Dynamic cable cost optimisation using genetic algorithm for lazy wave, tethered lazy wave and suspended configurations

Caroline Valenchon[1], Florian Castillo[1], Jean-Christophe Gilloteaux[1]
[1] OWC, Nantes, France

The dynamic cable system significantly impacts the total cost of a floating offshore wind (FOW) farm, with two main configurations currently in use or under investigation. In shallow to medium water depths, (tethered) lazy wave configurations are employed, where the cable hangs in the water column from the floater or floating substation. In deeper waters, suspended configurations are emerging as a cost-effective solution, allowing the cable to hang between the FOWTs high in the water column through strategic positioning of buoyancy modules. Beyond water depth, optimal configurations depend on numerous factors, leading to a highly time-consuming and iterative design process. The goal is to develop a code to find an optimized configuration in term of cost, allowing to compare (tethered) lazy wave to suspended configuration for cost.

OPTIMIZATION PROCESS

Design space
↓
Quasi static optimization
- NEAR: Current + offset
- FAR: Current + offset

↓
Optimized configuration
↓
Dynamic Check

Fitness function

$f = C_{cable} + C_{BM} + C_{ancillaries}$

C_{cable}: cost of cable

C_{BM}: cost of Buoyancy modules (BM)

$C_{ancillaries}$: cost of ancillaries (tether, touchdown protection)

Constraints

$max_{tension} < SF \times MBL = \text{Maximum Breaking Load}$

$min_{radius} > SF \times MBR = \text{Minimum Bending Radius}$

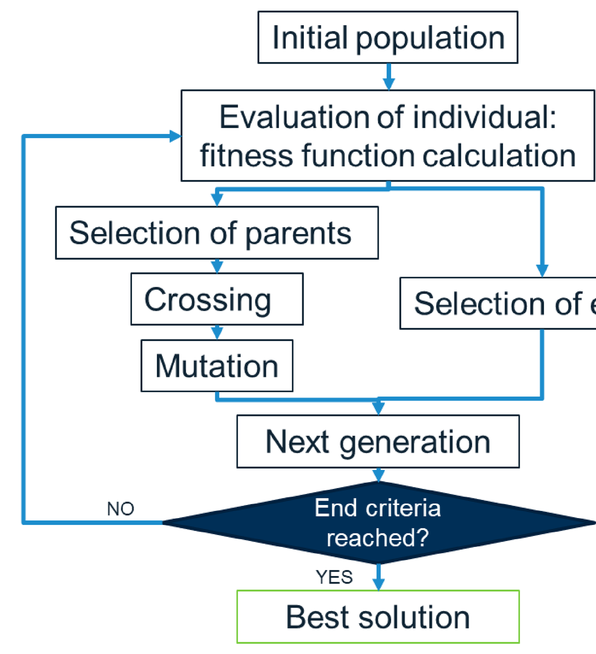
$min_{sag} > sag_{clearance} = 10m$

$min_{hog} > hog_{clearance} = 10m$

$min_{tension\ tether} > 1kN$

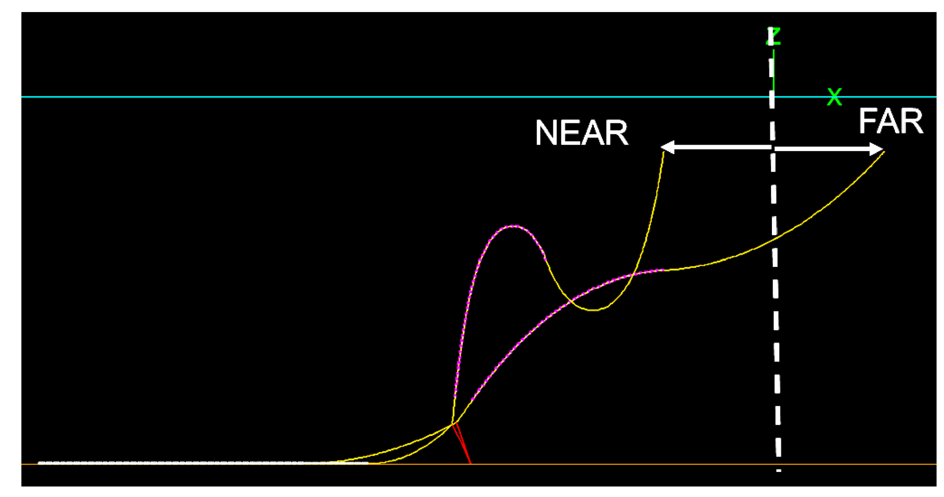
SF: Safety Factor

Optimization performed with Genetic Algorithm (GA)



