Structural Integrity Analyses of Dynamic Power Cables

Before a dynamic power cable is installed offshore, its ability to operate in the relevant environment must be verified. One important aspect of this is to ensure that the structural integrity of the cable is maintained for its planned service life.

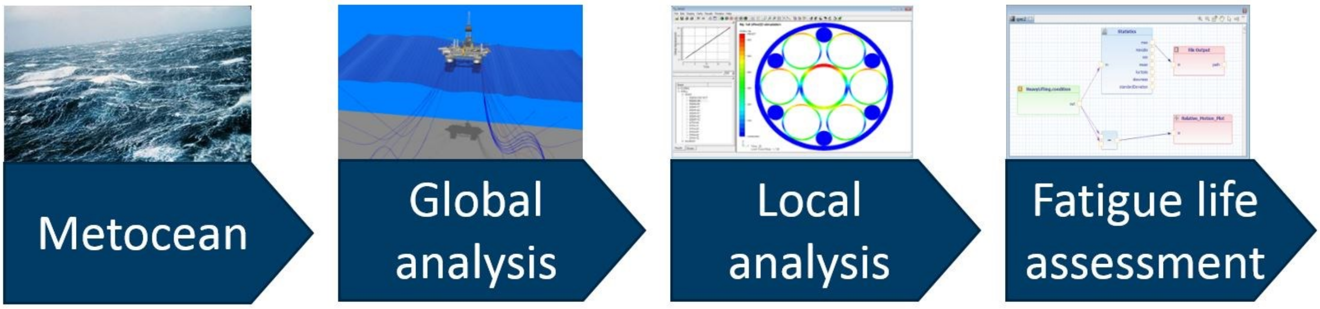
SINTEF Ocean* has a long track record of performing verification of integrity for flexible risers, including power cables and umbilicals, for the oil and gas industry. With our tailor-made software developed in-house, combined with expertise in structural behavior we are able to provide deep insight into the loads and structural response on component level for these kind of structures. This knowledge is also directly applicable to dynamic power cables to for offshore wind applications.

ANALYSIS WORKFLOW

The normal sequence of a cable verification study is illustrated below. The metocean data describes the environmental conditions for the relevant location. Through global analyses the expected behavior of the overall system over its life time is obtained, as well as the behavior in extreme cases. This provides the conditions that the cable must be verified to survive. Based on knowledge of the material properties of each component, typically in form of stress/strain– and SN-curves, the mechanical integrity of the structure can be checked by including local analyses to get more detailed results for the components in the cable cross section.

METOCEAN SELECTION / ENVIRONMENT SPECIFICATION

To ensure that all relevant load conditions are addressed, the relevant environmental conditions must be identified. This is normally obtained from site specific metocean



Analysis workflow for structural integrity verification

* Through an internal merger in the SINTEF Group, former **MARINTEK** is now part of SINTEF Ocean.

data, providing probability distributions for loads such as current, wave and wind conditions.

Based on these distributions, the **extreme load** conditions that the structure shall survive are identified, as well as the less severe but persistent conditions during its entire service life, the **fatigue loads**.

SYSTEM BEHAVIOUR AND GLOBAL RESPONSE ANALYSES

The dynamic behavior of the cable depends on its mechanical properties as well as the system geometry between seabed and the floater. The cable properties in terms of torsional-, axial- and bending-stiffness can be provided by FE analysis or by testing.

