Dynamic Cable Layout Optimization

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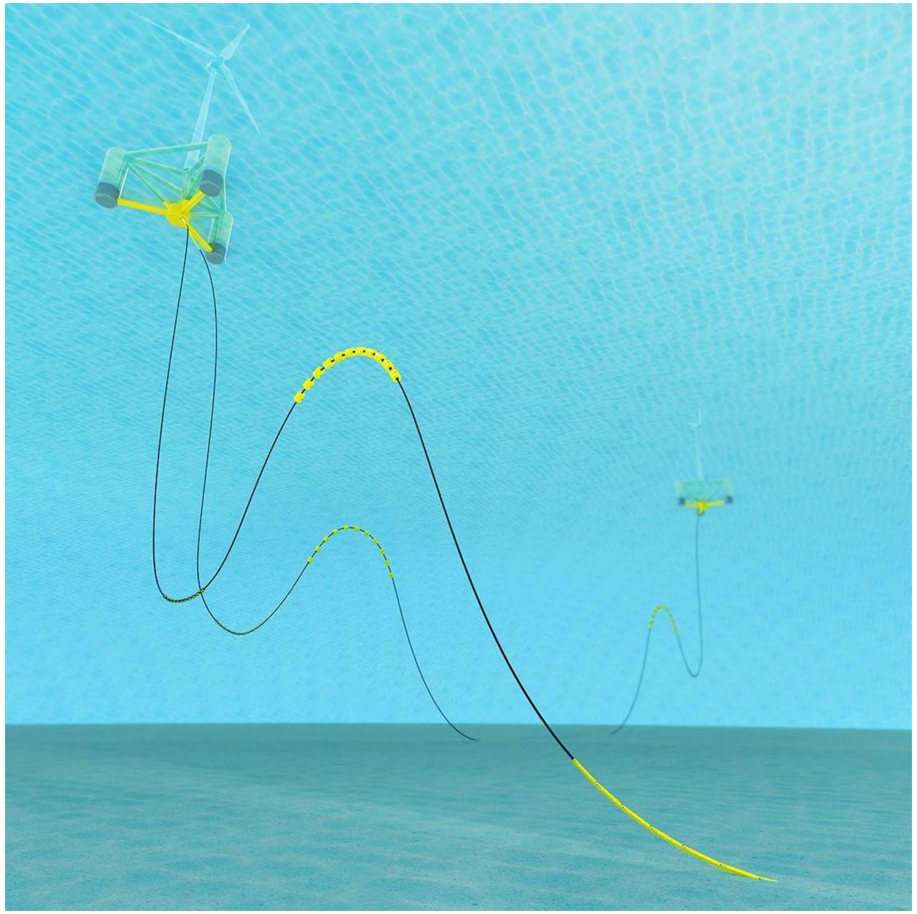
Dynamic cable challenges

