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D-KN1
Design of Flexible Cables for Floating Platforms

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TWIND Summer School
09/07/2021

Outline

1. Power cable
2. Dynamic cable
3. Metocean conditions
4. Design

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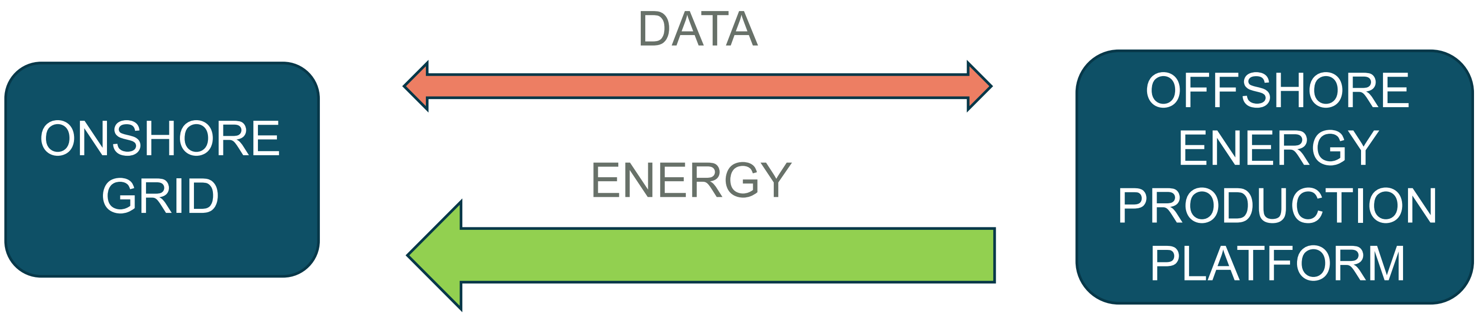
1. Power cable

1. Power cable

1.1 Power cable mission

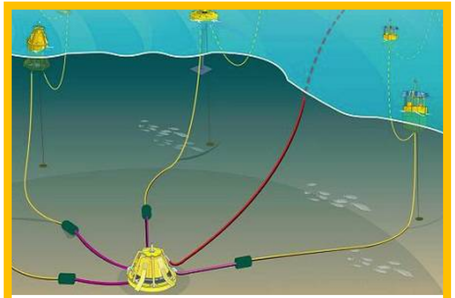
- The main function of power cables used in floating platforms is to provide a physical medium for energy and data transmission between the platform and the onshore infrastructure(s).



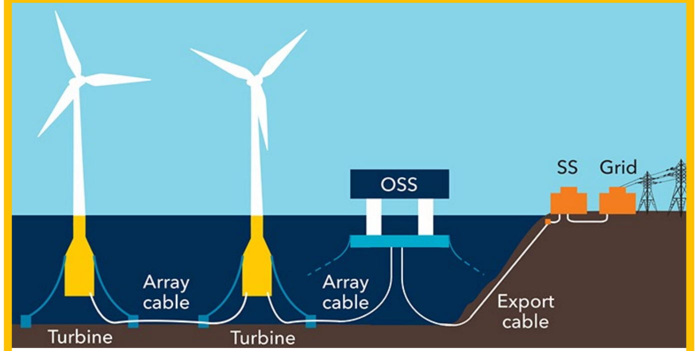
1. Power cable

1.2 Power cable layout

Depending of the number of devices, their total power, and the distance to onshore grid, could not be convenient to perform a **direct connection** (direct output from the floating devices to coast) with a reasonable value for the energy losses, so in such a scenario, a **cable grouping stage** (a hub) with the simply goal to reduce the number of cables going to coast or, even better, a **voltage transformation stage** (an offshore substation) may be required to achieve an efficient transmission.



Connection to hub



Connection to OSS

1. Power cable

1.2 Power cable layout

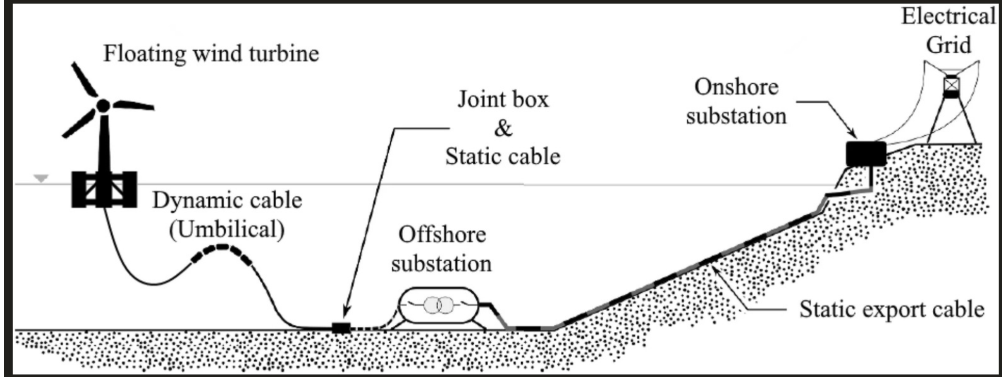
Talking about a farm of several floating platforms, it is common to have a voltage transformation stage located in a floating substation.

In such a case, the power cables are usually distinguished in:

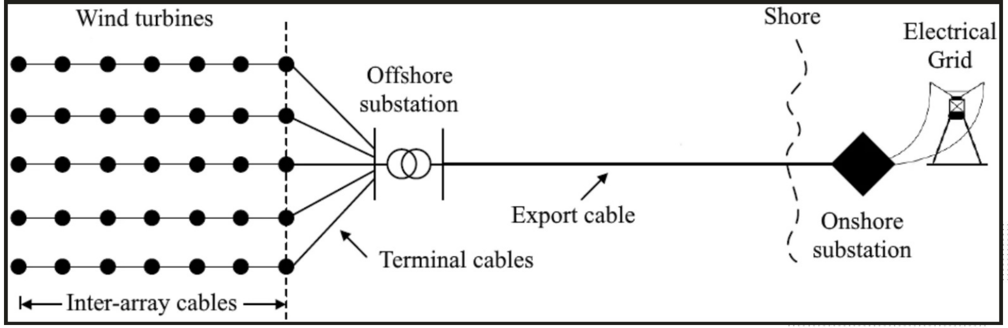
A. **inter-array cables** (from the energy generation platforms to the substation) and

B. **export cables** (from the substation to coast).

From: Parametric study of dynamic inter-array cable systems for floating offshore wind turbines



