cigre PARIS 2022

Study Committee B1

Insulated Cables

10538_2022

Failure cause analysis and prevention of subsea cable failures in a joint industry project (JIP CALM)

Mohsen KAVIAN[1], Debarshi SAHA[1], Satayish ANJUM[1], Frank de WILD[1], Peter van der WIELEN[1]

[1]DNV, Asset Management, The Netherlands

Niek BRUINSMA[2], Arjen LUIJENDIJK[2], Antonio MORENO-RODENAS[2], Niels JACOBSEN[2], Tom ROETERT[2], Etiënne KRAS[2]

[2]Deltares, Harbour Coastal and Offshore, Hydraulic Engineering, The Netherlands

Feike SAVENIJE[3], Edwin WIGGELINKHUIZEN[3], Jay JAYAKUMAR[3]

[3]TNO, Unit Energy Transition, Research group Wind Energy, The Netherlands

Marinus van der HOEK[4]

[4]VanderHoekPhotonics, The Netherlands

Erik de BRUIN[5]

[5]BREM funderingexpertise, The Netherlands

Motivation

- To reduce subsea power cable failures during the cable system design, manufacturing, installation, and operation stages
- Optimize modeling accuracy by inputting field data from real-time FO based monitoring, to make e.g., offshore wind energy more reliable
- Cable failures can be caused by external damages when the cable becomes exposed, therefor the long-term changes of the seabed bathymetry and burial depth of the cables need to be understood.

Method/Approach

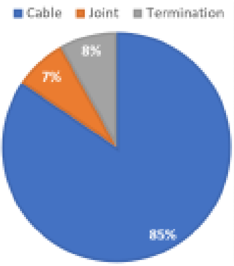
- 4 main tasks- The cable system failure root cause study, Lifetime monitoring system development, Cable-seabed interaction, and cost impact assessment
- Modeling, Design, prototyping, and testing of a FO-based monitoring system, including integration into real 3-core power cable
- Improving the ability to design and monitor safe and efficient cable routes, by developing methods to predict seabed changes along subsea cable routes and to monitor cable burial depth (e.g., via DTS)
- Developing a detailed model of the power cable installation process and validate it with real field data

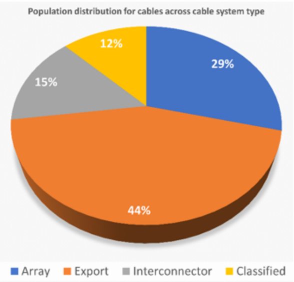
Objects of Investigation

- Failure data received from consortium partners
- FO-sensing unit(s) optimized for integration into different design of 3-core power cables
- Performance evaluation of instruments for distributed sensing of FO-sensing response
- Mechanical test, aligned with standards, to qualify the performance of the FO-sensing unit
- 3D morphological modelling for improved understanding of sand waves relevant for cable burial
- Using smart algorithms for the automatic generation satellite images for deriving near shore seabed bathymetry
- Optimizing cable routes to reduce significantly risks of failure due to exposure or overheating
- Burial depth monitoring model using several years of real DTS signal from an export cable

Task 1: The cable system failure cause

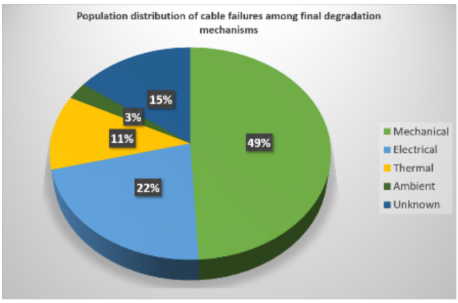
- 135 failure data received from consortium partners





Discussion and Conclusion

- JIP CALM is the first project allowing strictly confidential failure root cause analyses, thus providing rare insight into real application data
- Failures due to mechanical and electrical causes are dominant in the analyzed dataset