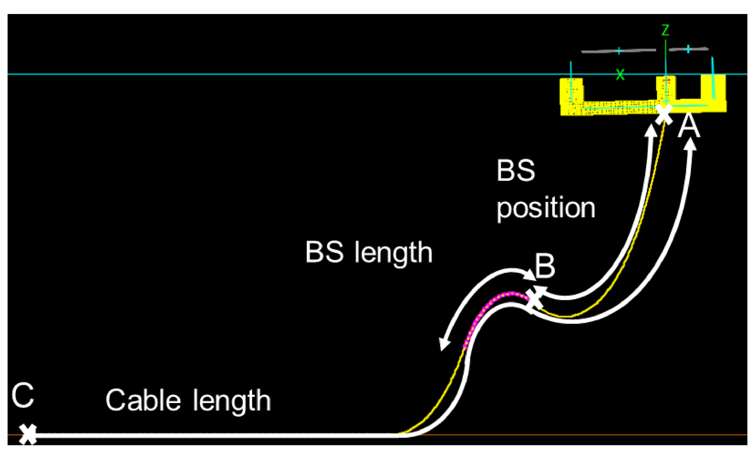
NEAR and FAR definition:

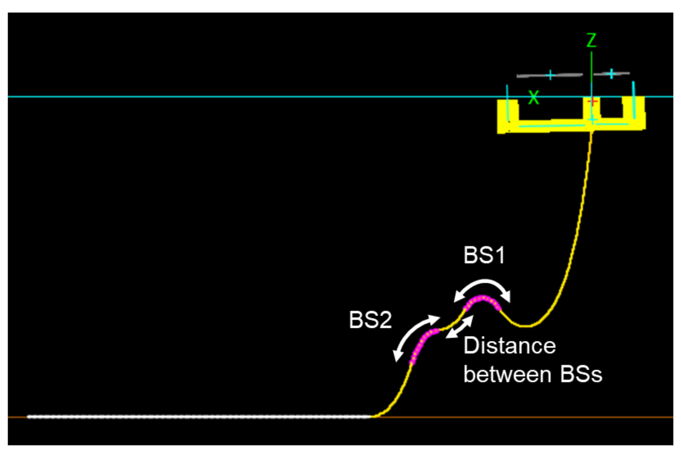
Extreme positions of the Hang-off point associated to the maximum FOWT offsets



CONFIGURATIONS PRESENTATION

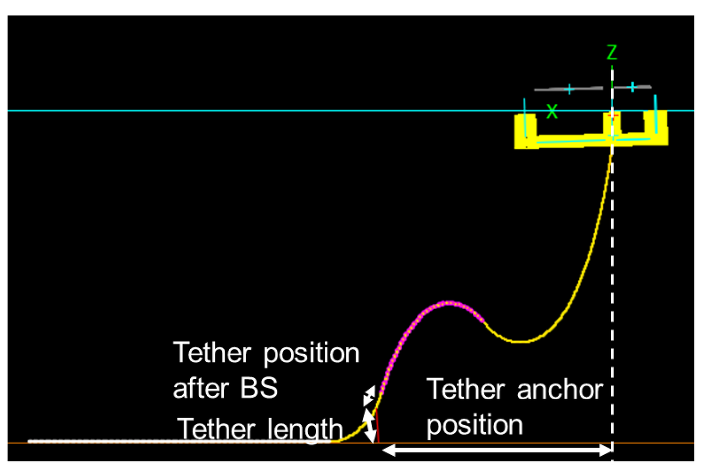
Lazy Wave / Double lazy wave (LW)