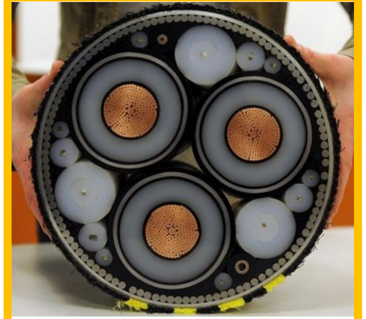
From: Parametric study of dynamic inter-array cable systems for floating offshore wind turbines



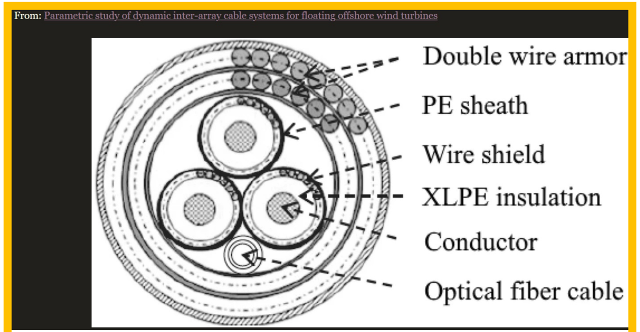
1. Power cable

1.3 Power cable internal structure

- The power cable can be composed, internally, of only by power conductors or by **conductors** with different cross-section and insulation (conductors for main power delivery and conductors for ancillary services) and **fibre optic wires** for data transmission.
- Depending on the typology of cable segment (**static** or **dynamic**), the cable may have single or double armour, in function of loads and motions it shall withstand.



Static cable



Dynamic cable

2. Dynamic cable

2. Dynamic cable

2.1 Dynamic cable requirements and functionalities

The **dynamics of the floating platform** and the **environmental loads** makes that the design of the dynamic cable is fundamental to perform the primary function of the electrical evacuation system.

a physical medium for energy and data transmission

The dynamic cable is intended to be that segment of power cable going from the floating platform to a certain fixed point on the seabed (which could be a submarine hub or a simple connector/joint between dynamic and static cable).

Dynamic cable is supposed to be → The only segment of power cable directly subjected to the platform motions.

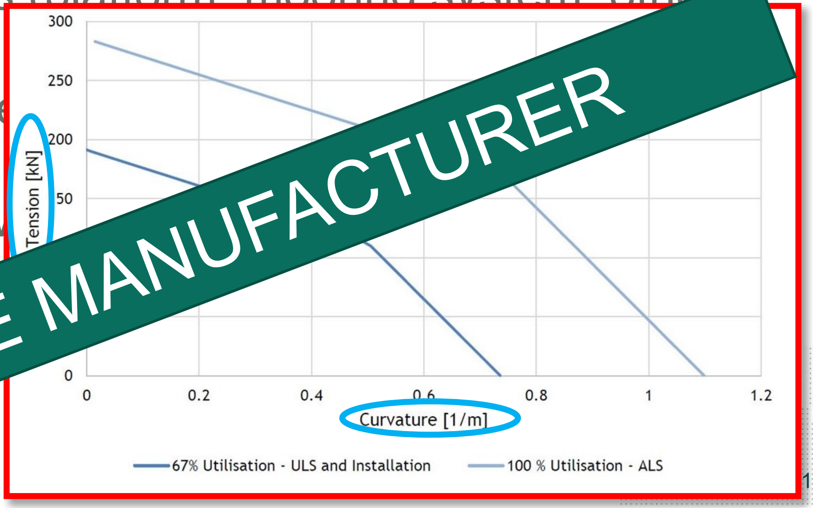
2. Dynamic cable

2.1 Dynamic cable requirements and functionalities

The dynamic cable configuration shall satisfy the requirements and functionalities of the power cable, as follows:

- To keep the integrity of the power cable (relationship curvature-tension)
- To avoid any contact with other elements (platform, mooring system, other cables, etc)
- To avoid any contact with seabed; any se… seabed shall be adequately protected;
- To keep a minimum clearance with the w…