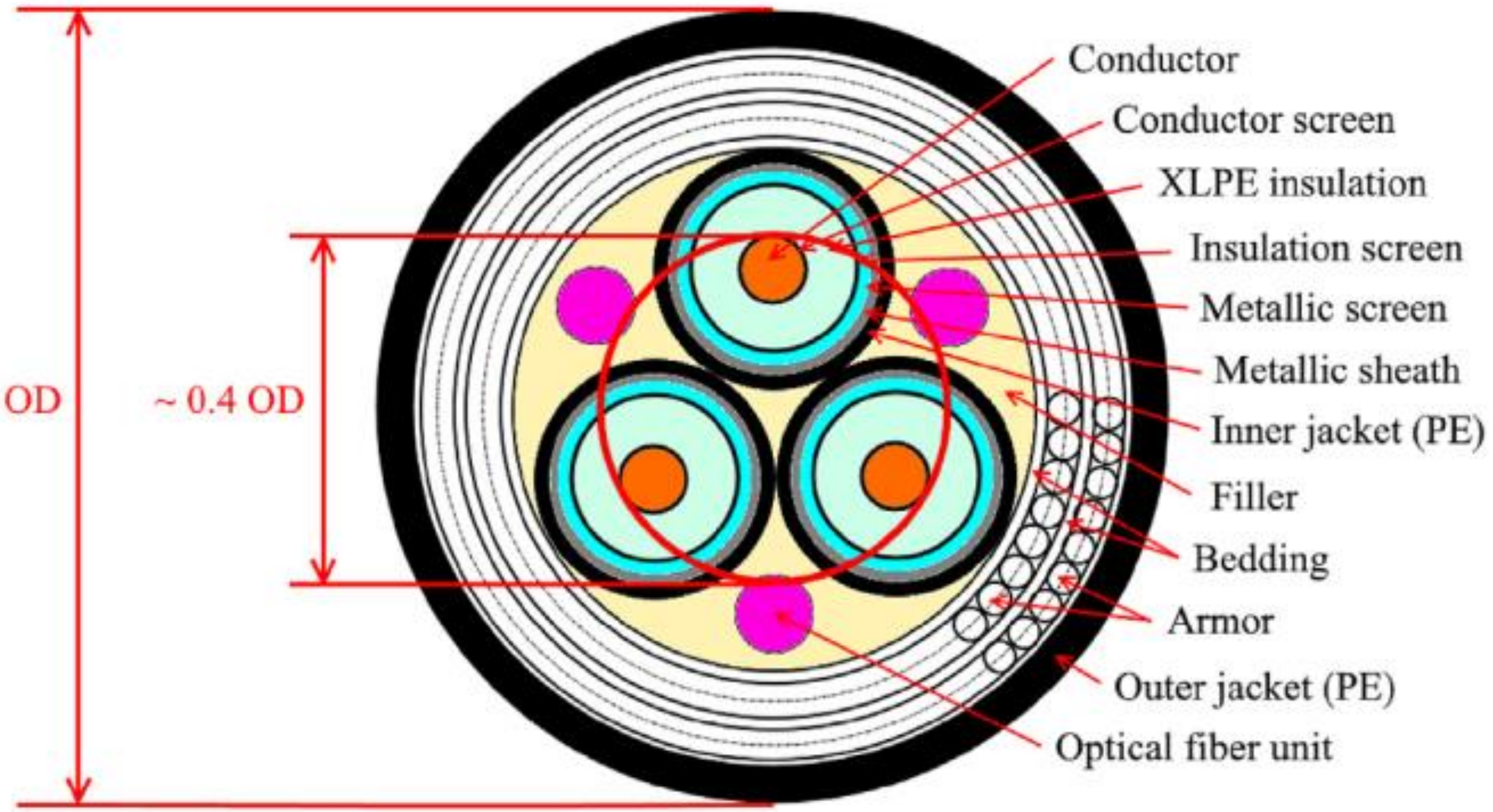
- **55% of insurance claims** and **75% of claim value** in offshore wind farms are related to inter-array cable faults (GCube 2019)
- **Root causes** for failures identified by JIP Cable Lifetime Monitoring
  - Design and manufacturing faults
  - Errors during installation process
  - Unearthing
- Additional challenges for **dynamic cables** exposed to
  - Platform motion
  - Wave excitation
  - Currents
- Very **limited field and research experience** in floating renewable energies environment!



Scope of WavEC’s umbilical layout tool

- Optimize dynamic behavior
- Reduce risk of mechanical failures and power loss
- Increase project reliability, longevity, and ultimately, profit

Umbilical cross section



Cable failure modes

WavEC's research

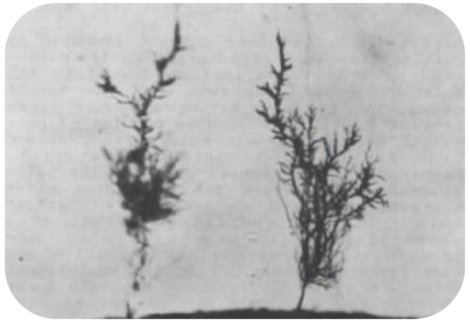
Exceeding max. tension (armor)

Compression → birdcaging (armor)

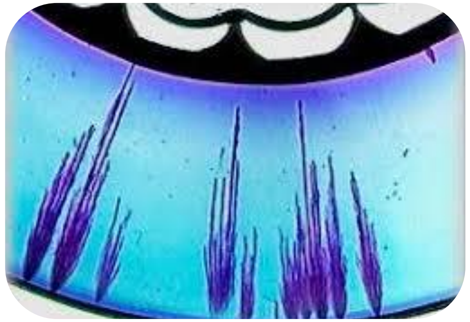
Overbending (core, insulation)