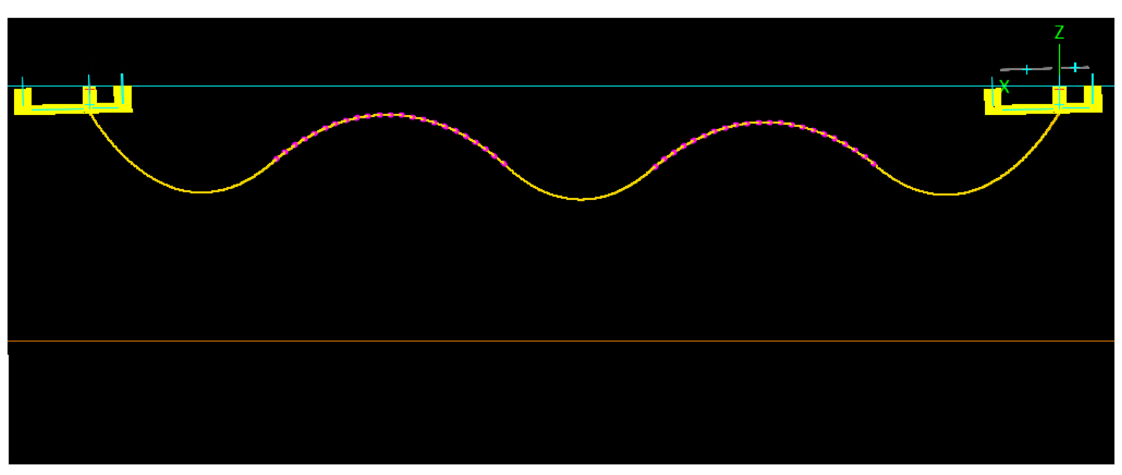


Parameters modified for all configurations:
- Cable length
- Position of the buoyancy section (BS)
- Number of buoyancy modules (BM)
- Ratio of buoyancy over mass use for outer diameter calculation of the BM
- BM pitch
- BM width

Tethered Lazy wave (TLW)



Suspended (W shape)

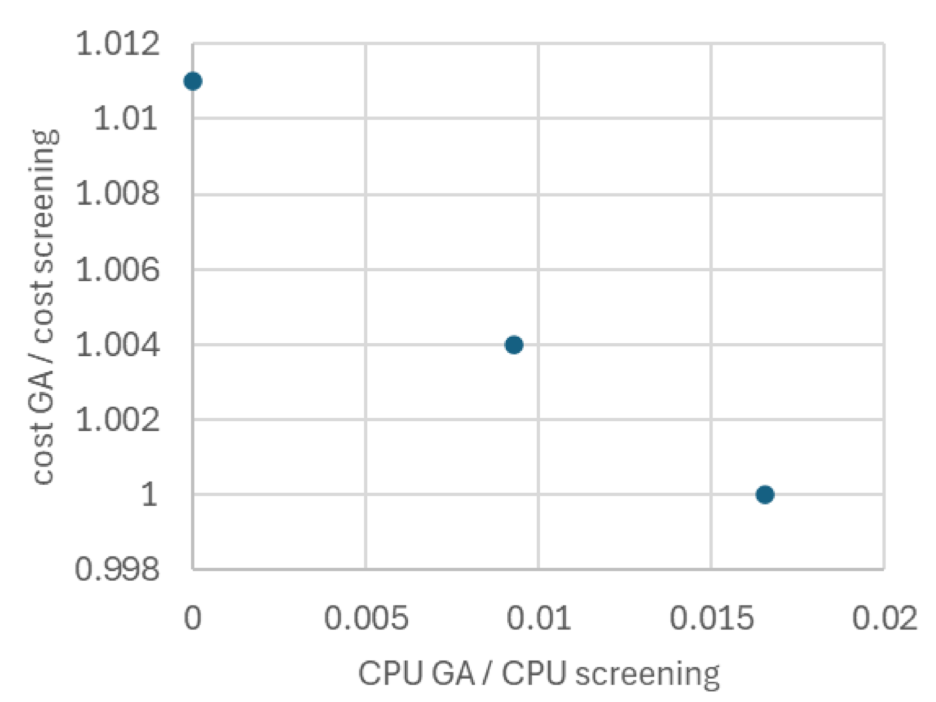


For Double LW:
- Distance between two BSs

For TLW:
- Tether position: it corresponds to tether position on cable after BS.
- Tether length
- Tether anchor position: horizontal position from (0,0)

VALIDATION – GA vs screening

Both methods provide similar costs. However, GA is far more efficient in term of calculation time leading to some cost saving on the design process.