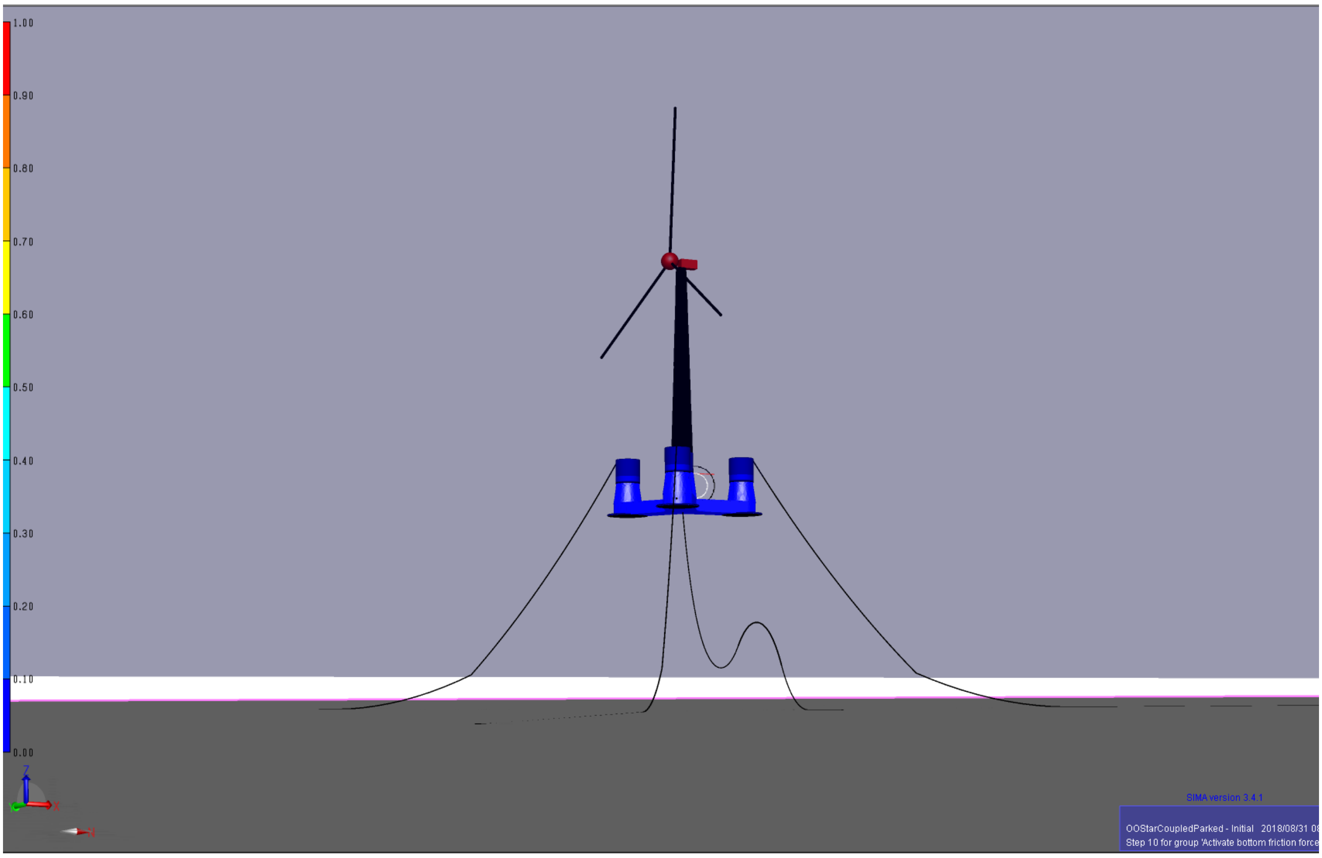
The boundary conditions of the cable are defined in terms of the transition to a static part at the seabed and the connection to a floating vessel at the top end. The floater motions must also be part of the analyses. To obtain the floater motions a separate analysis may be required to establish it's response to the sea state and environment, influenced by the vessel design itself and the applied mooring system.

The top connection that transferes the loads to the cable is usually a critical location. This connection will normally include a bending stiffener or a bellmouth to reduce and distribute the loads experienced by the cable. The suspended geometry of the cable may be a catenary shape or different forms of wave shapes enabled by use of buoyancy modules.

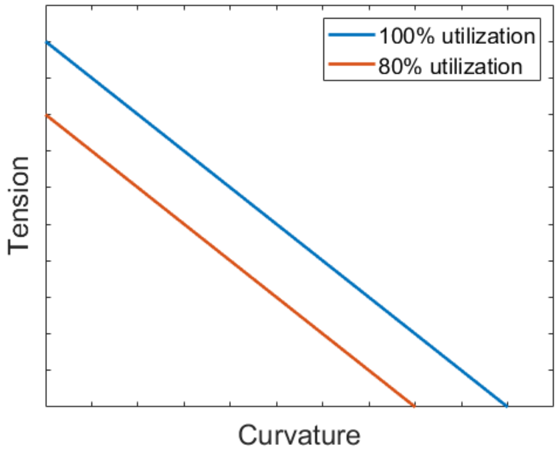
Once the global system is established, the metocean data are applied to provide cable **response** to the **extreme loads,** as well as the **response** to the **fatigue loads** experienced over the lifetime. This would typically be done using our SIMA/RIFLEX software. [1,2]

CROSS SECTION ANALYSES

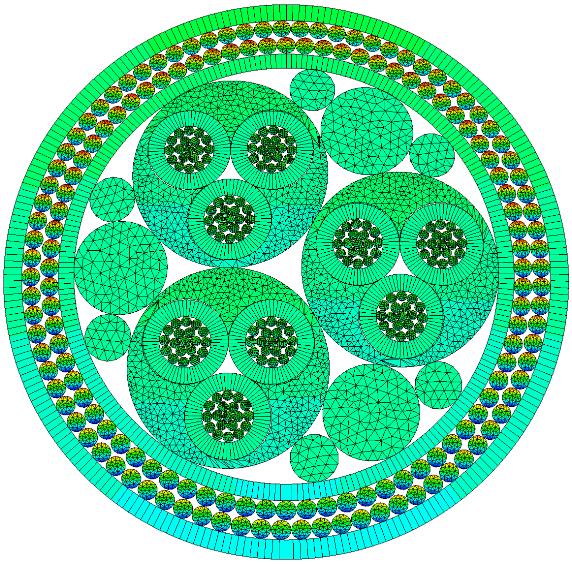
The **global properties** such as bending and axial stiffness can be obtained by FE analyses. To capture nonlinear effects due to internal friction, the individual components



Power cable connecting an offshore wind platform with a layzy wave configuration



Typical capacity curves



Cable cross section

of the structure must be modelled and the contact forces between them described in a proper manner. This is typically done using our UFLEX software [3] for cross sectional analyses of power cables and umbilicals.