Fatigue (core, sheath)

Abrasion (outer jacket)



Electrical treeing (insulation)



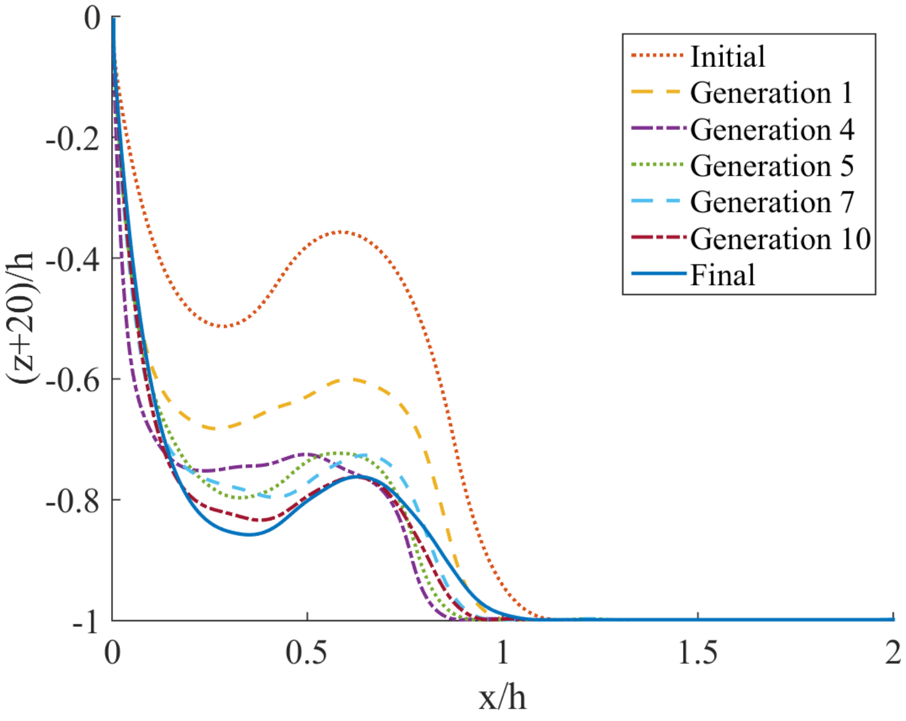
Water ingress (insulation)

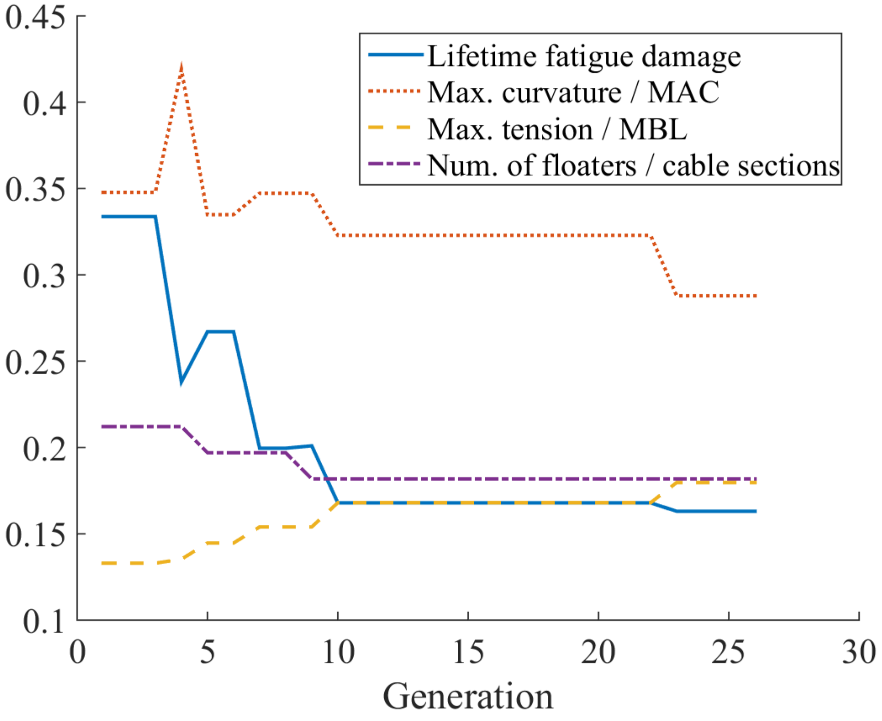
Impact...