Cable capa…



2. Dynamic cable

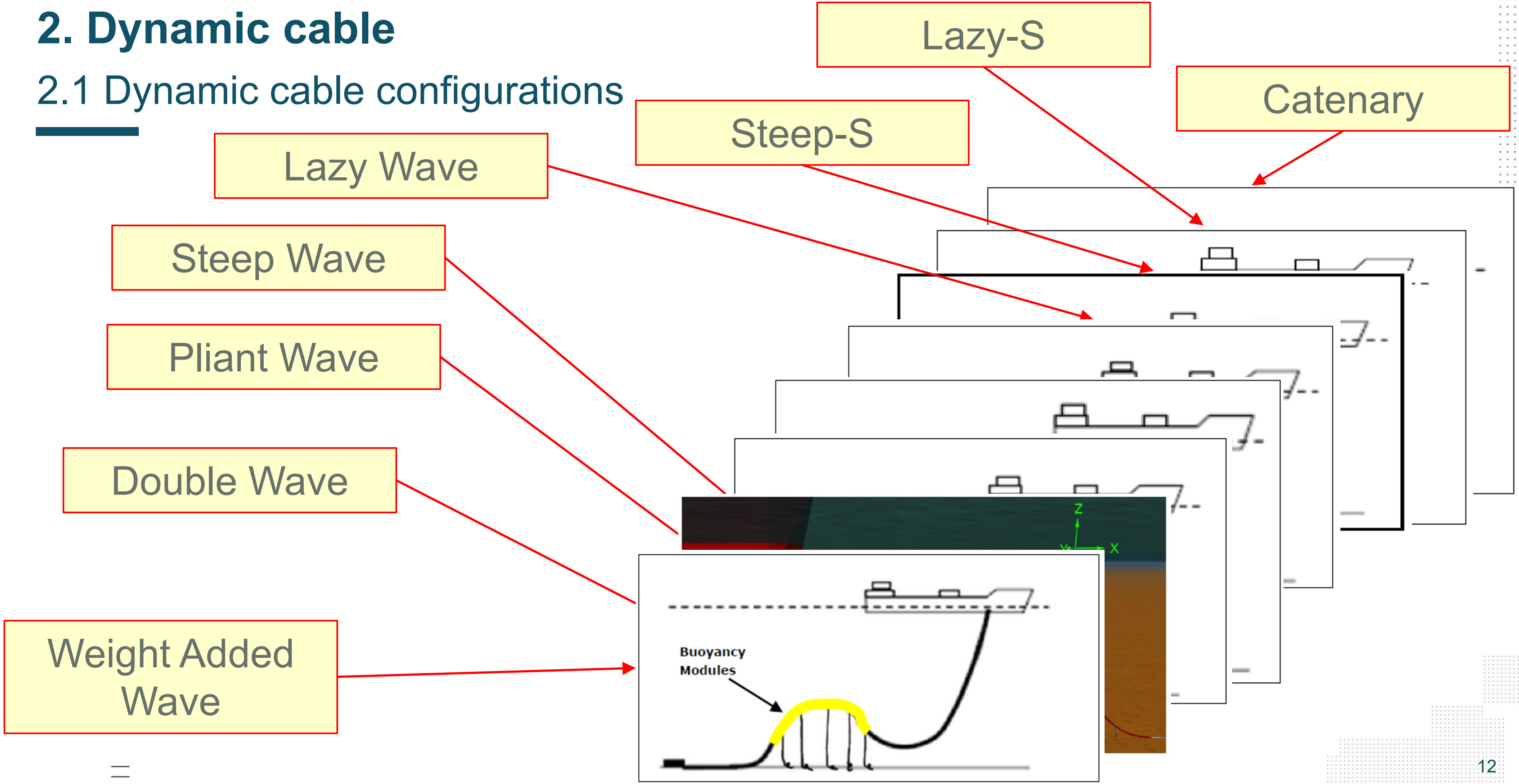
2.1 Dynamic cable configurations

A large number of different **configurations for dynamic cable** exists. The selection among them depends on several factors, mainly:

- Water depth;
- Platform draft and motions;
- Metocean condition;
- Power cable characteristics;
- Project life and O&M strategy.

2. Dynamic cable

2.1 Dynamic cable configurations

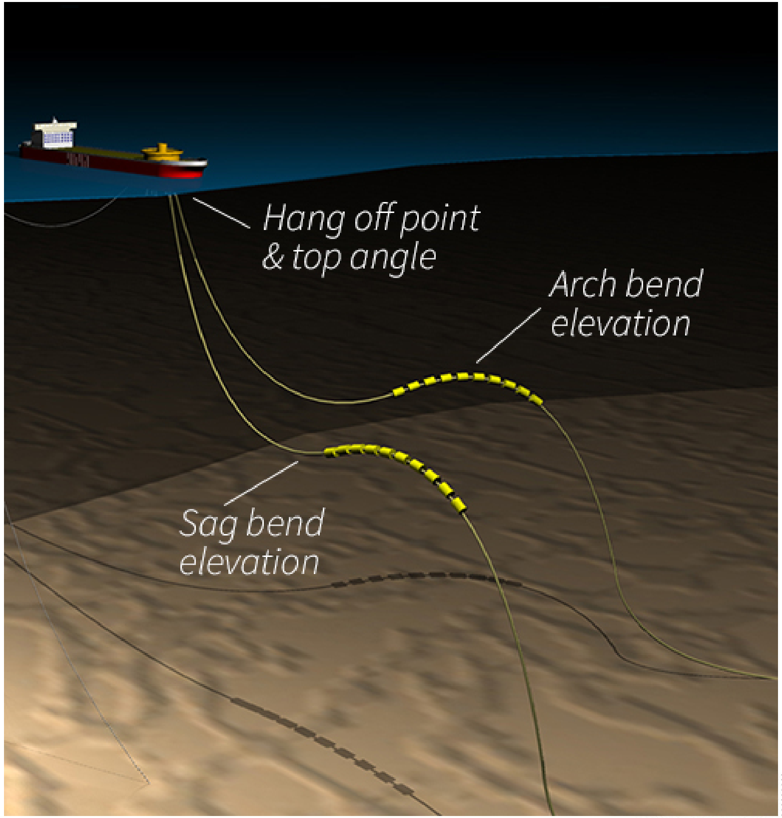


2. Dynamic cable

2.2 Lazy Wave configuration

"**Lazy-wave**" has gained popularity as a viable solution to improve fatigue and strength performance of the cable as response to the motions of the floating platform and to the environmental loads acting directing on the cable.

Along the time, other configurations have been derived from the original Lazy Wave.



2. Dynamic cable

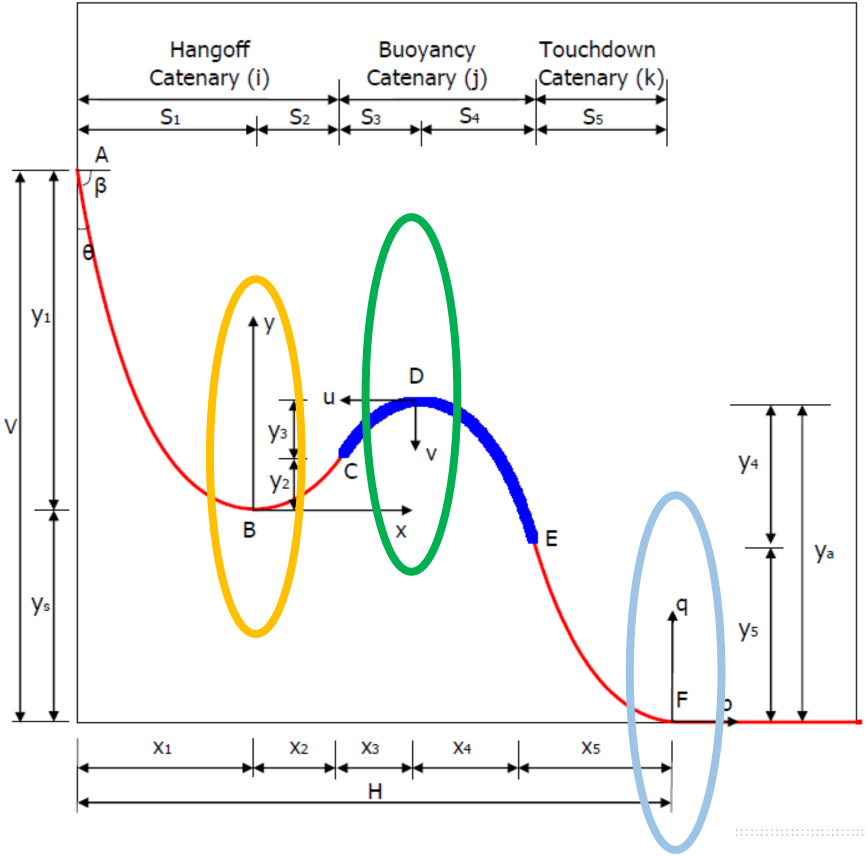
2.3 Lazy Wave properties

The **critical sections** of Lazy Wave configuration are:

B. The sag bend

D. The arch bend

F. The touchdown point



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3. Metocean conditions and loads

3. Metocean conditions and loads

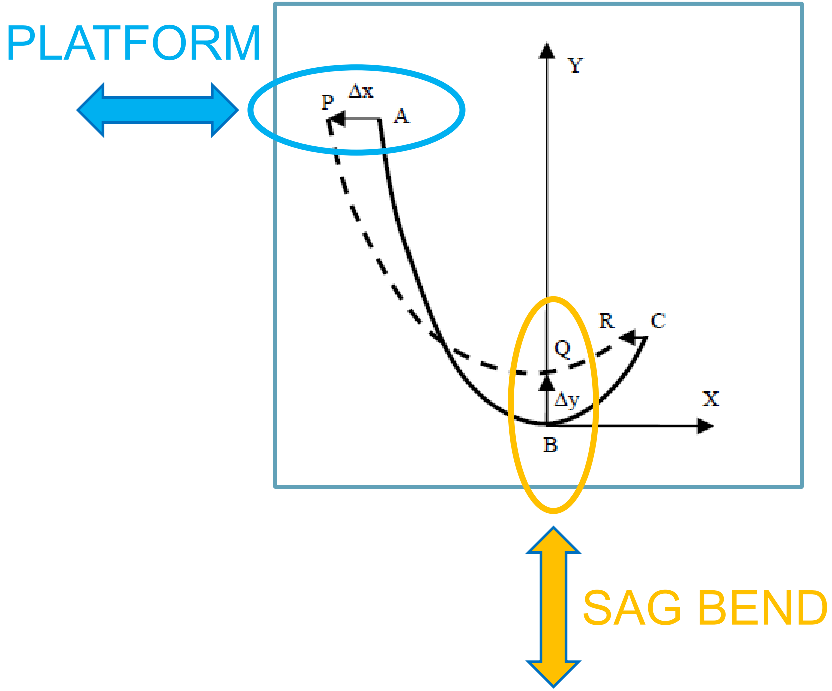
3.1 Indirect loads

The main environmental loads which act **indirectly** to the cable behaviour are due to wind, waves and current, by acting to the floating platform and, in turn, to the dynamic cable through the motions of the hang-off point.

3. Metocean conditions and loads

3.1 Indirect loads

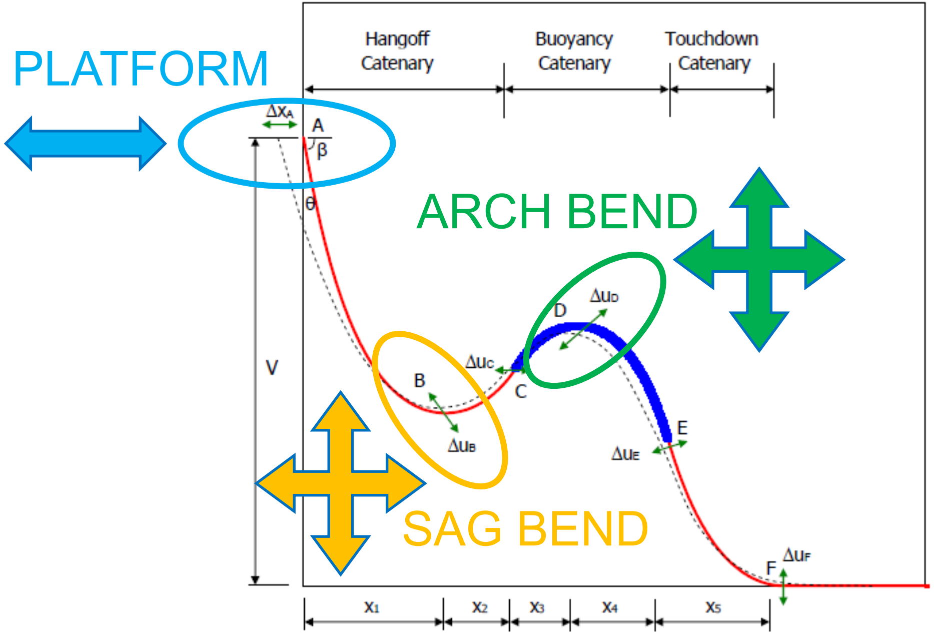
The 1st **order** motions in heave, surge and sway directions of the platform are mainly translated into **heave motions** at the sag bend.



3. Metocean conditions and loads

3.1 Indirect loads

The 2^{nd} **order** motions give the more time for the Lazy Wave to respond globally: the motions in heave, surge and sway directions of the platform turns into both horizontal and vertical motions at the sag bend.



3. Metocean conditions and loads

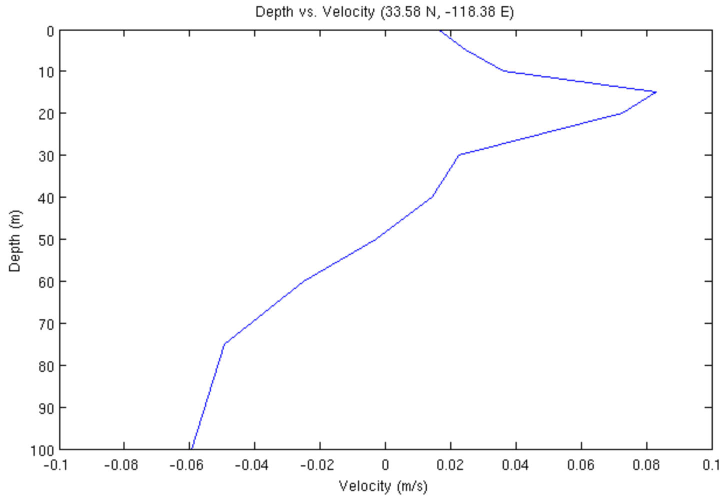
3.2 Direct loads

The main environmental load which acts directly to the cable behaviour is due to the current: it is important to that both cable orientation and vertical profile are designed in function of current load.