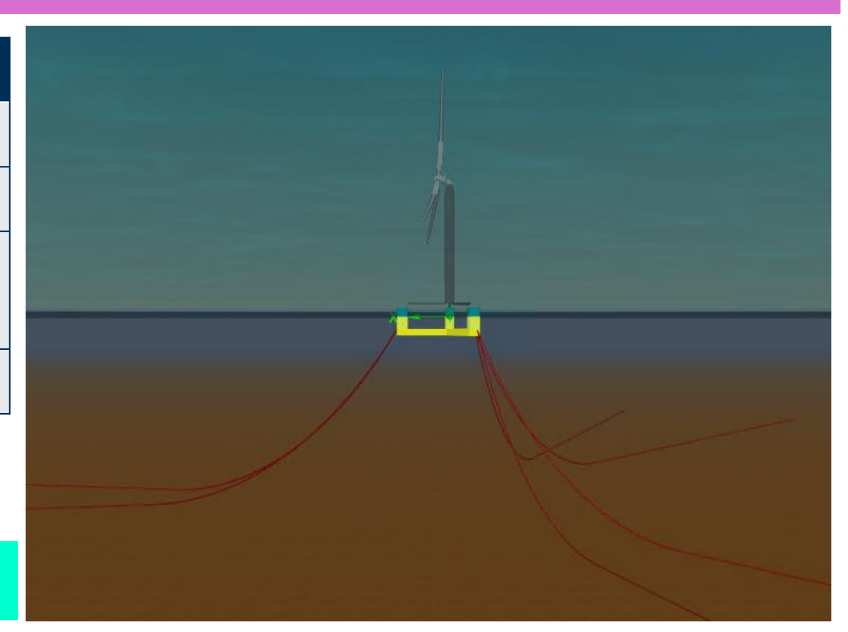


CONDITIONS

- Floating Wind Turbine: VolturnUS-S (from University of Maine) floater combined with a 15MW wind turbine (from NREL) [1]
- Conditions: West of Barra conditions [2]
- Marine growth: based on Norsok N-003 [3]
- EOL case: buoyancy loss (5%) considered
- LC1: used for TLW and suspended configuration
- LC2: used for LW and suspended configuration

Water depth (m)	Marine growth Thickness (mm)
Up to 40m	60
Up to 100m	30
Below 100m	20

Parameter	Unit	LC1	LC2
Hs	m	15.6	15.6
Tp	s	12	12
Current (at sea surface)	m/s	1.82	0
Offset	m	59	38