Optimization procedure

- Buoyancy supported **lazy wave** decouples motions of floating platforms and power cable
- **Genetic algorithm** optimizes number and location of buoyancy elements 

- Multiple failure modes/evaluation criteria are considered at same time





Evaluation procedure

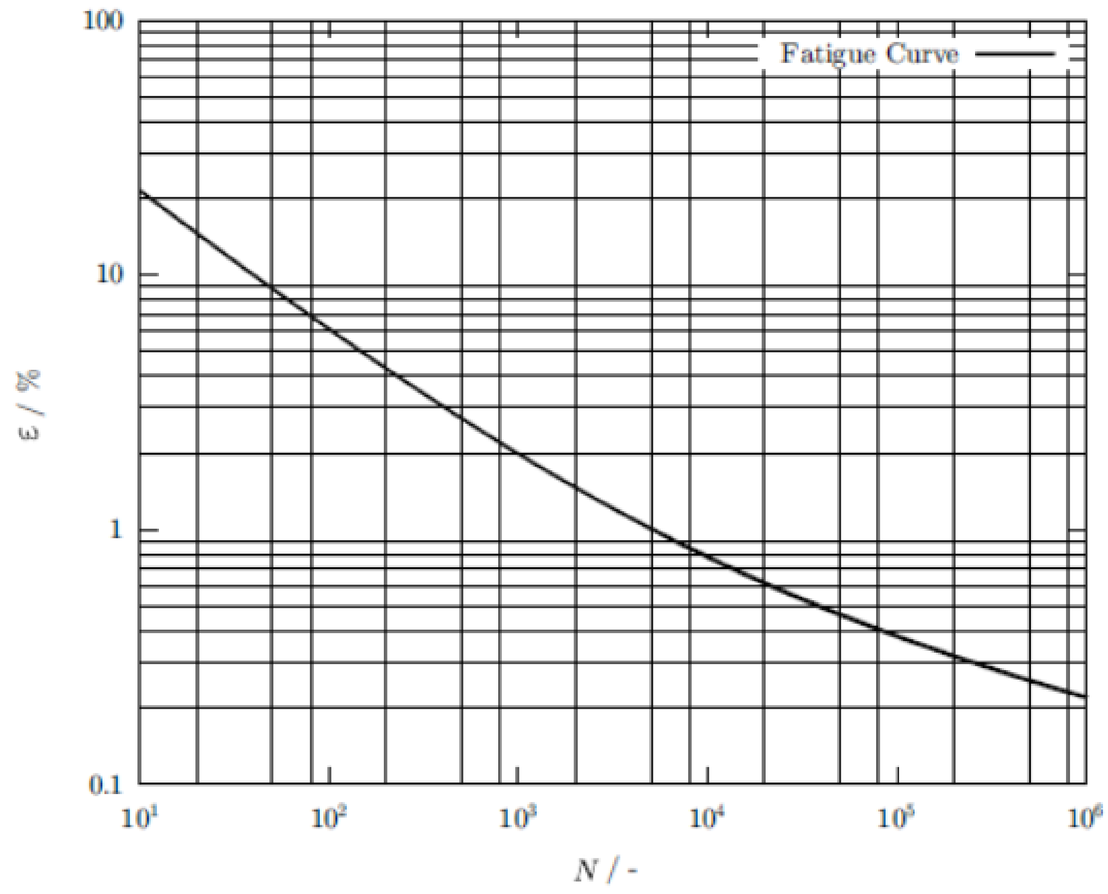
- **Fitness function** with customizable weights

$$fit = (D_{max})^{\alpha} + \left(\frac{\rho_{max}}{MAC}\right)^{\beta} + \left(\frac{T_{max}}{MBL}\right)^{\gamma} + \left(\frac{l_{buoyancy}}{l_{total}}\right)^{\delta}$$

- **Fatigue assessment**
  - Based on non-linear material properties of the copper conductors → strain-cycle curve
  - Strain from curvature history from OrcaFlex