CURRENT
- direction
- vertical profile

→

CABLE
- orientation
- vertical profile



4. Design methodology

4. Design

4.1 Design Conditions

Dynamic cable should be compliant to power cable requirements under different design conditions:

Installation →
- T&I

Operation →
- Service (SLS)
- Extreme (ULS)
- Fatigue (FLS)
- Accident (ALS)

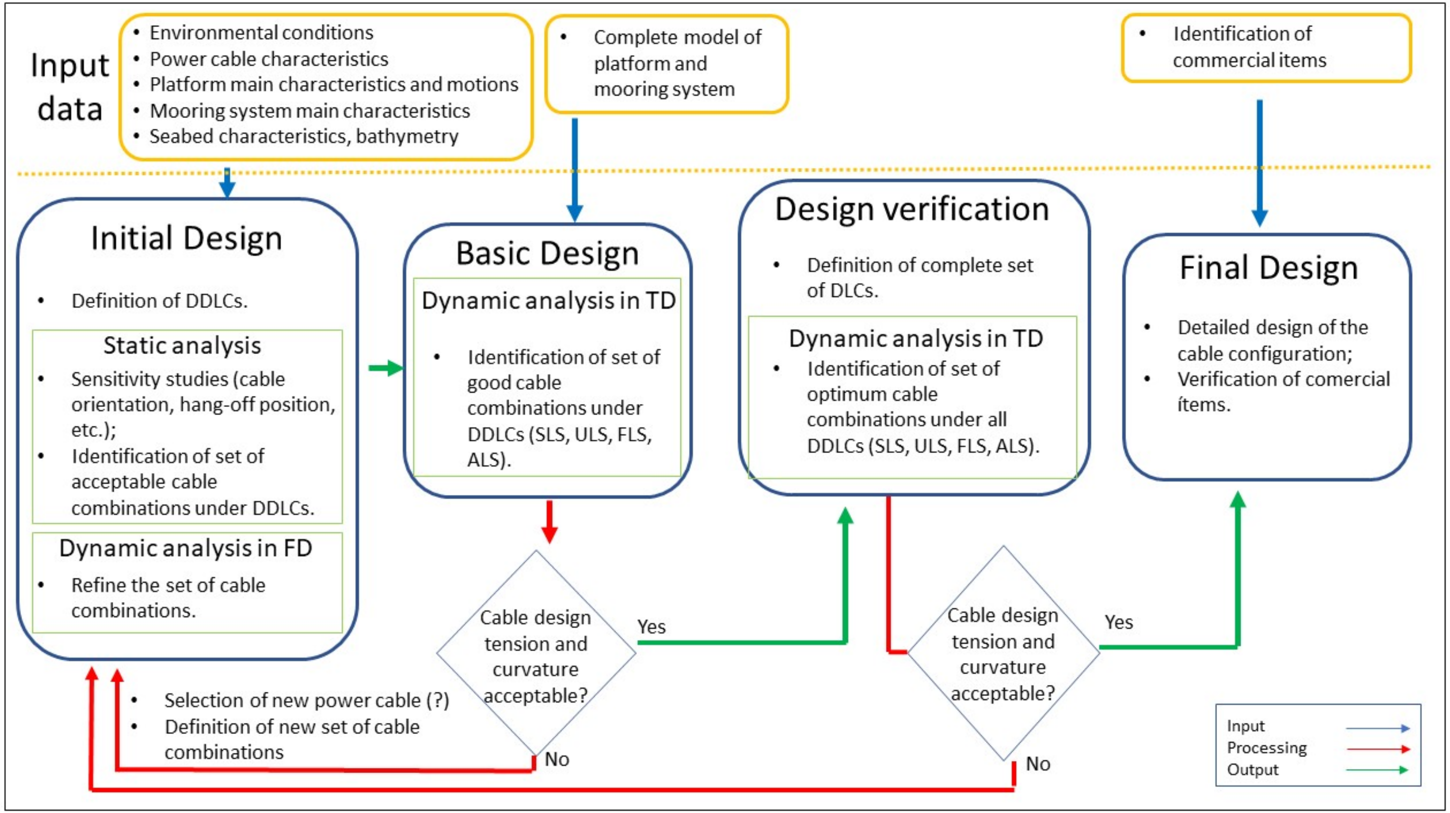
Cable manufacturer may provide different requirements

What's the worst?

Mandatory or optional?

