BLADED

4.8.0.34 **27/09/2016**

BASE MODULE

Multi-part Blade, Flexibility Modeller, and Modal Viewer

The “multi-part” blade model in Bladed 4.8 is a major step forward for stability and load analysis of flexible modern wind turbine blades.

The blade can be sub-divided into many finite element bodies, in order to more rigorously model large blade deflections. The outer parts can undergo rigid body rotation due to deflection of the inner parts. This allows for non-linear load transfer between each linear part, and a more accurate model of the blade deflection. A two part blade is illustrated in Figure 1.

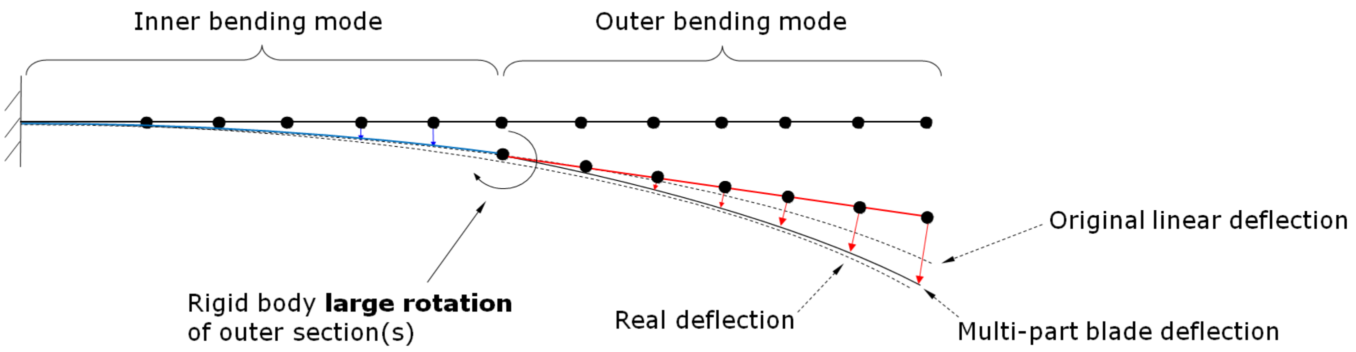

Figure 1: Two-part blade model

Any number of blade parts can be defined in the new *Flexibility Modeller* screen, shown in Figure 2.

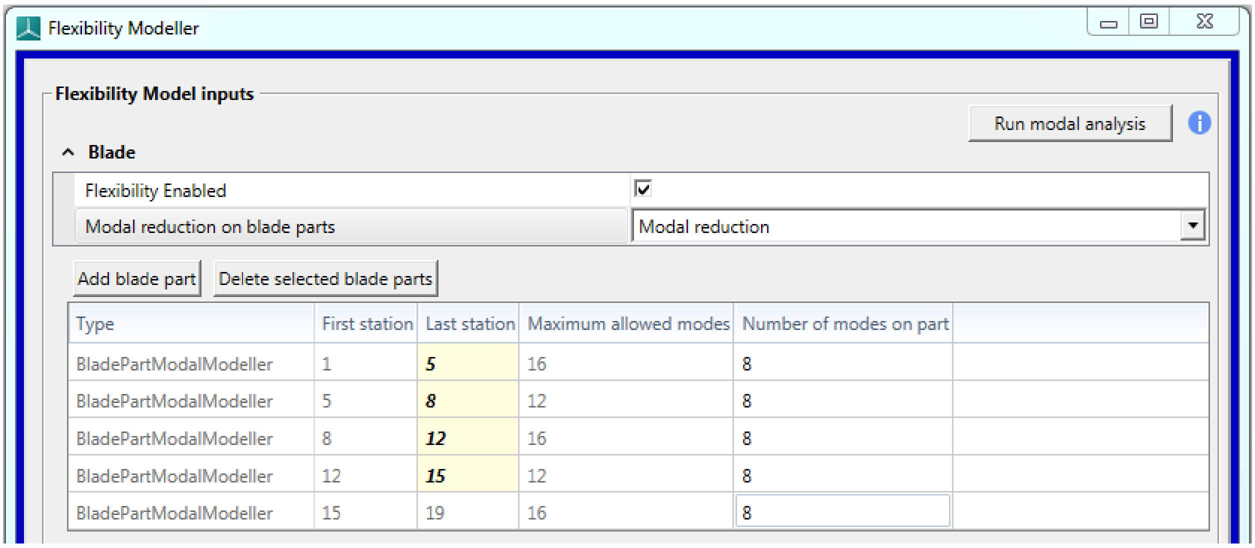

Figure 2: Definition of blade parts in the Flexibility Modeller screen

The blade and tower mode shapes can be viewed in the new 3D viewer shown in Figure 3.