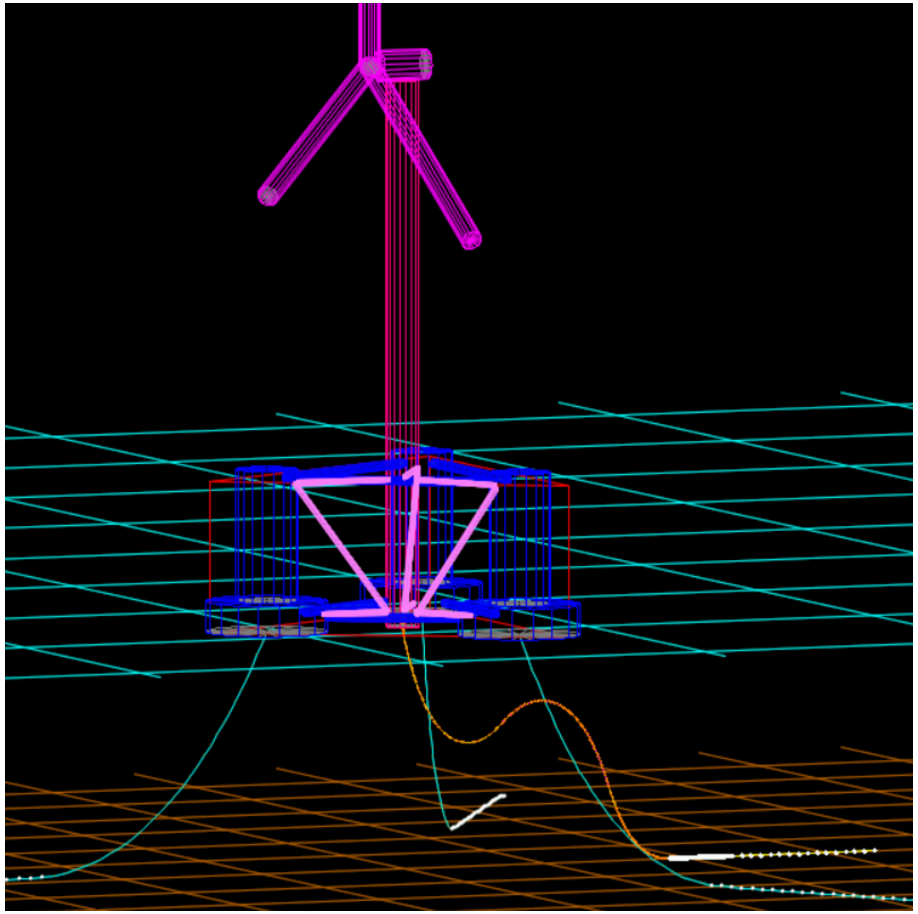
$$\varepsilon = \frac{D_{\varepsilon}}{2 \cdot BR} = \frac{D_{\varepsilon}}{2} \cdot \rho$$

  - Accumulative damage value through application of Rainflow counting and Miner's rule



Applicability throughout project lifecycle

- **Design tool for (Pre-)FEED**
  - Feasibility study
  - Layout recommendation
  - Auxiliary element specifications
- **Asset management/O&M tool during operational life**
  - Monitoring, digital twin:
    Fatigue assessment in (almost) real time
  - Mid-life refit, e.g. if
    real environmental conditions ≠ design conditions
- **After project lifetime**
  - Life extension
  - Second life