- To learn more from power cable system failures, creating transparency and willingness to share sensitive information with at least a single company (e.g., DNV) that can securely keep sensitive information confidential while analyzing the technical causes is crucial
- A clear and strong set of quality management, assurance, and control measures for power cable projects lifetime can prevent many failures

http://www.cigre.org

Study Committee B1

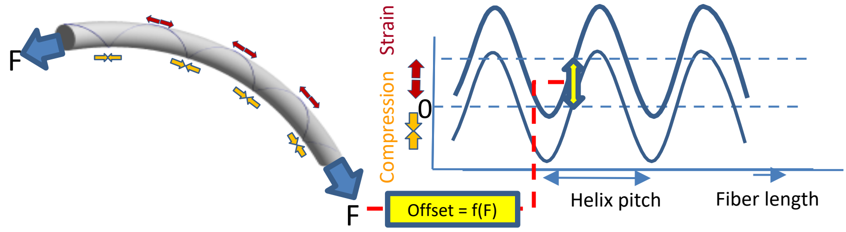
Insulated Cables

10538_2022

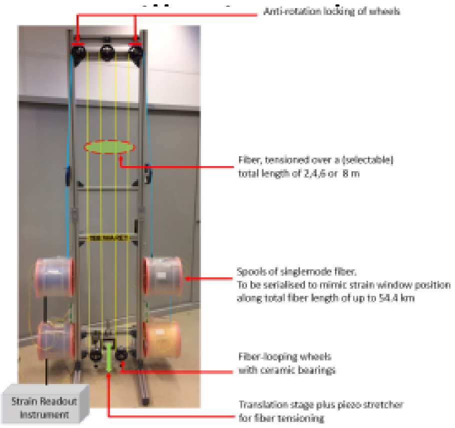
Failure cause analysis and prevention of subsea cable failures in a joint industry project (JIP CALM)

Task 2: Lifetime monitoring system development

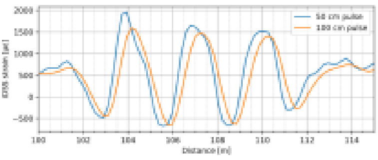
- Modeling of FO-sensing units



- Performance of read-out instruments (DSS &DAS)

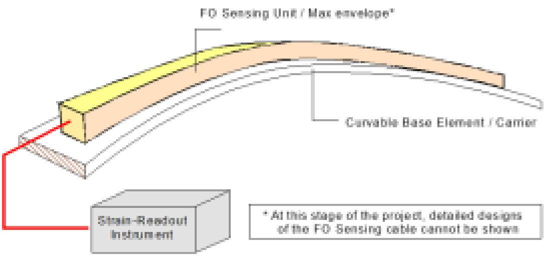


- Full scale pre-qualification tests according to IEC and CIGRE recommendations



Tensile bend test on a 3-core power cable (Top), Strain vs cable length results (Left down), and 3-point bend testing on another 3-core power cable (Right down)

- Radius of curvature measurement using various designs of manufactured FO-sensing units



Discussion and Conclusion

- FO sensing proved to be a viable solution to monitor cable and opens way to preventing some of the failures in the future
- Results of full-scale testing using 3-core power cable with integrated FO-sensing units are inline with theory (refer to bullet item 1 & strain graph in the bullet item 4)
- The minimum bending radius (MBR) of a 3-core power cable was calculated accurately from the strain as maesured with the FO-sensing units
- Other mechanical loading of the cable, e.g., torsion and tensile forces could be recorded as well from the strain signals in the FO-sensing units

http://www.cigre.org

Study Committee B1

Insulated Cables

10538_2022

Failure cause analysis and prevention of subsea cable failures in a joint industry project (JIP CALM)

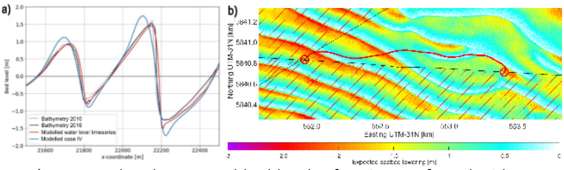
Topic 3: Cable-seabed interaction

3.1 Sand wave modelling using a process-based 3D morphological model.

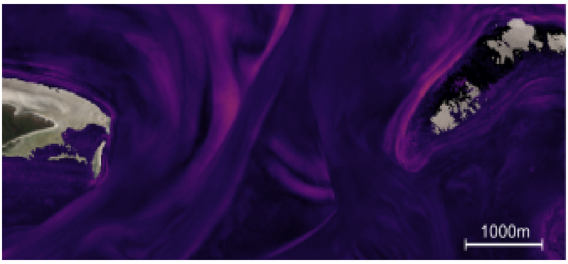
3.2 Satellite derived bathymetry for seabed mobility in nearshore areas.