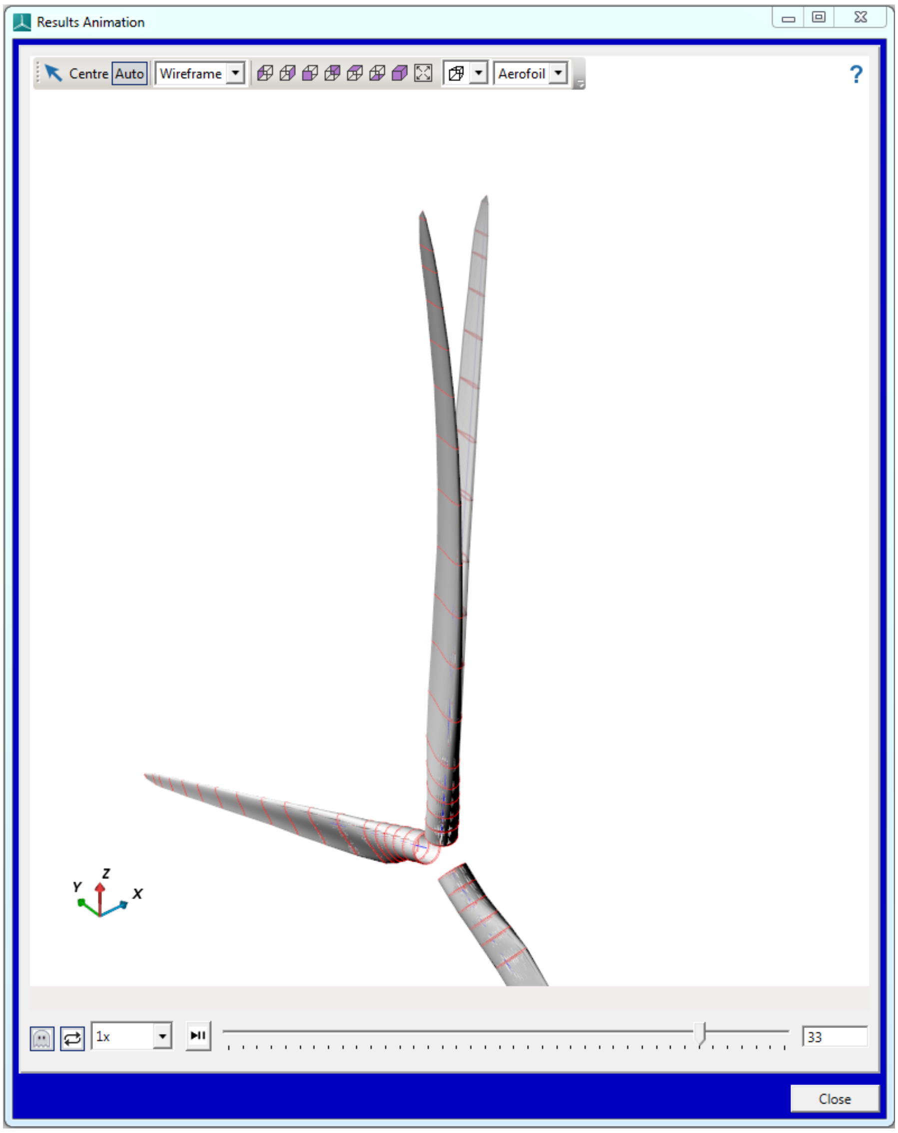

Figure 3: New modal viewer screen in Bladed 4.8

New Aerodynamics Implementation

The implementation of Blade Element Momentum (BEM) aerodynamics that was released as Beta in Bladed 4.7 is now officially released.

Some key advantages of the new model compared to the previous aerodynamics are

- The new implementation takes a rigorous and consistent approach to aerofoil geometrical orientation, allowing for more accurate aerodynamic modelling of blade features such as sweep, prebend, pre-cone and pre-sweep.
- The new implementation includes options for a Glauert skew wake model, Oye dynamic wake model and the Oye dynamic stall model.

The new implementation options can be defined in the “Aerodynamics Control” screen as shown in Figure 4.

