Study Committee B1

Insulated cables

10665-2022

Temperature monitoring and current rating computation for the Cluster Westlich Adlergrund

Etienne ROCHAT[1], Zeno ROBBIANI[1], Alexandre GOY[1], Rudiger GUERICKE[2]

1: Omnisens SA, Switzerland; 2: 50Hertz Transmission GmbH, Germany

Motivation

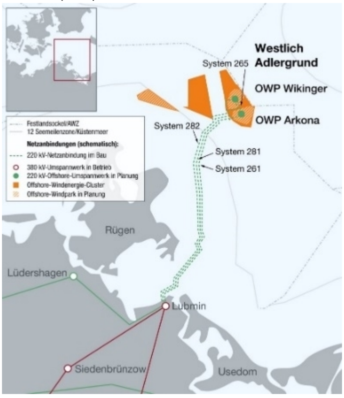
Provide monitoring of Cluster Westlich Adlergrund (CWA) in the Baltic Sea in view of:

- ensuring cable integrity
- guaranteeing uninterrupted energy transfer from production site to mainland grid

by means of Distributed Temperature Sensing (DTS) and Real Time Thermal Rating (RTTR) for conductor temperature computation and forecasting.

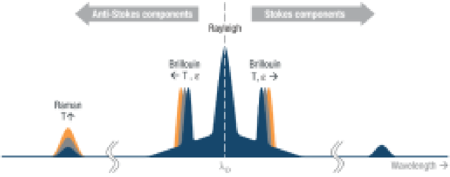
Cluster Westlich Adlergrund is located in the Baltic Sea; is made of:

- Wikinger, featuring 70 AD 5-135 5MW turbines, for a total capacity of 350MW
- Arkona, featuring 60 SWT-6.0-154 6.3MW turbines, for a total capacity of 385MW
- 93km long export cable route, with two export cables (281 & 282) to Wikinger, one export cable (261) to Arkona and one interconnector between the two (265)



Distributed temperature sensing

Raman and Brillouin processes can be used for DTS [1].



Raman DTS

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

Brillouin DTS

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

DTS Key parameters - IEC 61757-2-2

IEC 61757-2-2 provides

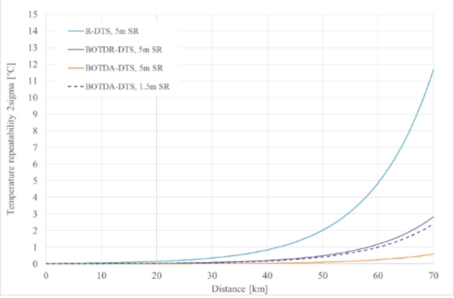
- Definition for key concepts
- Test setup for DTS characterisation
- Methods to compute and publish results

Temperature repeatability is a function of:

- Distance measurement range L and fibre loss α.
- Measurement time t
- Spatial resolution ΔL

$$\frac{(c e^{\alpha L})^2}{\Delta L}\frac{\sqrt{t}}{2\sigma} = FOM_{interrogator} \quad [2]$$

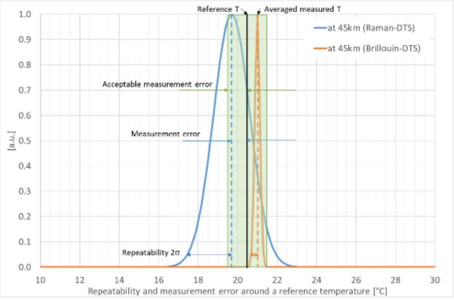
FOM computed from data in [3], [4] and [5], allowing comparison between Raman (R-DTS), spontaneous Brillouin (BOTDR) and stimulated Brillouin (BOTDA).



BOTDA is the best repeatability / spatial resolution choice for long distance project.

Temperature repeatability and temperature measurement error are independent and must be specified accordingly:

- Temperature repeatability is related to instrument performance
- Temperature measurement error is related to the calibration process



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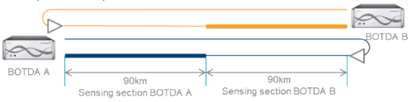
Long distance monitoring

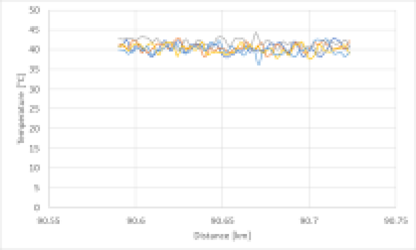
BOTDA compatible with optical amplifications. Allows for long distance coverage [6].

Scheme based on optical repeater for probe signal at loop distal end.

Field proven up to 180km [7].



Featuring 5m spatial resolution, 15 minutes measurement time and <3°C repeatability at 2σ.



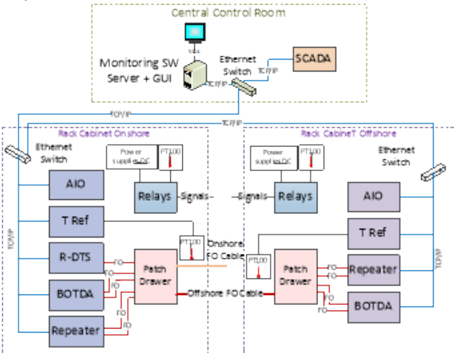
CWA monitoring scheme

281: Raman DTS in MMF for land section, BOTDA with amplifier at distal end for export section.

