Simulation of Cable Dynamics For Moored Ocean Platforms

Modeling Aids Design of Large, Underwater Power Cable

By Joana Prat • Marisa Zaragozá • Joaquín del Río Fernández

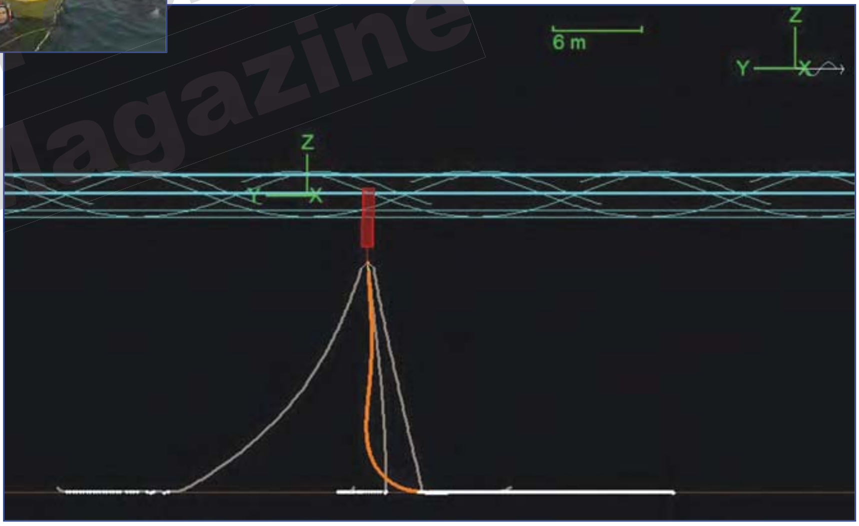
Observation platforms at sea need power cables for energy. Such platforms and cables are exposed constantly to the dynamic behavior of sea waves, wind and current.

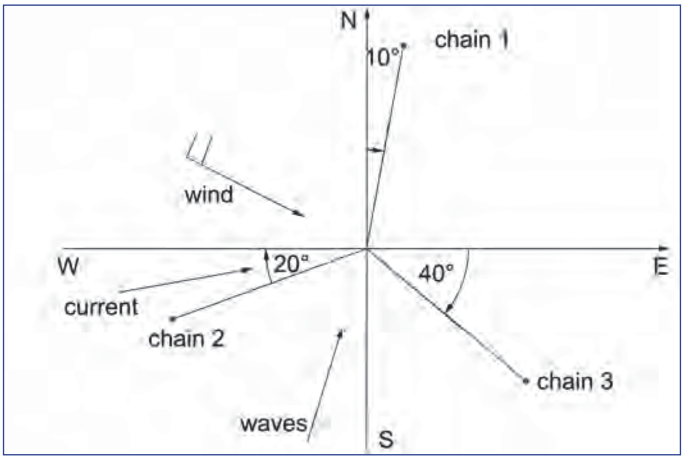
It is useful to carry out numerical simulations of how a large underwater power cable connecting an ocean surface platform to a seafloor technology would behave with regard to marine conditions prior to design and installation at sea. This would help a manufacturer identify critical parameters that could affect the cable in the field, for instance, in projects that would require mooring wind turbines in the ocean.

We conducted a simulation experiment using a small, existing platform, OBSEA, located 4 kilometers offshore the Vilanova i la Geltrú coast in a fishing protected area of the Catalan coast of Spain. OBSEA is a cabled seafloor observatory connected to a station on the coast by a power-and-communication cable. The station located onshore provides the power supply and a fiber-optic communication link, while carrying out alarm management tasks and storing data in real time. The marine observatory is located at 20 meters depth and gathers data on waves, current and pressure, among other environmental factors. A buoy to gather meteorological data is moored to the seafloor observatory by three chains of 30 meters length each.