4. Design

4.2 Proposal of methodology

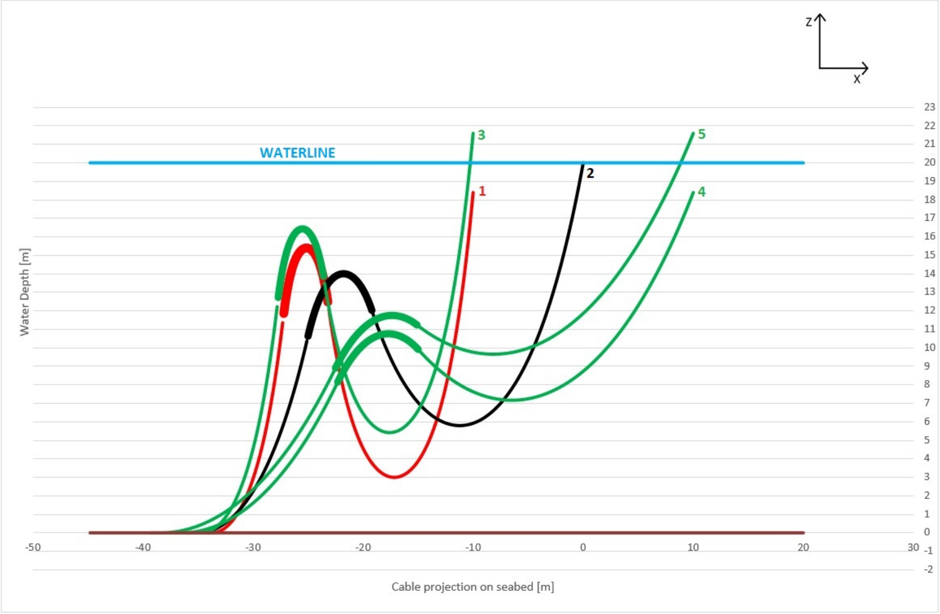


4. Design

4.3 Static analysis

Static design tool for flexible cables

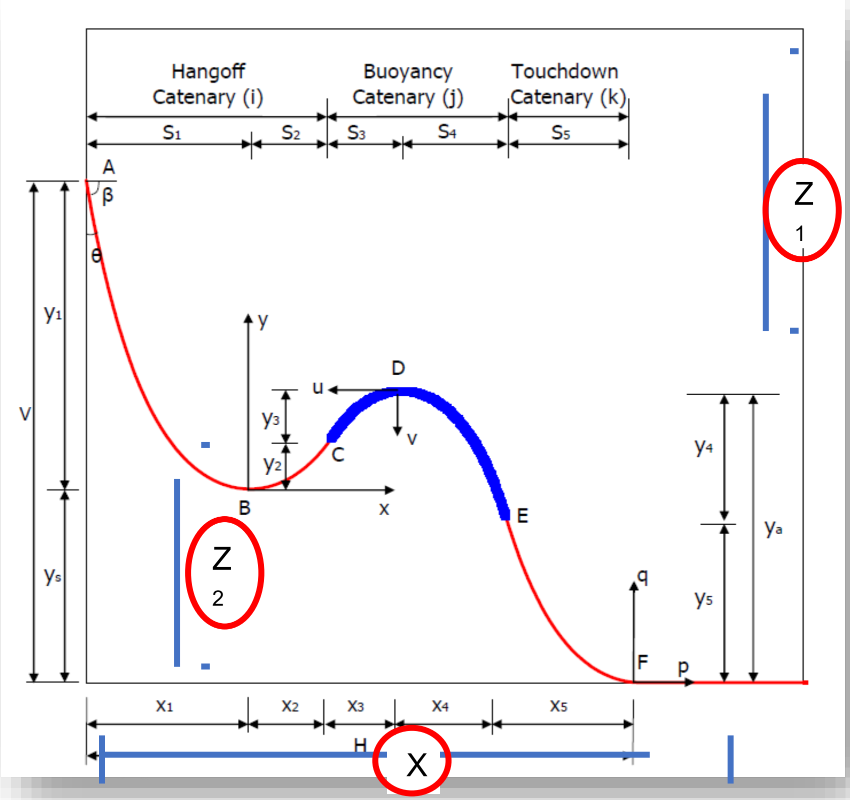
For the first step of the analysis, an in-house algorithm is used in order to perform a static analysis of the cable and select a set of acceptable configurations.

