PO.ID 012

Continuous remote follow-up by in-situ grout condition monitoring

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Abstract

Grout has been used as a construction material since about the very beginning of offshore wind construction. Examples are the grouted connections between monopile foundations and transition pieces as well as in fixing jacket foundations near the seabed [1]. As foundation structures are foreseen to support the wind turbines on top for at least the entire operational life foreseen, it is essential to be able to monitor their structural integrity in order to identify as early as possible potential structural defects. Monitoring schemes represent a powerful tool for the follow-up of structural integrity. The present paper presents a set of results obtained with a new, in-situ sensor designed to continuously monitor grout integrity in a monopile-type foundation.

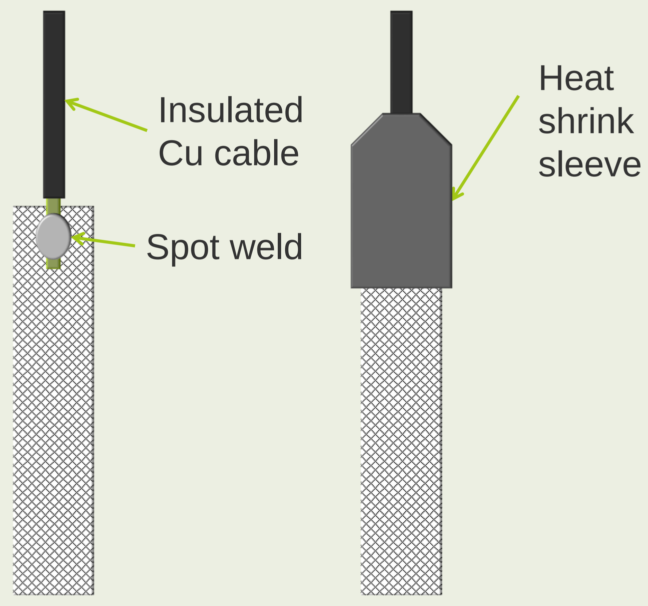
From [2]

Objectives

The aim of the project presented here was to develop a sensor that allows a more direct measurement of the integrity of grout in operational conditions.

In the same time the sensor should be applicable in offshore conditions, requiring robust installation methods as well as a sufficiently long operational life.

Sensors and Installation Methods

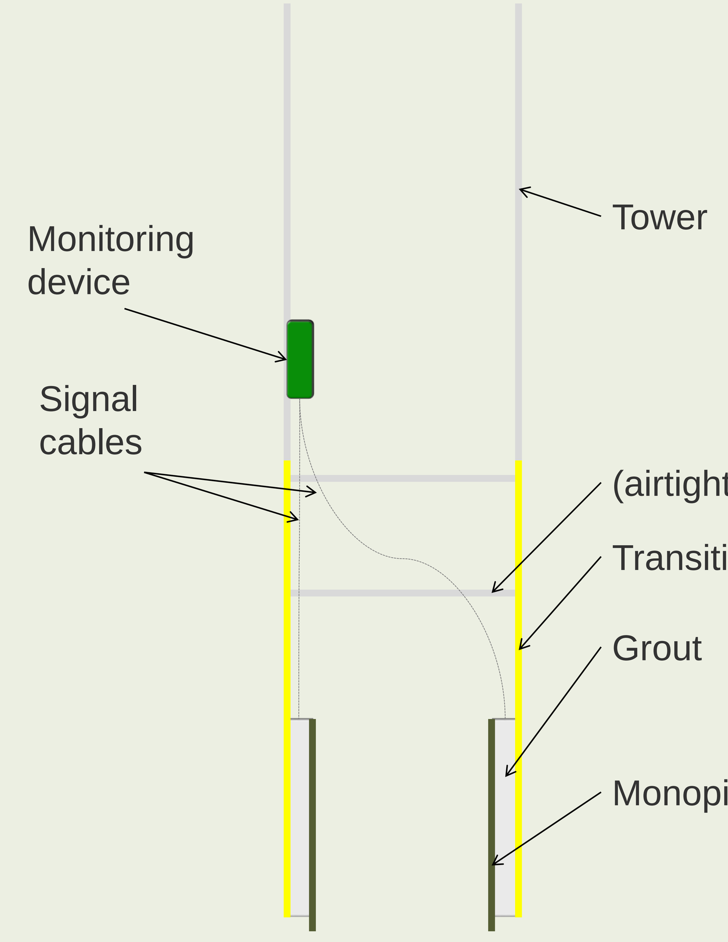


- Inert electrodes (Top picture and bottom scheme on the left: MMO coated Ti) are placed in the grout and connected to a central monitoring unit (center picture on the left). Placement (bottom 2 pictures) is done at grouting (or in retrofit in existing grouted connections after drilling installation holes).
- The monitoring unit applies a sinusoidal signal different frequencies
  - Between the electrode and the nearby steel structure (wall or rebar)
  - Between 2 neighboring electrodes
- From the system's response the monitoring unit calculates the conductivity