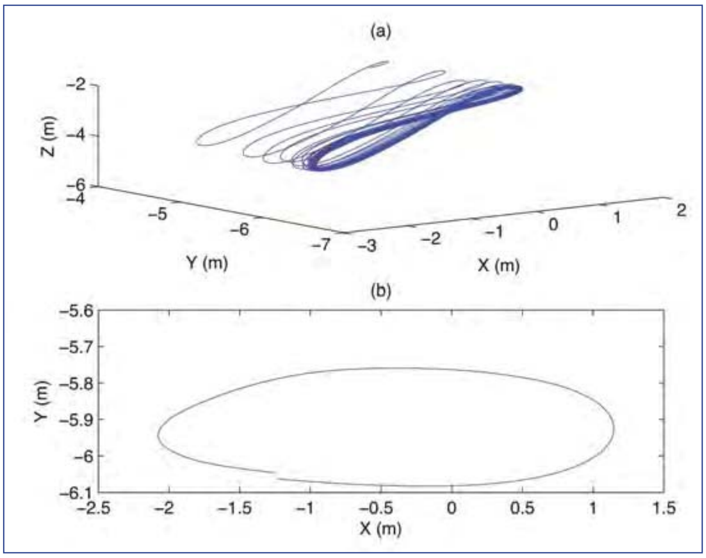
Methodology and Simulations

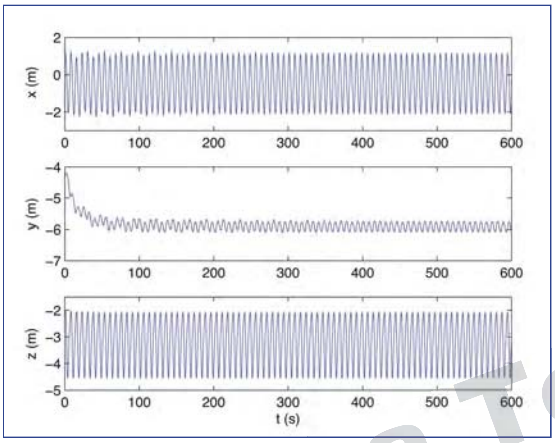
OBSEA's buoy is currently moored to the seafloor observatory by an umbilical. Instead of using an umbilical in our simulation, we modeled the buoy to simulate a large power cable connecting the buoy to a technology on the seafloor. The purpose of this simulation was to predict the behavior of such a cable and a moored platform at sea using real-world conditions.

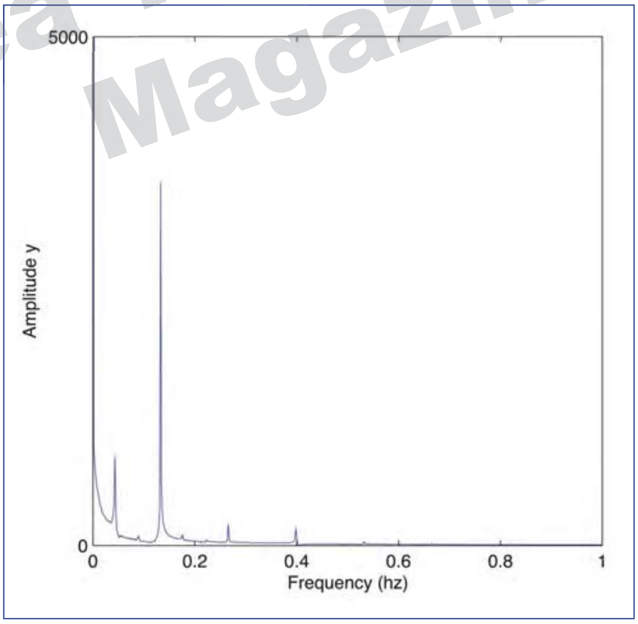




(Top) OBSEA's buoy at the Vilanova coast. (Middle) OrcaFlex 3D view of a dynamic simulation of the buoy model for OBSEA with a simulated power cable. (Bottom) Schematic view in a northeast plan of the buoy model showing chain location and wind direction, waves and current at 9 p.m. UTC on December 16, 2011.







The orbit of the buoy model with power cable shows an oscillatory pattern. (Top) 3D view at 10 minutes. (Middle) Horizontal projection view during one wave period (7.52 seconds). (Bottom) Temporal evolution of buoy coordinates. The amplitude spectrum of one relative horizontal position is a function of frequency without transient.

The numerical simulations were done with the help of OrcaFlex software, a marine dynamics program developed by Orcina (Ulverston, England) for static and dynamic analysis of a wide range of offshore systems. OrcaFlex provides fast and accurate analysis of umbilical cables under wave and current loads and externally imposed motions. It is a 3D nonlinear time domain finite element program capable of dealing with arbitrarily large deflections from the initial configuration.