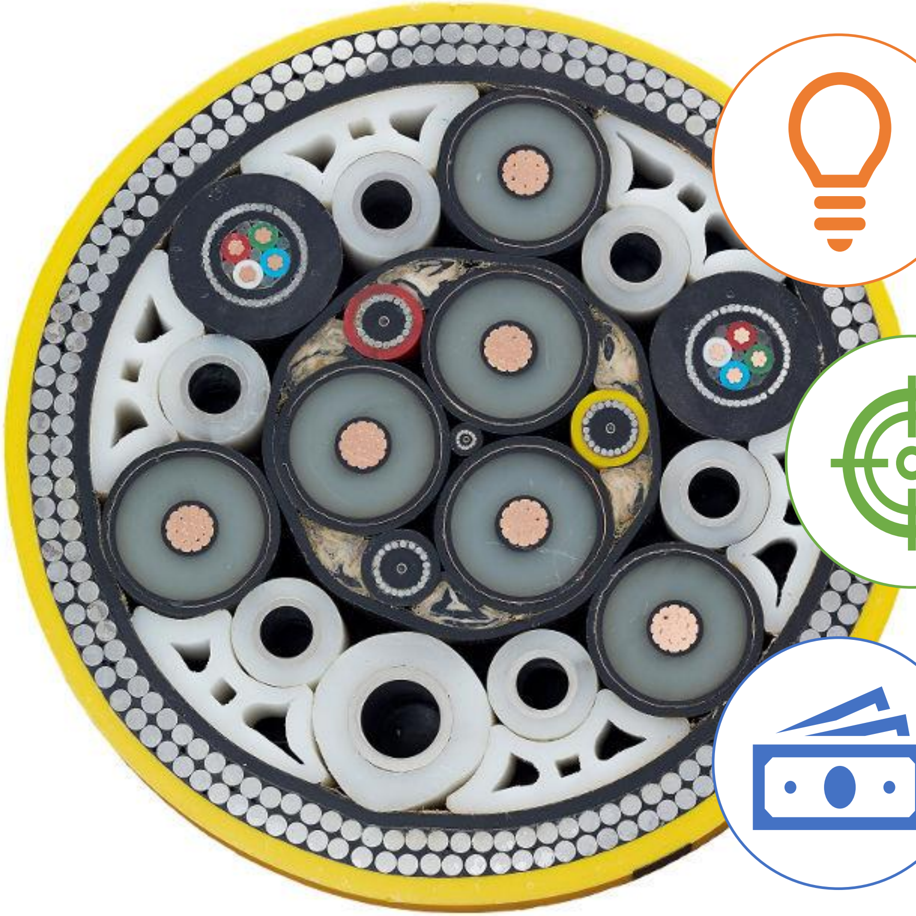


Case study

- **Challenge:** Selection of load cases to comply with DNV GL
  - Operational and extreme metocean conditions
  - Vortex induced vibrations (VIV)
  - Marine growth
  - Cable clashing
- **Implementation**
  - Two different cable configurations (scopes) optimized by GA
  - Hydrodynamic simulations performed with industry standard software OrcaFlex
- **Results**
  - Overview of safety factors
  - Discussion of dimensioning hang-off loads
  - Selection of best performing cable configuration
  - Specifications for auxiliary elements (floaters, bend stiffener)

	Cable Specification	*Configuration A*		*Configuration B*	
		Value	Safety Factor	Value	Safety Factor
Max. effective cable tension	100 kN	5 kN	20.0	9 kN	11.1
Max. effective cable tension (fouled)	100 kN	8 kN	12.5	12 kN	8.3
Max. cable curvature (1/MBR)	0.8 m^{-1}	0.38 m^{-1}	2.1	0.35 m^{-1}	2.3
Max. cable curvature (fouled)	0.8 m^{-1}	0.35 m^{-1}	2.3	0.25 m^{-1}	3.2
Min. cable clearance		0.50 m		2.5 m	
Min. cable clearance (fouled)		0		1.5 m	
Max. axial force at the I-tube		5 kN		10 kN	
Max. shear force at the I-tube		7 kN		8 kN	
Max. bending moment at the I-tube		10 kNm		10 kNm	

Benefits & advantages



Novel optimization approach
Customizable multiparametric evaluation with fitness function
Superior to generic layout, typical fatigue reduction ≥ 50 %

Wide applicability throughout project lifecycle

Reassure investors, increase bankability
Empowering new business models (leasing)

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WavEC Offshore Renewables

References

- **Publications**
  - K. Krügel, Hydrodynamic design of umbilical systems for floating offshore wind applications, presented at the FOWT 2017 Conference on 15th March 2017
  - M. Rentschler et al., Design optimization of dynamic inter-array cable systems for floating offshore wind turbines, *Renewable and Sustainable Energy Reviews* **111** (2019), https://doi.org/10.1016/j.rser.2019.05.024
  - M. Rentschler et al., Parametric study of dynamic inter-array cable systems for floating offshore wind turbines, *Marine Systems & Ocean Technology* **15** (2020), https://doi.org/10.1007/s40868-020-00071-7
- **Picture credits**
  - p.2: BARDOT. Floating wind turbine cables protection systems for both inter-array cables and export cables
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