3.3 Cable route optimization using seabed dynamics.

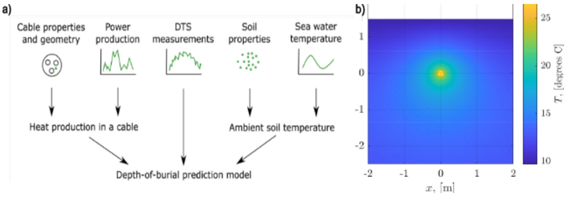
3.4 Burial depth monitoring using distributed temperature sensing (DTS)



1. a) Measured and computed bed levels after 6 years forced with water level timeseries, b) Cable route between two turbine locations avoiding areas of significant seabed mobility & constraints (red hatched areas)



2. Satellite-derived Depth Proxy Heat Map of the 'Friese Zeegat' (area between Wadden Sea islands Ameland and Schiermonnikoog). Bright colors indicate dynamic areas, while dark colors indicate stable regions



3. a) Seabed-cable thermal interaction components, b) Simulated temperature 2D field for a 1.5 m buried cable section

Discussion and conclusion

3.1 Significant advances in 3D modelling of sand waves has resulted in better understanding of the driving forces and quantitative predictions for future seabed levels and associated uncertainties relevant for cable burial (risk) assessments

3.2 Satellite-derived heat maps can be used to perform qualitative assessments of suitable areas for cable landfalls as well as more detailed quantitative assessments of channel, depression, shoal, and sand wave dynamics in terms of migration speed and direction

3.3 Cable route optimization tool capable of significantly reducing risks of failure due to exposure or overheating over the lifetime of the windfarm

3.4 Fiber-optic based distributed temperature sensors (DTS) provide measurements of temperature dynamics in export cables, which have been used to derive insights on the cable operating conditions with a focus on the estimation of the cable's depth of burial

Topic 4: Cost impact assessment

For the cost and impact assessment of the proposed innovations in this project, the team developed a detailed model of the power cable installation process and validated it with real wind farm cases

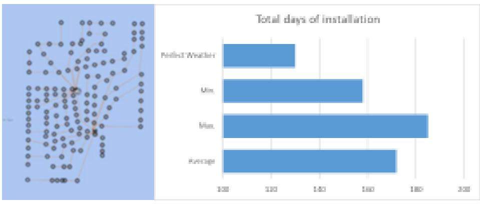
Methodology

The method is based on discrete event modelling of the logistic processes, and involves the following steps:

- Detailed method statement, containing all the required steps in the process, including the personnel and equipment needed and duration of the activity
- Definition of the reference wind farm case and the innovations to evaluate
- Simulations of the scenarios in a framework that allows uncertainty quantification through stochastic (Monte-Carlo) variation of inputs

Results

The offshore wind farm in the baseline scenario is located approximately 18 km from the Dutch coast in the North Sea. The wind farm covers approximately 225 km2 and consists of 140 wind turbines of 11MW (left figure). The pull-in team and the installation support vessel are based at a port which is 30 km from the wind farm



The right figure shows the duration of the installation campaign in number of days, when considering no weather effect ('perfect weather') and the different realizations of the wind and wave conditions. On average, including weather effects, this results in an approximately 30% increase in duration

Discussion and conclusion

The method for logistics modelling consists of a discrete event process description, simulated using Monte-Carlo variation analysis. The method has been validated on two specific cable installation cases, which gives confidence to use this for the impact assessment of the innovations. The model for a typical offshore wind farm of 140x11MW wind turbines has been defined to serve as a representative reference case for the proposed cable installation innovations. Impact of FO monitoring solution on installation coast is reasonable