Simulations of OBSEA's buoy show the dynamics of the buoy, power cable and chains under real-world conditions, i.e., the orbit of the buoy and cable and chain tension as a function of time or variations of curvature.

Real data of meteorological conditions on December 16, 2011 were used for the OrcaFlex model, with some restrictions. A periodic sea wave, a constant wind and a time-constant profile of current were used. The day was chosen to represent typical wind conditions on the Vilanova coast instead of averaged values between time periods to offer more realistic ocean conditions for modeling. We fixed the real-world conditions at the time of 9 p.m. UTC, characterized by a maximum wind speed of 11.27 meters per second and 117° direction of advance. The significant wave height was 3.05 meters, with a period of 7.52 seconds and 17° direction of advance. The current intensity profile was divided into three layers: on the top, a linear boundary layer of 3 meters, with a maximum of 0.92 meters per second and 87° direction of advance; a middle layer of 10 meters depth, where current intensity was constant at about 0.55 meters per second; and a third layer of 7 meters above the seabed, with intensity decreasing linearly to zero. The current direction depended on depth.

The OBSEA buoy simulation was moored with three chains on the seabed in a circle of 20 meters radius. The chains were equally spaced at 120°. The buoy consists of one cylinder 4 meters long and 0.8 meters in diameter, and another small cylinder on the bottom that is 0.9 meters long and 0.05 meters in diameter. It weighs 650 kilograms in air. At the bottom is a free link to three chain branches 0.65 meters long, 0.03 meters in diameter and 130° declination, equally distributed.

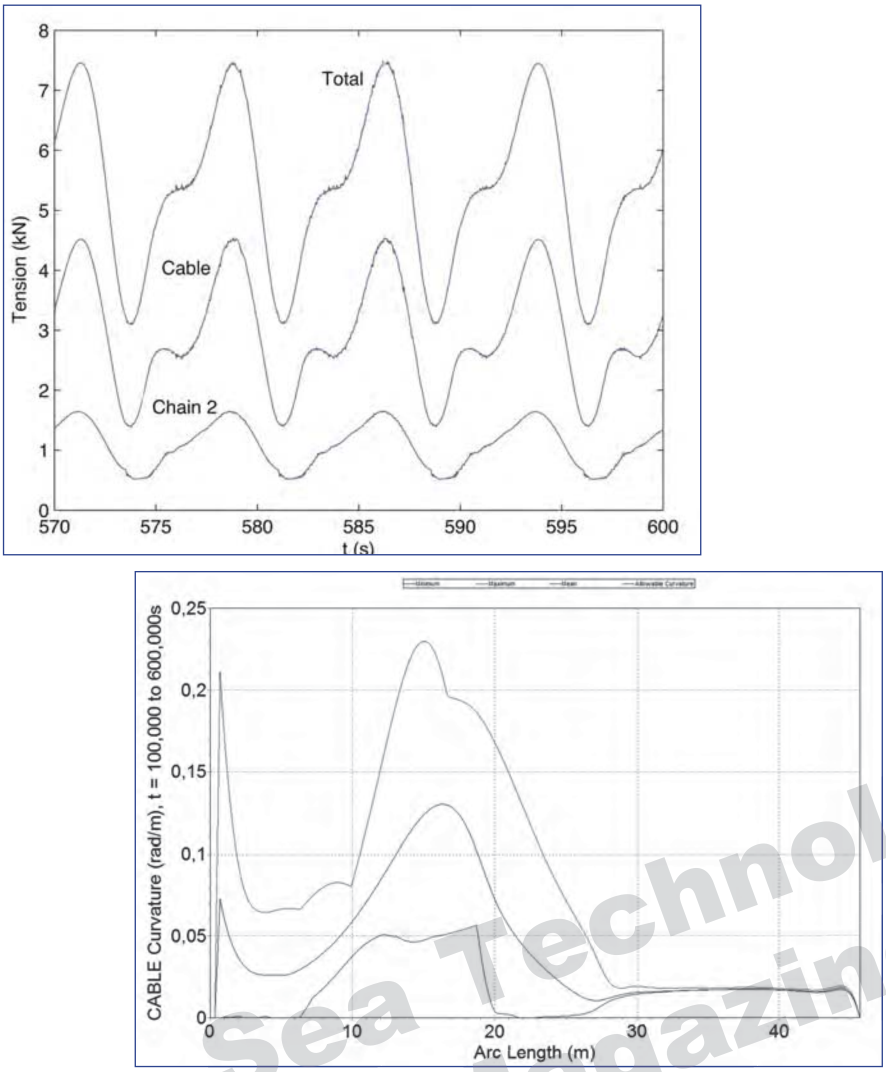
The simulated power cable was 0.1 meters in diameter and 45 meters long, with a bending stiffness of 7 kilonewtons per square meter moored at the steady state position. The cable was linked to the buoy with a vertical branch 0.65 meters long, 0.12 meters in diameter and 60 kilograms per meter.