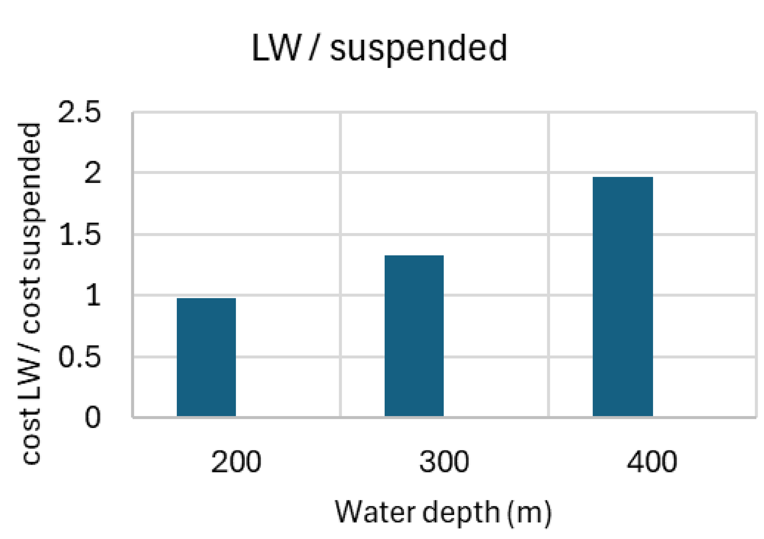


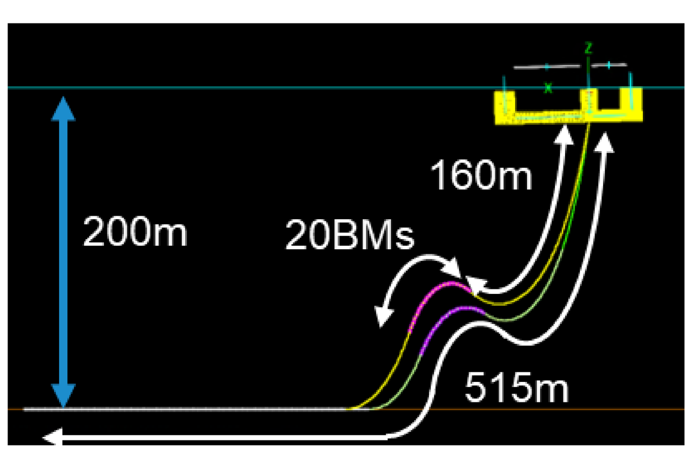
RESULTS

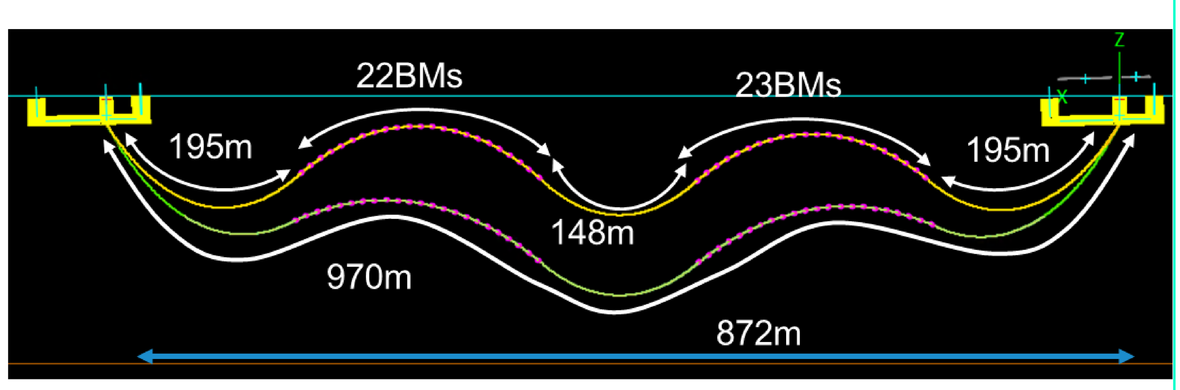
Cost comparison: LW vs Suspended

4D distance between FOWT

Beyond 200m water depth, the suspended configuration becomes more cost-effective than the LW configuration, mainly due to reduced cable length required.