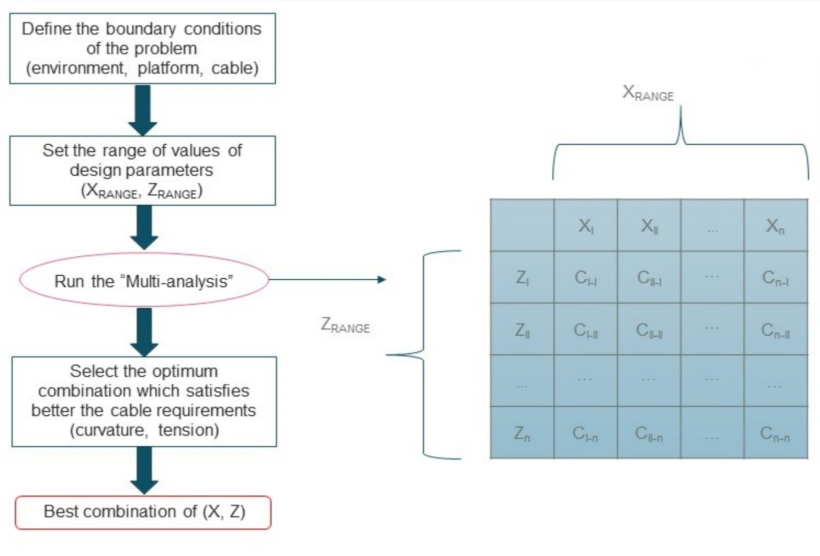


4. Design

4.3 Static analysis

Static design tool for flexible cables

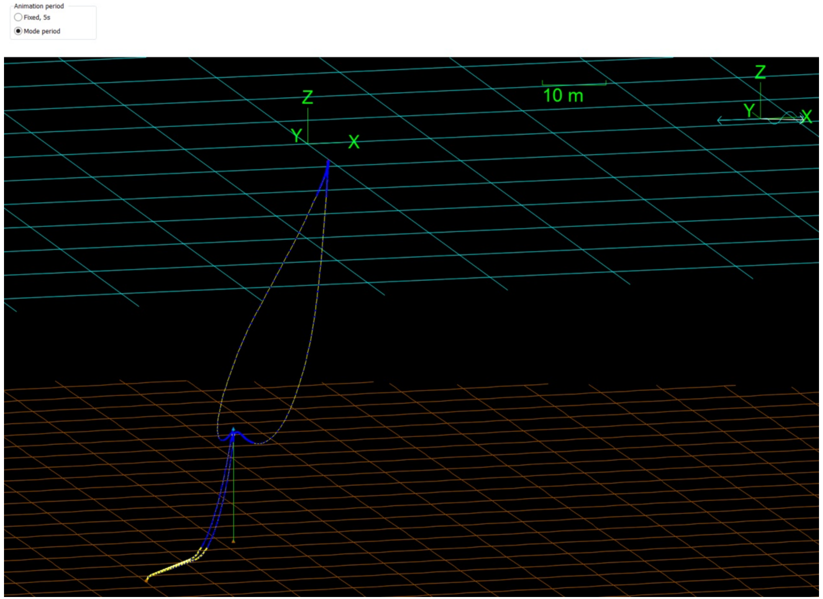




4. Design

4.4 Modal analysis

Orcaflex by Orcina



Animation period
Fixed, 5s

Modal analysis

Modes view | Modes table | Modes graph | Loads table | Loads graph | VIV

Mode shapes with respect to:
Global axes
Local axes

Q26 22.43254426128691e-6

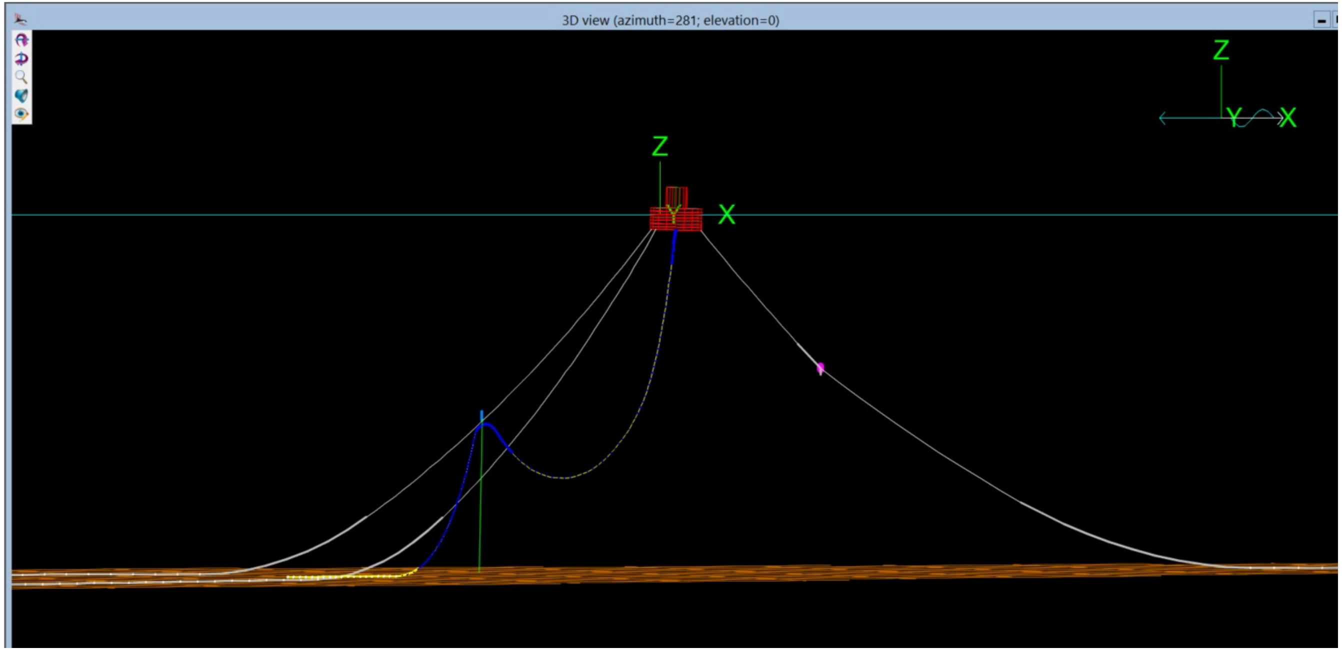
Mode shapes for Power_Cable_V5

Mode number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Period (s)	12.2997	10.1706	9.67148	6.68176	5.21603	4.848	4.40165	3.61417	3.52252	3.37546	3.28512	2.70143	2.67113	2.57532
Frequency (Hz)	0.0813	0.09832	0.1034	0.14966	0.19172	0.20627	0.22719	0.27669	0.28389	0.29626	0.3044	0.37017	0.37437	0.3883
Node 2, X (m)	-42.5e-6	-2.47e-6	-26.7e-6	38.7e-6	-6.92e-6	36.6e-6	-96.7e-6	-40.7e-6	-43.8e-6	81.2e-6	2.26e-6	-63.8e-6	160e-6	66.7e-6
Node 2, Y (m)	-18.7e-6	-1.12e-6	61e-6	16.9e-6	-3.43e-6	-82.7e-6	-41.9e-6	95.6e-6	-17.3e-6	34.4e-6	-8.52e-6	159e-6	62.3e-6	29e-6
Node 2, Z (m)	-11.4e-9	-880e-12	43e-9	11.3e-9	-1.43e-9	150e-9	-30.7e-9	-78.6e-9	-22.5e-9	28.2e-9	-115e-9	-104e-9	53.6e-9	35.9e-9
Node 3, X (m)	-168e-6	-9.76e-6	-106e-6	153e-6	-27.4e-6	145e-6	-383e-6	-161e-6	-173e-6	321e-6	8.98e-6	-252e-6	634e-6	264e-6
Node 3, Y (m)	-74.1e-6	-4.42e-6	242e-6	67e-6	-13.6e-6	-327e-6	-166e-6	378e-6	-68.4e-6	136e-6	-33.7e-6	628e-6	247e-6	115e-6
Node 3, Z (m)	-125e-9	-7.76e-9	164e-9	115e-9	-20.3e-9	196e-9	-292e-9	-33.7e-9	-146e-9	249e-9	-244e-9	3.19e-9	476e-9	232e-9
Node 4, X (m)	-381e-6	-22.1e-6	-239e-6	347e-6	-62e-6	328e-6	-866e-6	-364e-6	-392e-6	727e-6	20.3e-6	-571e-6	0.00143	597e-6
Node 4, Y (m)	-168e-6	-10e-6	547e-6	152e-6	-30.7e-6	-741e-6	-375e-6	856e-6	-155e-6	308e-6	-76.2e-6	0.00142	558e-6	260e-6
Node 4, Z (m)	-459e-9	-27.5e-9	452e-9	420e-9	-76.5e-9	19.2e-9	-1.05e-6	275e-9	-488e-9	884e-9	-402e-9	561e-9	1.69e-6	771e-9
Node 5, X (m)	-684e-6	-39.7e-6	-430e-6	623e-6	-111e-6	588e-6	-0.00156	-654e-6	-704e-6	0.00131	36.6e-6	-0.00102	0.00258	0.00107
Node 5, Y (m)	-301e-6	-18e-6	982e-6	272e-6	-55.2e-6	-0.00133	-673e-6	0.00154	-278e-6	553e-6	-137e-6	0.00255	0.001	467e-6
Node 5, Z (m)	-1.15e-6	-68.2e-9	1.01e-6	1.05e-6	-193e-9	-518e-9	-2.62e-6	1.01e-6	-1.18e-6	2.19e-6	-606e-9	1.85e-6	4.2e-6	1.87e-6
Node 6, X (m)	-0.00108	-62.7e-6	-680e-6	986e-6	-176e-6	930e-6	-0.00246	-0.00103	-0.00111	0.00206	58e-6	-0.00162	0.00408	0.0017
Node 6, Y (m)	-476e-6	-28.4e-6	0.00155	431e-6	-87.3e-6	-0.0021	-0.00107	0.00243	-440e-6	874e-6	-216e-6	0.00404	0.00158	738e-6
Node 6, Z (m)	-2.36e-6	-139e-9	1.95e-6	2.15e-6	-398e-9	-1.57e-6	-5.35e-6	2.35e-6	-2.39e-6	4.47e-6	-876e-9	4.17e-6	8.57e-6	3.77e-6
Node 7, X (m)	-0.00158	-91.6e-6	-993e-6	0.00144	-257e-6	0.00136	-0.00359	-0.00151	-0.00163	0.00301	84.7e-6	-0.00237	0.00595	0.00247
Node 7, Y (m)	-695e-6	-41.5e-6	0.00227	629e-6	-127e-6	-0.00307	-0.00155	0.00355	-641e-6	0.00128	-315e-6	0.00589	0.00231	0.00108
Node 7, Z (m)	-4.27e-6	-251e-9	3.4e-6	3.88e-6	-722e-9	-3.31e-6	-9.67e-6	4.51e-6	-4.3e-6	8.07e-6	-1.23e-6	7.89e-6	15.5e-6	6.77e-6
Node 8, X (m)	-0.00218	-126e-6	-0.00137	0.00199	-355e-6	0.00187	-0.00496	-0.00208	-0.00224	0.00416	117e-6	-0.00326	0.00821	0.00342