The unit segment length used to simulate chains was 0.25 meters. Dynamic simulations were done with fixed step size of an implicit integration method. The step size was small enough to generate results that did not change when the step size was decreased. A step size of 0.025 seconds was needed when the cable was added to the structure. Simulations were done from 20 to 600 seconds to study temporal behavior.

Results and Conclusions

The simulation results help us to predict the dynamics of a moored platform and its components under real-world conditions before deployment. When the power cable was added to the buoy in the simulation, the position of the buoy was modified from its origin. However, the buoy's range of movement was similar in all cases.

The modeling results with a power cable in all cases show oscillatory behavior. For instance, when the cable was



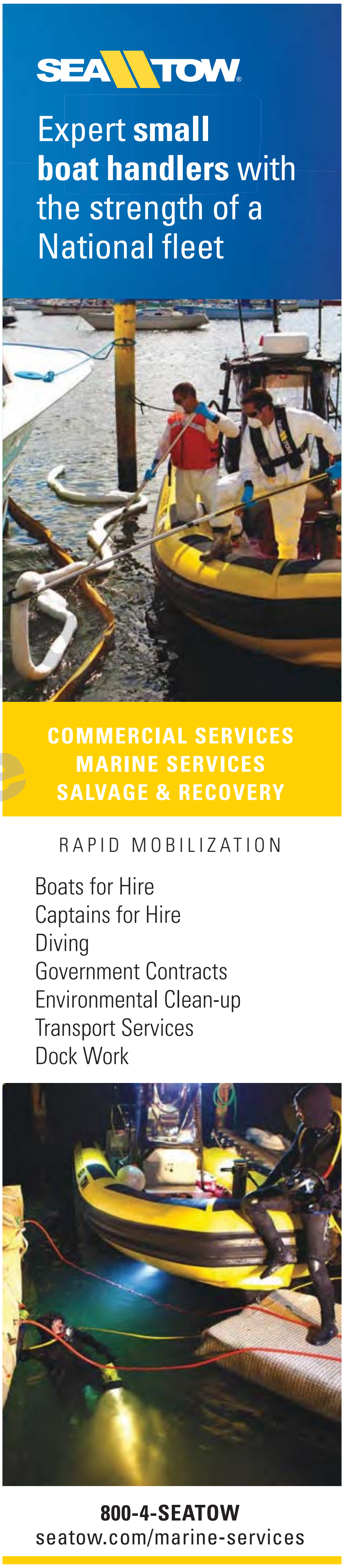
A model of the tensions at the top of the buoy. Instabilities detail total structural tension and power cable and chain tension over time.

