosion protection, or the lack of, is a major threat to offshore wind foundations with cost and safety implications.
Existing guidance does not cater for the design of galvanic anodes for the protection of the internal compartment of monopile foundations.
This study shows that the use of existing guidance for such purposes could likely result in an environment where, overtime, the structure would become under protected.
Finally the authors set-out an evidence based body of knowledge forming the basis for effective guidance and design parameters that allow standards agencies to upgrade existing standards and provide designers with adequate design tools.
This study enables the reader to understand how galvanic anode behaviour in the internal compartment of monopiles deviates from accepted wisdom and explores a number of conditions relevant to offshore wind monopile foundations.
Crucially it provides the tools for the effective design of such systems using different materials and highlighting key considerations which are critical to ensuring long term system performance and the effective corrosion protection of the internal compartment of offshore wind monopile foundations.

Acknowledgments: RES Offshore, UK National Physical Laboratory, Deepwater and RS Clare.

References

1. *Internal Cathodic Protection of Offshore Wind Turbine Monopile Foundations, Icorr corrosion Management, Feb 2015*
2. *DNV-OS-J101: Design of Offshore Wind Turbine Structures.*
3. *DNV-RP-B401: Cathodic Protection Design*

OFFSHORE 2015 COPENHAGEN ORGANISED BY EWEA

EWEA Offshore 2015 – Copenhagen – 10-12 March 2015