Study Committee B1

Insulated cables

10667_2022

Complex cable temperature monitoring within the largest commissioned offshore wind farm

Etienne ROCHAT[1], Alexandre GOY[1], Fabien RAVET[1], Lukas Milan DOMURATH[2], Maria-Eftychia VESTARCHI[2], Hossein GORBANI[2]

1: Omnisens SA, Switzerland; 2: Oersted, Denmark

Motivation

Hornsea project one (HOW01), 120 km off UK Yorkshire coast, currently the largest operating windfarm worldwide.

HOW01 features:

- 400 km²
- 174 turbines, each with a 7 MW capacity
- 1.2 GW total capacity
- 3 offshore substations (OSS)
  - each connected to mainland with a dedicated AC export cable
  - each connected to the adjacent one with an interconnector
- First of its kind offshore reactive compensation station (RCS) near middle of the export cables, for reactive power compensation

Offshore cables [1]

- 3-cores, 220 kV
- XLPE insulation
- 1000 mm² or 1200 mm² Cu conductor (export, 3x)
- 950 mm² (interconnector2x)
- all with embedded Fibre Optic Cable.

Land cables

- split flat phases, 6m spaced
- XLPE insulation
- 1600 mm² Al conductor
- all with embedded Fibre Optic Cable.

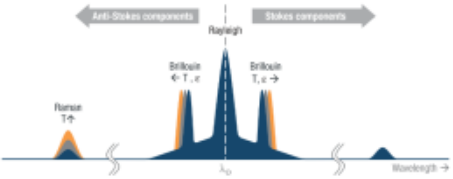
HOW01 has 438 km offshore cable, 117 km land cable and 27.5 km interconnector.

The 580 km cable length are totally monitored using Distributed Temperature Sensing (DTS).

The HOW01 system is one of the most complex and currently the longest fully monitored wind asset worldwide. Similar complex projects include monitoring of Cluster Wikinger Arkona [2] and the 180 km long Crete-Peloponese interconnector [3].

Distributed temperature sensing

Raman and Brillouin processes can be used for DTS [4].



Raman DTS, intensity based typically 30km measurement range:

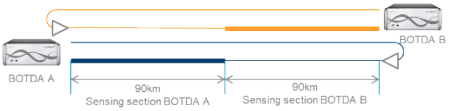
- MMF and SMF fibres
- Difficult calibration process for long cable

Brillouin DTS, frequency based, with fibre loop for stimulation (BOTDA mode):

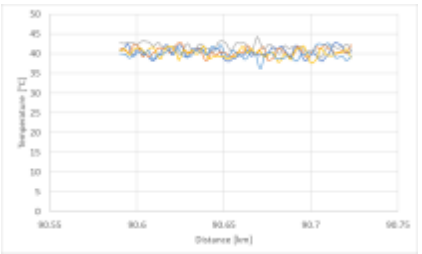
- SMF fibres
- Laboratory calibration
- Strain/temperature decoupling by using lose tube fibre design

Brillouin DTA are compatible with discrete and distributed optical amplification for long measurement range [5].

At HOW01, optical amplification is located at the distal end of the longest loops.



Performance demonstration over a 180 km long fibre, 37.1 dB with 100 m long section (at 90 km) in a thermally controlled water bath.



With 5 m spatial resolution, 15 min measurement time, temperature repeatability (2σ) below 3°C at 90 km.

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HOW01 monitoring scheme

Onshore sections, 3x 39 km from onshore substation (OnSS) to the transition joint beach (TJB) measured by a single DTS with 3ch.

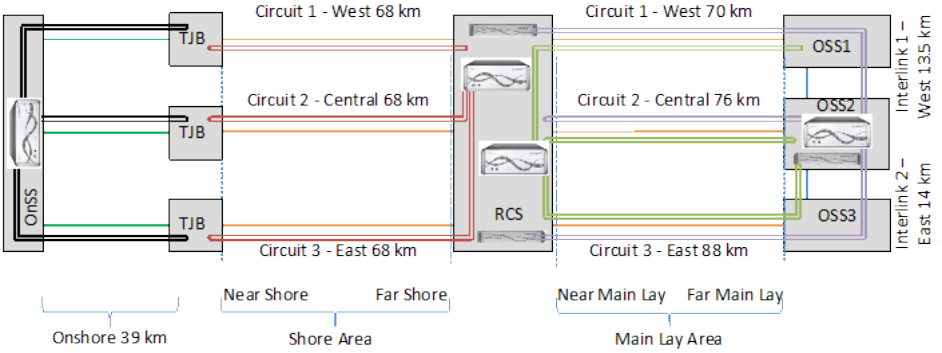
Shore area, 3x 68 km from TJB to reactive converter station (RCS) measured by a single DTS located on the RCS.

No need for amplification for these links.

Main lay section, from RCS to offshore substation OSS1 (70 km), OSS2 (76 km) and OSS3 (88 km) and interconnectors OSS1-OSS2 and OSS3-OSS2 are measured in both directions.

OSS2-OSS1-RCS, OSS2-OSS3-RCS and RCS-OSS3-OSS2 are based on amplified schemes.

