



EERA DeepWind'2021: "Dynamic cable model for layout optimisation purposes in Floating Offshore Wind Farms"

Virtual conference, 14th Jan 2021

José Ignacio Rapha Juan, Power Systems Group at Catalonia Institute for Energy Research, <u>jirapha@irec.cat</u> José Luis Domínguez-García, Power Systems Group at Catalonia Institute for Energy Research

Part 1: Introduction

Part 2: Cables

Part 3: Cable model

Part 4: Algorithm

Part 5: Results





GOING OFFSHORE 1





The best locations are far from the coast but...



GOING OFFSHORE 2

... it is all about costs.

LCOE 2020 [€/MWh]







GOING OFFSHORE 3



Shaping Energy for a Sustainable Future

However:

- In Europe, the best locations for onshore wind farms are already exploited. Remaining locations present winds with lower quality, are remote areas or are just protected.
- Bottom-fixed offshore wind farms are now a consolidated technology, but their costs make it unviable at depths greater than 50 m.
- Floating offshore wind has a great potential: combining Europe, US and Japan, around 7.000 GW are available!!

SOME FOWFS CHALLENGES



Standardisation



Logistics & assembly



Repair & maintenance



Dynamic cables



Costs









FOWF CABLING OVERVIEW





ANCILLARY EQUIPMENT FOR DYNAMIC CABLES





SUSPENDED CABLE CONFIGURATIONS









EXISTING MODELS

Advantages

 Some existing programs can perform accurate dynamic analysis of dynamic cables (e.g., OrcaFlex)

Disadvantages

- Lacking or limited optimising capabilities (e.g., only 2D optimisation)
 - Long simulations
 - Difficult integration for expanded optimisation or additional evaluations
- Complex tasks even for early stages of projects



OBJECTIVE

The aim is to develop a model of the suspended cables with several degrees of freedom and including the main ancillary equipment as well as the relevant loads, finding a balance between realistic behaviour and moderated computation times when it comes to optimising.

The existing cable configurations are assessed, plus additional configurations that may be feasible and viable for FOWFs.

The model is developed to meet the requirements of the next steps.



MODEL OVERVIEW

The position of a suspended cable, even in static conditions, can't be determined analytically in most of cases

Lumped mass model: all cable properties are transferred to the nodes (except its length) The position and tensions are determined imposing equilibrium conditions at each node





EXTERNAL ACTIONS

Marine growth



Currents





FORCE MODELS





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THE CATENARY

Mathematical definition and properties

Equation

$$\frac{d^2 z}{dx^2} = \frac{\lambda}{T_H} \sqrt{1 + \left(\frac{dz}{dx}\right)^2}$$

• Integrated equation

$$z - z_0 = a \cdot \cosh\left(\frac{x - x_0}{a}\right)$$

• Arc length

$$L = a \cdot \sinh\left(\frac{x_0 - x_A}{a}\right) + a \cdot \sinh\left(\frac{x_B - x_0}{a}\right)$$

Physical properties

• Horizontal tension

$$T_H = a \cdot \lambda$$

Vertical tension

$$T_V = T_H \cdot z' = a \cdot \lambda \cdot \sinh\left(\frac{x - x_0}{a}\right)$$

Tension

$$T = T_H \cdot \cosh\left(\frac{x - x_0}{a}\right) = \lambda(z - z_0)$$



INITIAL GUESSES





CABLE POSITION CALCULATION



Loaded Loaded	cable: marine	Nexans growth	V333x80035 profile: Default									
Step	Iter	Flag	Cable T Min	[kN] Max	Curv [m-1] Max	Alpha [deg] Max	Lengtł Laid	ns [m] Susp	Tether T [kN]	Check		
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1	37	1	GuessLW									
2	3	1	7.3	68.4	0.058	3.1	10	370	-	ОК		
3	5	1	7.3	67.8	0.177	9.6	10	370	-	ОК		
4	27	1	7.1	69.0	0.178	9.7	18	362	3.5	ОК		
5	12	1	7.4	76.6	0.190	10.4	18	362	2.6	ОК		
6	16	1	6.9	76.3	0.177	9.7	19	361	2.8	ОК		
7	Cable strain of 0.013% (5 cm) neglected.											
Elapsed	ed time is 6.656814 seconds.											







Part 5: Results



GRAPHIC RESULTS 1







GRAPHIC RESULTS 2







FINAL REMARKS

Floating offshore wind is an available technology but requires optimisation to lower its costs

The dynamic cables play a relevant role in the technology progress as they are being developed specifically for this task

A good initial guess saves time and prevents the algorithm from reaching wrong solutions (or not finding any solution), and variable scaling is important

Buoyant sections should be below the euphotic zone

Bend stiffness is usually negligible due to the low cable bending

Site-specific marine growth and current profiles are important to avoid additional uncertainty, as their effect is relevant

Axial stiffness can be neglected almost always



AKNOWLEDGEMENT

The research leading to these results has received funding from the European Union's Horizon 2020 Research and Innovation programme under grant agreement No. 815083 (COREWIND)





Horizon 2020 European Union Funding for Research & Innovation







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