282 & 261:

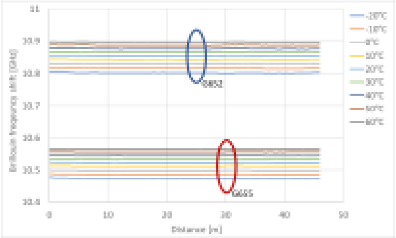
Raman DTS in MMF for land section, BOTDA without amplifier at distal end for export section.

All interrogators and ancillaries connected to SCADA system.



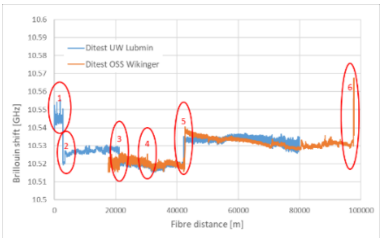
Calibration process

Multiple fibres tested in the lab through different temperature cycles. G655 and G652 have different Brillouin frequencies but same slope.



Combining laboratory data and external sources, field fibres were correctly calibrated.

Field data also features:

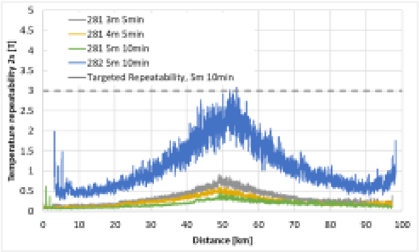


1) Land section (peaks corresponds to $T_{manhole}$, away from cable
2) HDD at the beach transition point
3) Subsea joint
4) Crossing of Nord Stream pipeline 1&2
5) Two subsea joints in close vicinity
6) J-tube and transition cable to the control room

Performance

Temperature repeatability computed according to IEC-61757-2-2 recommendation.

Impact of distal end repeater for identical conditions clearly visible; repeatability (5m, 10min, 2σ) increases from 0.5°C (**with repeater**) to 2.5°C (**without repeater**).



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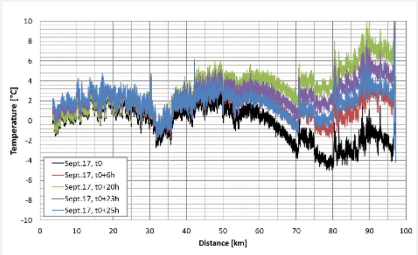
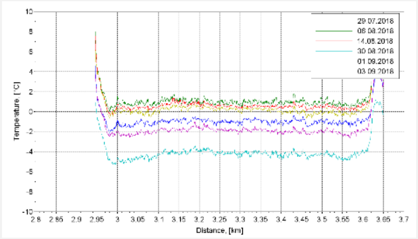
Temperature measurements

Pre-energization temperature measurements (below variations) allow for the identification of potential hot spots and provide references for Real Time Thermal Rating.



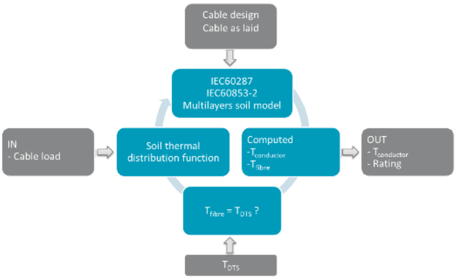
Temperature evolution in HDD (variations), as a function of load, is very homogenous.



RTTR concept

Cable loss computed from IEC60287 and IEC 60853 and combined into a ladder model describing cable and soil thermal properties.

DTS measurement used as a feedback loop to adjust for soil thermal distribution function.



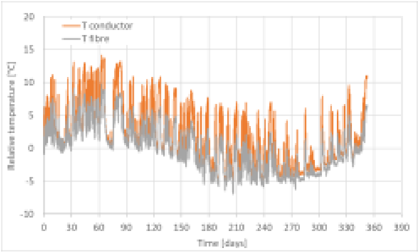
When computed temperature at fibre position is equal to DTS measurement, the model is at equilibrium.

Conductor temperature and rating are provided.

RTTR results

Data from cable 281, variations only:

- DTS measurement follows quickly load variations, featuring close to 10°C ΔT between high load and low load episode.
- Conductor temperature features variations up to 15°C ΔT.
- Absolute cable temperature is strongly influenced by water / ocean bottom temperature, with a nearly sinusoidal yearly variation.



Conclusion

Fibre Distributed Temperature monitoring of CWA1, combined with DTS driven RTTR is the most complex of its kind so far.

Three export cables, each close to 100km, and a short interconnector are fully measured using Raman DTS for short land sections (~3km) and offshore sections (>90km).

Optical amplification was deployed at distal end of some of the offshore sections, to improve sensing performances.

Similar schemes are deployed on the Hornsea One windfarm (paper 667).

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