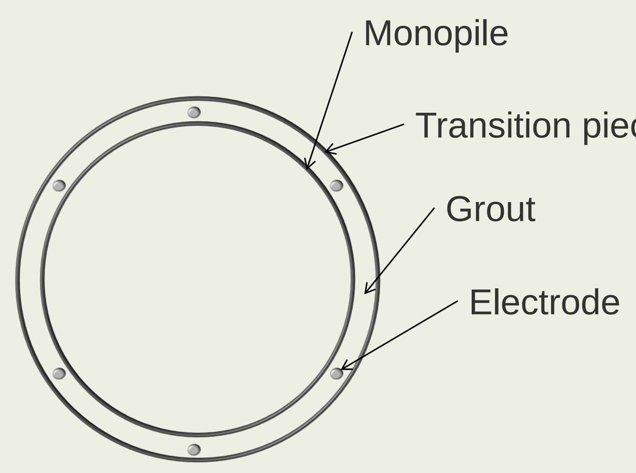
Situation right after grouting

Situation after removing temporary supports

Results



The results in the present presentation were obtained on a grouted monopile connection. The sensors were located at different positions around the circumference and at 2 depth levels. As such a 'map' of the grout integrity can be generated.

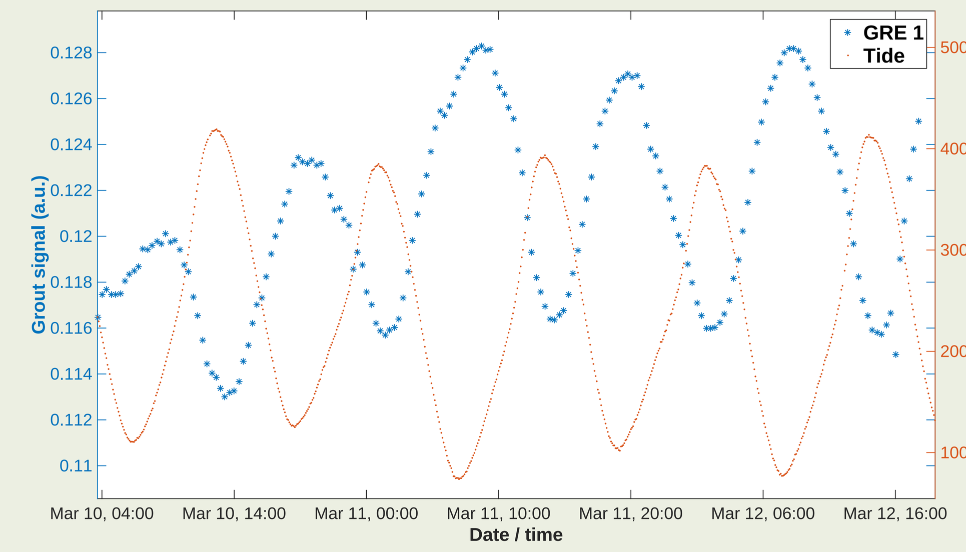


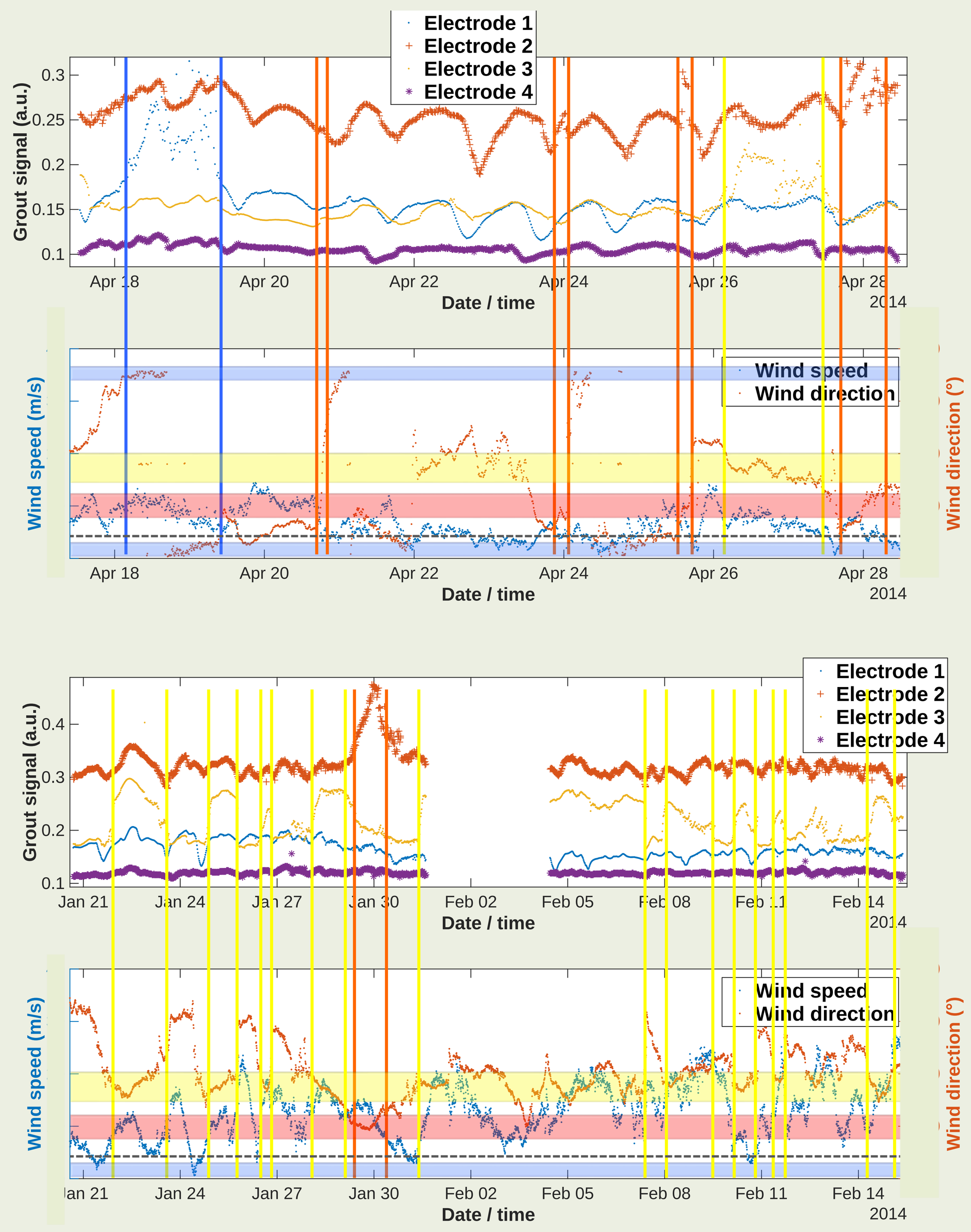
Red line = tide

Blue line = grout conductivity

Periodicity is equal

Sensor measures water uptake in grout





Top graphs = grout signals (3 electrodes)

Matching bottom graphs = wind speed and direction

Vertical lines = grout signal above threshold (color matches grout electrode)

Horizontal bands = associated wind direction (color matches grout electrode)

Dashed line = minimal wind speed for effect to take place

The sensors indicate decreased adhesion between the steel and the grout in the position matching the wind direction (linked to steel deformation)

Conclusions

Using the sensor developed here, unwanted issues such as water uptake and detaching (cracking) can be identified in a very early stage and repair or other remediation actions can be planned and prepared well in advance.

Moreover the sensors described are coupled, using the same monitoring setup, with other, more traditional sensor types such as LVDT and/or strain gauge, accelerometers, temperature, pressure… to allow for a deeper understanding of the origin of the undesired effects. After repair and/or remediation the same setup is implemented for the follow-up of the effectiveness of the corrective means implemented.

References

[1] http://www.renewableenergymagazine.com/article/grouting-still-a-major-issue-for-offshore
[2] http://www.redwave.nl/2743614/Funderingstypen-windmolens-offshore.html
[3] Approvals for Grouted Joints in Offshore Structures in Germany, EWEA 2013, Schaumann, P.; Bechtel, A.; Lochte-Holtgreven, S.; Lohaus, L.; Lindschulte, N.; Griese, R.