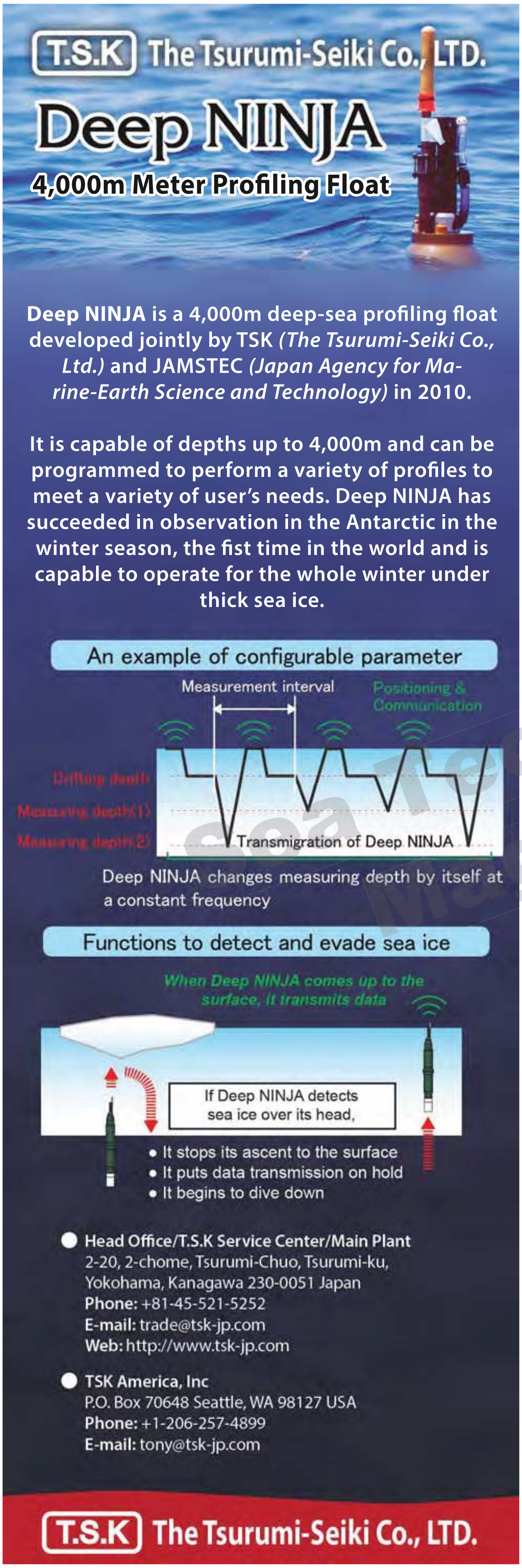
moored in the south position, a bigger transient was found until it stabilized to an oscillatory pattern. The study of trajectories and tensions were focused on this particular case, wherein the cable experienced the highest tension, with a maximum of about 4.6 kilonewtons and oscillation range of 3.2 kilonewtons.

There was a regular, circular trajectory of the buoy and the cable at the top. Even though it was not a periodic pattern, nor quasi-periodic, a careful study of the amplitude spectrum with the horizontal y coordinate shows "dirty" picks at a main frequency of 0.1329 at 1/7.52 hertz, inherited by the sea wave period and the corresponding multiples. A small frequency was also present at 0.0166 at 1/60 hertz that describes traces of the modulation of 60 seconds in the temporal evolution of orbit. It is likely that traces of quasi-periodicity appear because of the physical attachment of the buoy to the chains. The range of movement of the buoy was predicted from the model results, from 2.5 meters vertical amplitude (smaller than the amplitude of the waves) and a horizontal movement in the area of 3.5 by 0.79 meters.

The effect of the cable to the total effective tension of the moored platform structure was the following: The amplitude of oscillations with the cable was three times bigger than without, and the maximum value was about 2.3 times bigger. Total tension evolution was similar to the cable tension evolution.

The regularity of the cable trajectory contrasted with tension instabilities at every wave period. Such instabilities arose at the bottom turning point of the buoy trajectory, and the cause was the unstable chain movement. The insta-





> *"We found a big variability of curvature, between 10 and 20 meters' arc length."*

bility of the chains at every main period translated to the cable and the total tension. Furthermore, the effect of the cable to the total effective tension was the following: Not only were the oscillations of total tension bigger, but their range was much bigger when a cable was added. Also, total effective tension at the buoy was similar to the cable, and the temporal pattern also shows traces of quasi-periodicity.

The study of the range of curvature variation along the dynamic cable informs us about the more unstable cable segments. We found a big variability of curvature, between 10 and 20 meters' arc length.

This simulation experiment shows that the design process for a large, underwater cable intended to moor a surface platform to a technology on the seafloor could benefit from modeling by offering information on the more unstable part of cable dynamics and the changing components of the platform structure. Such modeling could be of use in marine renewable energy projects, helping in the design of appropriate power cables for mooring surface turbines at sea.

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References

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