Node 8, Y (m)	-960e-6	-57.3e-6	0.00313	868e-6	-176e-6	-0.00424	-0.00215	0.0049	-885e-6	0.00176	-435e-6	0.00813	0.00319	0.00149
Node 8, Z (m)	-7.08e-6	-416e-9	5.51e-6	6.44e-6	-1.2e-6	-5.94e-6	-16e-6	7.71e-6	-7.1e-6	13.4e-6	-1.7e-6	13.4e-6	25.7e-6	11.2e-6
Node 9, X (m)	-0.00289	-167e-6	-0.00182	0.00263	-470e-6	0.00248	-0.00657	-0.00276	-0.00297	0.00551	156e-6	-0.00432	0.01087	0.00452
Node 9, Y (m)	-0.00127	-75.9e-6	0.00415	0.00115	-233e-6	-0.00562	-0.00284	0.00649	-0.00117	0.00233	-576e-6	0.01077	0.00423	0.00197
Node 9, Z (m)	-11e-6	-649e-9	8.44e-6	10e-6	-1.87e-6	-9.67e-6	-25e-6	12.2e-6	-11e-6	20.8e-6	-2.31e-6	21.1e-6	40e-6	17.4e-6
Node 10, X (m)	-0.00371	-215e-6	-0.00233	0.00338	-604e-6	0.00319	-0.00843	-0.00354	-0.00382	0.00708	200e-6	-0.00555	0.01396	0.00581
Node 10, Y (m)	-0.00163	-97.5e-6	0.00532	0.00148	-299e-6	-0.00722	-0.00365	0.00834	-0.00151	0.003	-739e-6	0.01383	0.00543	0.00253
Node 10, Z (m)	-16.4e-6	-963e-9	12.4e-6	14.9e-6	-2.78e-6	-14.7e-6	-37.1e-6	18.3e-6	-16.4e-6	30.9e-6	-3.09e-6	31.5e-6	59.4e-6	25.8e-6
Node 11, X (m)	-0.00465	-269e-6	-0.00292	0.00423	-757e-6	0.00399	-0.01056	-0.00444	-0.00478	0.00886	251e-6	-0.00695	0.01749	0.00728
Node 11, Y (m)	-0.00205	-122e-6	0.00667	0.00185	-375e-6	-0.00904	-0.00457	0.01044	-0.00189	0.00375	-925e-6	0.01732	0.0068	0.00317
Node 11, Z (m)	-23.5e-6	-1.38e-6	17.4e-6	21.3e-6	-3.98e-6	-21.4e-6	-53.1e-6	26.2e-6	-23.4e-6	44.2e-6	-4.06e-6	45.1e-6	84.8e-6	36.8e-6
Node 12, X (m)	-0.00571	-331e-6	-0.00359	0.0052	-929e-6	0.0049	-0.01297	-0.00545	-0.00587	0.01088	309e-6	-0.00853	0.02147	0.00893
Node 12, Y (m)	-0.00251	-150e-6	0.00819	0.00227	-460e-6	-0.0111	-0.00562	0.01282	-0.00232	0.00461	-0.00114	0.02126	0.00835	0.00389
Node 12, Z (m)	-32.5e-6	-1.91e-6	23.9e-6	29.5e-6	-5.51e-6	-29.8e-6	-73.5e-6	36.3e-6	-32.4e-6	61.2e-6	-5.26e-6	62.4e-6	117e-6	50.9e-6
Node 13, X (m)	-0.0069	-400e-6	-0.00433	0.00628	-0.00112	0.00591	-0.01566	-0.00658	-0.00709	0.01314	374e-6	-0.0103	0.02592	0.01078
Node 13, Y (m)	-0.00303	-181e-6	0.00989	0.00274	-556e-6	-0.01341	-0.00678	0.01548	-0.0028	0.00556	-0.00137	0.02567	0.01008	0.00469
Node 13, Z (m)	-43.8e-6	-2.57e-6	31.8e-6	39.8e-6	-7.44e-6	-40.4e-6	-99.1e-6	48.8e-6	-43.6e-6	82.6e-6	-6.73e-6	83.9e-6	158e-6	68.6e-6
Node 14, X (m)	-0.00821	-476e-6	-0.00516	0.00748	-0.00134	0.00704	-0.01865	-0.00783	-0.00844	0.01564	446e-6	-0.01226	0.03085	0.01283
Node 14, Y (m)	-0.00361	-216e-6	0.01178	0.00327	-662e-6	-0.01597	-0.00807	0.01843	-0.00333	0.00662	-0.00163	0.03056	0.012	0.00559
Node 14, Z (m)	-57.8e-6	-3.39e-6	41.5e-6	52.5e-6	-9.8e-6	-53.2e-6	-131e-6	64.1e-6	-57.5e-6	109e-6	-8.49e-6	110e-6	209e-6	90.3e-6
Node 15, X (m)	-0.00966	-560e-6	-0.00607	0.00879	-0.00157	0.00828	-0.02193	-0.00921	-0.00992	0.01839	526e-6	-0.01442	0.03627	0.01509
Node 15, Y (m)	-0.00425	-254e-6	0.01385	0.00384	-779e-6	-0.01878	-0.0095	0.02168	-0.00392	0.00779	-0.00191	0.03594	0.01411	0.00657
Node 15, Z (m)	-74.6e-6	-4.37e-6	52.9e-6	67.8e-6	-12.7e-6	-68.5e-6	-169e-6	82.2e-6	-74.2e-6	140e-6	-10.6e-6	141e-6	270e-6	117e-6

4. Design

4.5 Dynamic analysis in TD

Orcaflex by Orcina



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GRACIAS
THANK YOU
MERCI

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