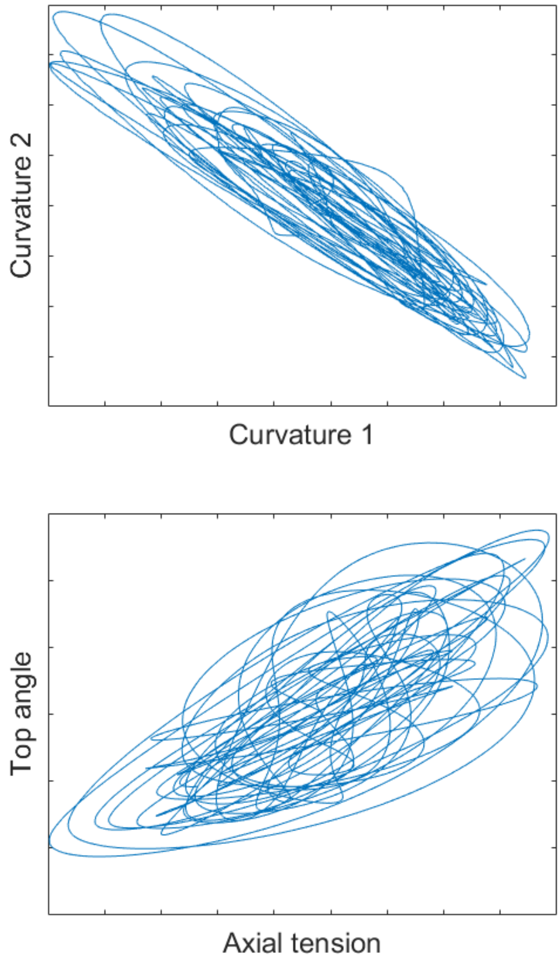
Based on the same analysis model, the **capacity curves** for the cable are defined. These curves provides limits for acceptable combinations of tension and curvature.

From the global response analyses detailed data on tension levels and curvature variations that the cable will be exposed to is available. Through the UFLEX local analysis, the resulting **stress variation** on component level can be obtained, hence linking the tension/curvature to the component stresses.

STRUCTURAL INTEGRITY VERIFICATION

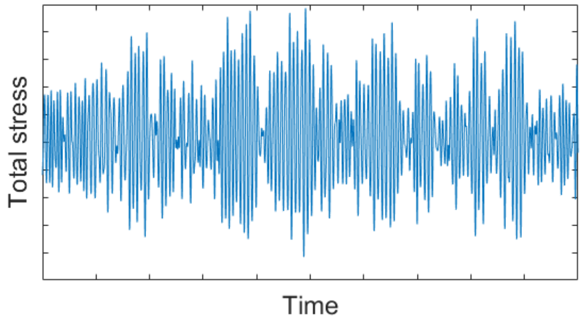
Checking that the **extreme response** is within the relevant **capacity curve** verifies the integrity for the extreme conditions.

To verify the **fatigue life** of the cable, the metocean data is usually lumped into a number of classes, each covering a fraction of what the cable will experience in its full lifetime. Each class has its separate wave, current and wind magnitude and direction. A global response analysis is performed for each class to provide time series of tension and curvature variations for the cable.



Upper: Bi-directional time trace of curvature variation
Lower: Time trace, tension variation vs. cable top angle

At critical locations along the cable, the curvature/tension time series is transformed to stress variation time series based on results from the local cross section analyses. We will typically use a transfer function method to create the stress time series. This is described in [4] and implemented in our CONCORDIA tool.



Total stress variation for one critical component at one location

Once the time series of stress has been established, **fatigue life verification** can be done directly on the stress time series based on rainflow counting, Miner's rule and the appropriate SN-curve.

Other types of relevant specialist evaluations and testing we provide to supplement an analysis study may be

- Full scale verification testing
- Compression/bending testing
- Material testing, in particular to define SN data and friction factors
- VIV analyses
- Clashing analyses

The electrical integrity is obviously the overall requirement for a power cable, in which structural integrity is an important but not sufficient part.

As SINTEF Ocean is a branch of the SINTEF group including SINTEF Energy, we can offer joint studies to cover both electrical and structural integrity of a cable.

REFERENCES

[1] RIFLEX www.sintef.no/globalassets/upload/marintek/pdf-filer/factsheets/riflex.pdf

[2] SIMA www.sintef.no/en/software/sima/

[3] UFLEX www.sintef.no/en/software/uflex-stress-analysis-of-power-cables-and-umbilicals/

[4] Gaidai Oleg,Ye Naiquan, Jin Joe, Reid Dale, Maincon Philippe Emmanuel: Fatigue analysis methods of dynamic umbilicals, ISOPE 2015

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