No instrumentation on OSS1 and OSS3.

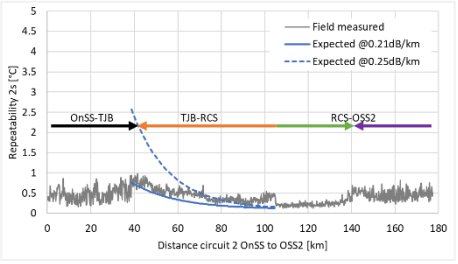


Performance

Conservative 0.25 dB/km fibre loss used for designing measurement scheme.

RCS-OSS3-OSS2 (longest link) estimated at 52.6 dB (full loop) with a need of 20 dB amplification at loop distal end.

In field measurement repeatability corresponds to a 0.21dB/km loss. With 3m spatial resolution, kept below 1°C (2σ) regardless of distance to DTS.

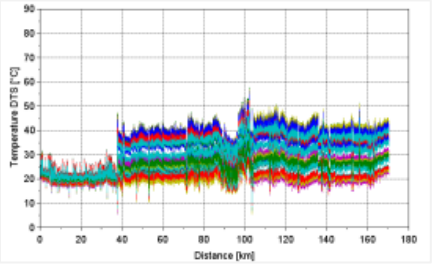


Measurement times:

- 9 min OnSS-TJB
- 15 min RCS-TJB
- 15 min RCS-OSS3-OSS2 (data until mid position)
- 16 min OSS2-OSS3-RCS (data until mid position)

Temperature measurements

Concatenated temperature profile (West circuit) with variable load conditions. All variations can be traced to cable properties like cross-section, laying depth seabed parameters [5].



Peaks in land section related to road crossing and HDD/tubing used to protect cables.

Changes in seabed properties and cable properties also visible.

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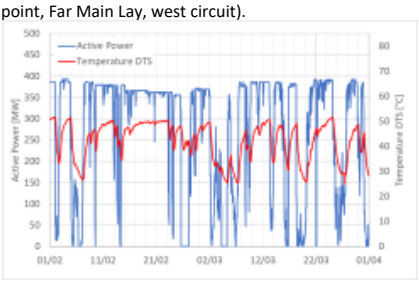
Temperature measurements

Along cable

Temperature evolution as a function of load (arbitrary point, Far Main Lay, west circuit).

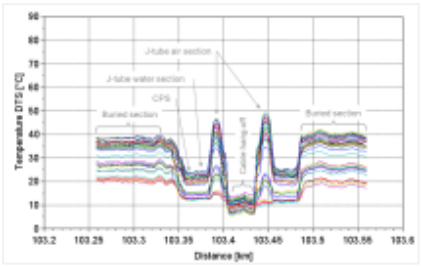


Cable thermal inertia on fibre temperature clearly visible. Must be considered if using real time thermal rating.

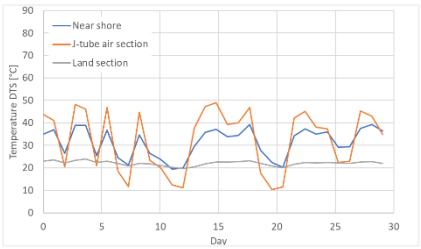
J-tube area (RCS)

Air section features large temperature variations with load.

In water sections and cable protection systems (CPS) change similarly to buried section, at lower absolute temperature.



Time comparison of land section, J-tube (air) and near shore sections shows very different behaviours.



Conclusion

HOW01 largest operating windfarm, 1.2 GW installed capacity.

Cable system is 580 km long, with 3 exports cables and 2 interconnectors between offshore substations.

Reactive compensation station mid-way of export route.

Full temperature measurement (all cable routes) using Brillouin DTS, featuring 15 min measurement time, 3 m spatial resolution and better than 1°C repeatability (2σ) in the field.

Field proven technology, with similar schemes deployed for Cluster Wikinger Arkona [1] in the Baltic and for the Crete-Peloponese interconnector [3].


HOW01-RCS ©Oersted

References

[1] M. Zourarakil, M. A. Vilhelmsen, T. Kvarts, R. Østerø, T. Page and J. Hjerrild, "Hornsea projects 1 and 2 – Design and Optimisation of the Cables for the World Largest Offshore Wind Farms," (10th International Conference on Insulated Power Cables (J-Cable), 2019).

[2] E. Rochat, Z. Robiani, A. Goy and R. Guericke, "Temperature monitoring and current rating computation for the Cluster Westlich Adlergrund," paper 667, CIGRE, 2022).

[3] Omnisens, "Omnisens sets a new world record in long subsea cable monitoring," 27 08 2020. [Online]. Available: linkedin.com/omnisens-sets-new-world-record-long-subsea-cable-monitoring. [Accessed 07 01 2022]

[4] A. Hartog, An Introduction to Distributed Optical Fibre Sensors, CRC Press, 2017.

[5] E. Rochat, S. Chin and F. Ravet, "Condition monitoring of 88km long Offshore HVDC Power Cable: comparison of DTS and as built data" (Journal of Physics: Conference Series, vol. 1102, p. 012038, 2018).