Cost comparison: TLW vs Suspended

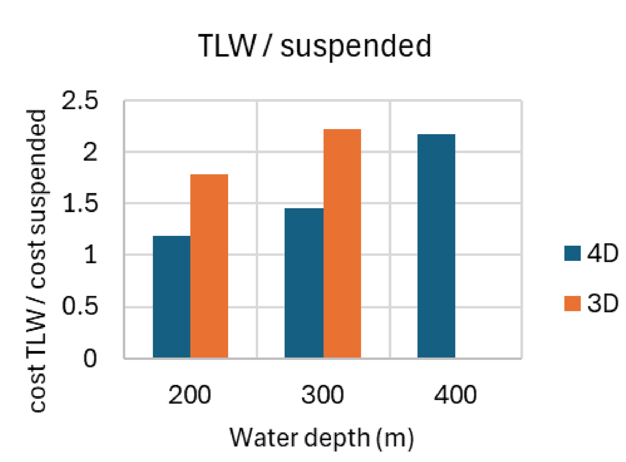
4D distance between FOWT

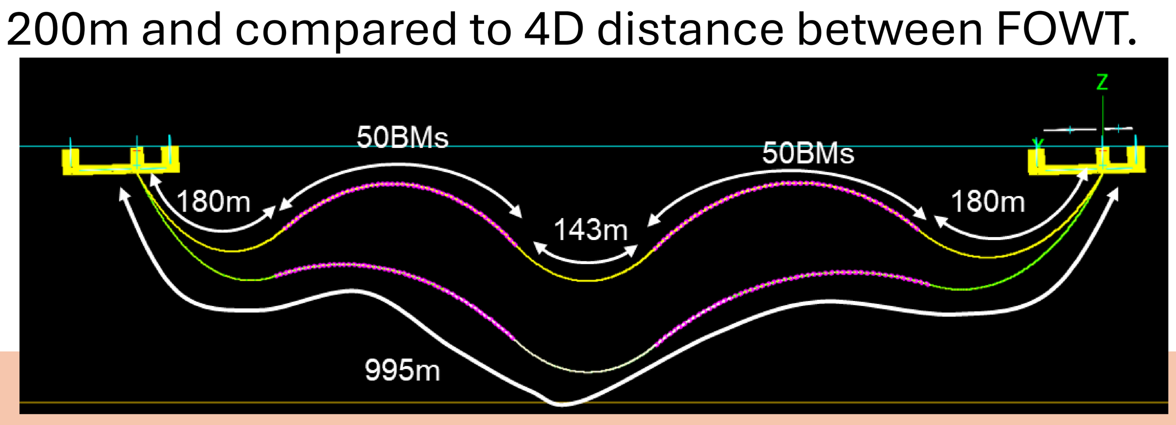
Suspended configuration is more cost effective from 200m due to additional ancillaries needed compared to LW.

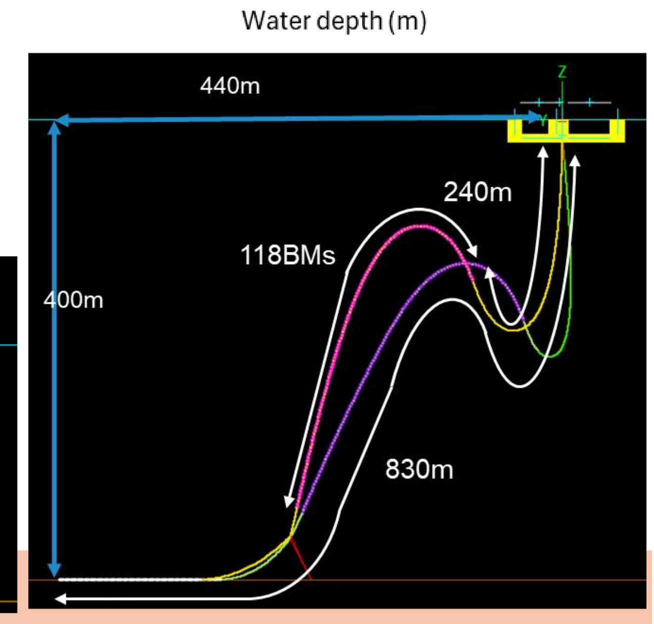
It is more difficult to find an acceptable suspended configuration at 200m due to close limit with seabed and max tension increased due to offset and current increased.

3D distance between FOWT

Suspended configuration is more cost-effective from 200m and compared to 4D distance between FOWT.







MAIN TAKEAWAYS

- Current has a small impact on the results for suspended configurations
- As distance between WT increases it is more difficult to find acceptable solutions for suspended configurations: for 5D and 7D, no configurations were found with the current marine growth profile
- Marine growth has a high impact on finding suitable suspended configurations. Moreover, as the distance increases, the compensation of tension by buoyancy modules is limited by the hog clearance with sea level. For long distances between wind turbine, a double BS configuration is not suited.
- Increasing the number of buoyancy sections could be the solution to remove the hog clearance issue. For the suspended configuration, an additional parameter, the number of buoyancy sections, will be added in the new version of the code.

ACKNOWLEDGEMENT

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[1] C. Allen, et al, Definition of the UMaine VolturnUS-S Reference Platform Developed of the IEA Wind 15-Megawatt Offshore Reference Wind Turbine, 2020
[2] Corewind, D1.2 Design Basis, 2019
[3] Norsok Standard, Actions and action effects, N-0003, 2007