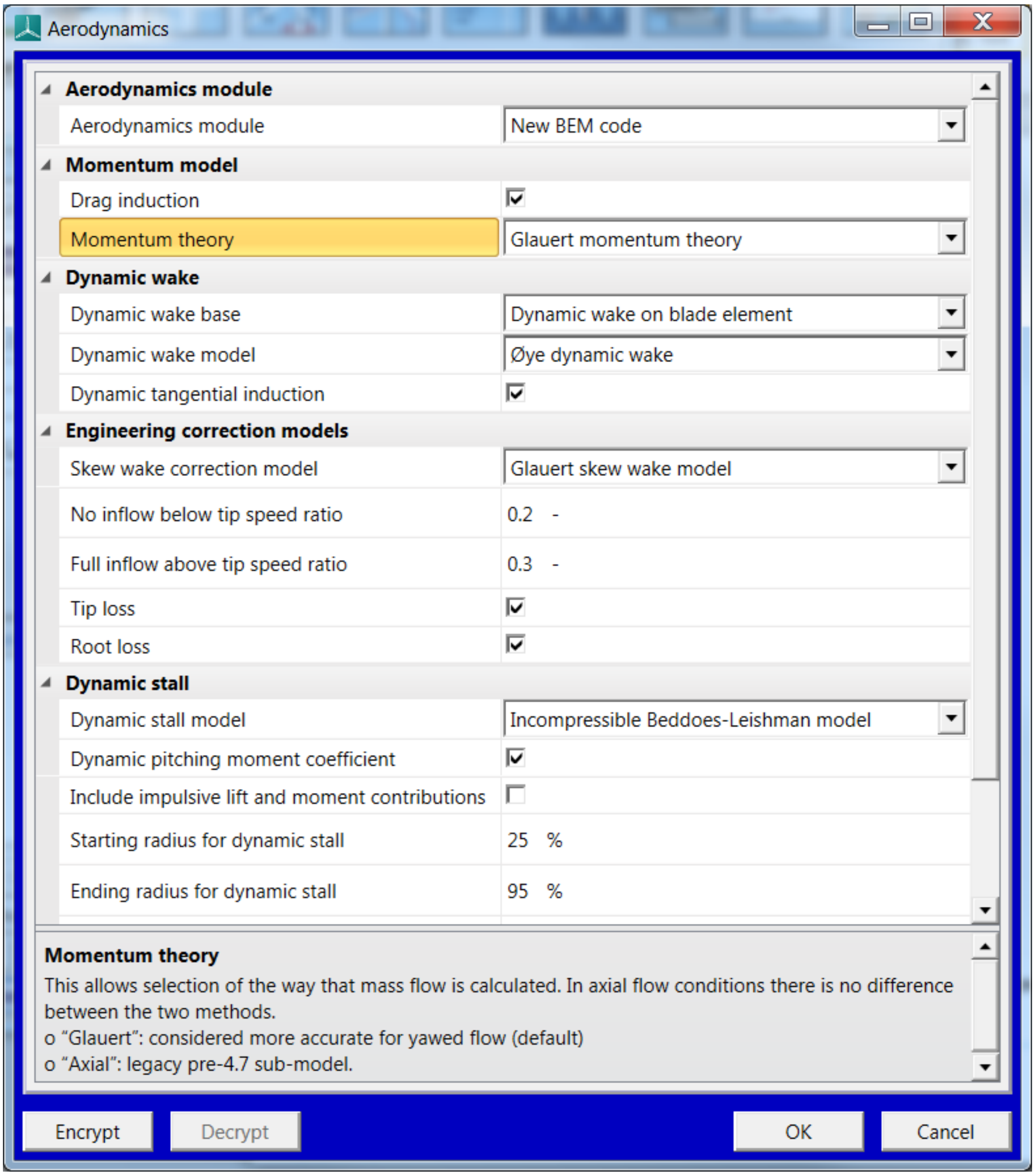

Figure 4: New Aerodynamics Control screen for Bladed 4.8

Results animation

Bladed 4.8 provides 3D animation of simulation results, allowing the user to view the motion of the blades, tower, support structure and dynamic mooring lines from any angle.

The animation viewer is accessible by opening the data picker, choosing an output group created in Bladed 4.8, and clicking *View Results Animation*:

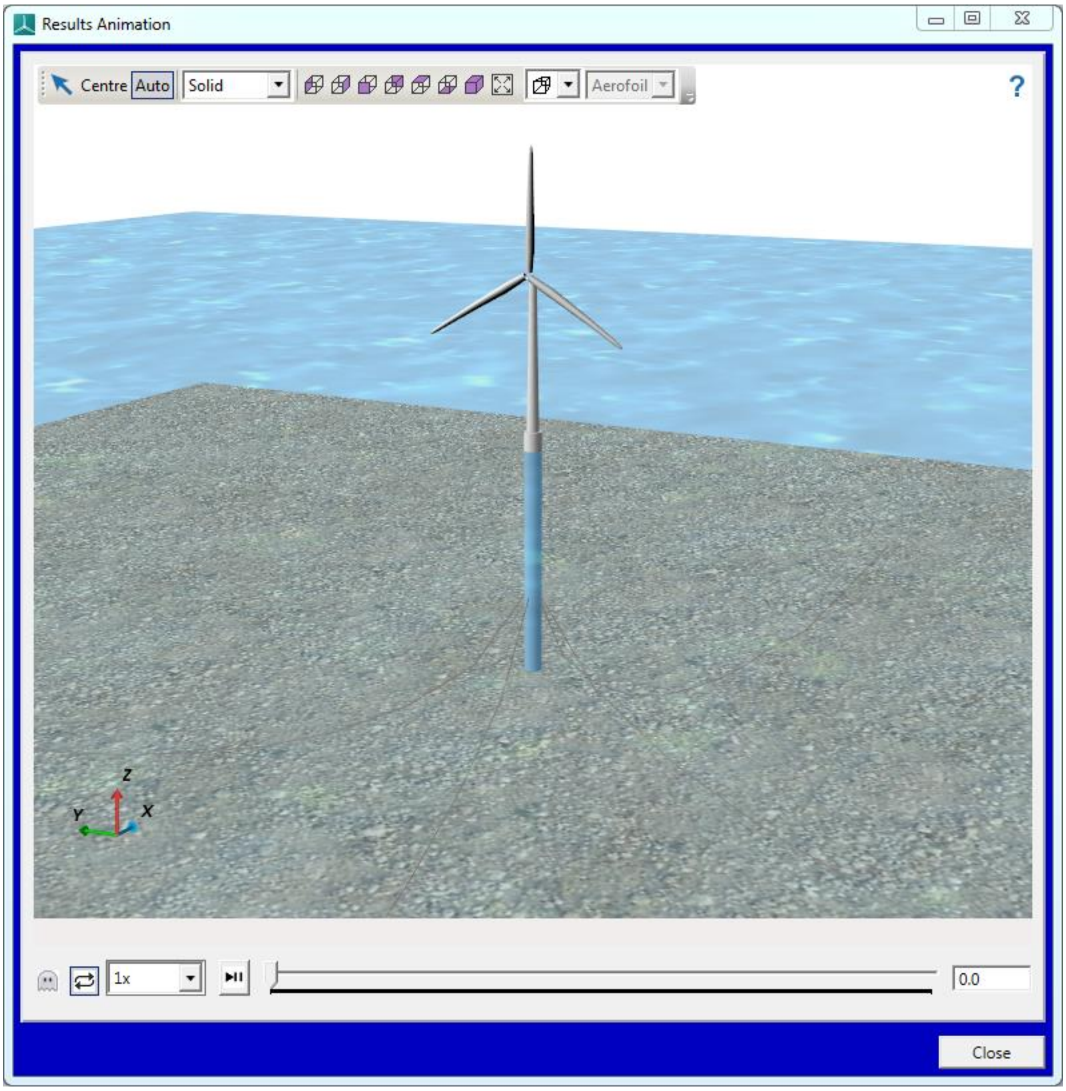

Figure 5: Results Animation

- Skip to any point in the simulation time history using the horizontal slider or entering an output timestep value.
- Change the frame rate using the dropdown to the left of the play/pause button.
- Toggle the undisplaced model and continuous playback using the buttons to the left of the frame rate control.
- Change the rendering mode and node type using the dropdown on the main toolbar.
- Click the top right question mark button for navigation help.

Integration settings

In previous versions of Bladed, the time domain numerical integration method was a variable step Runge-Kutta formulation. However, for some simulations that involve much higher frequencies typical Bladed simulations (e.g. multi-part blades, dynamic moorings), the Runge-Kutta family of integrators is particularly inefficient, as a small time step is required.

In 4.8, two new integrators, Newmark-β and Generalised-α, have been made available, which are specifically designed for integrating structural systems with high frequencies. These are currently presented a fixed-step version. The user is also able to choose two fixed-step Runge-Kutta integrators. However, the existing variable-step Runge-Kutta integrator is still the default and recommended for most Bladed simulations without high frequencies present.

Linear analysis

The model linearisation screen has been redesigned. It includes the new blade stability tool which is mentioned in a later section. Otherwise, the screen offers largely similar options as before and also exposes some options that were only available through "project info". There is also a new field which determines the maximum frequency plotted on the Campbell diagram, which is useful for multi-part blade simulations.

For model linearisation, individual wind speed perturbations for each blade have been deprecated and replaced by perturbations in linear horizontal and vertical wind shear. The latter is seen as more applicable and useful to individual pitch control design.

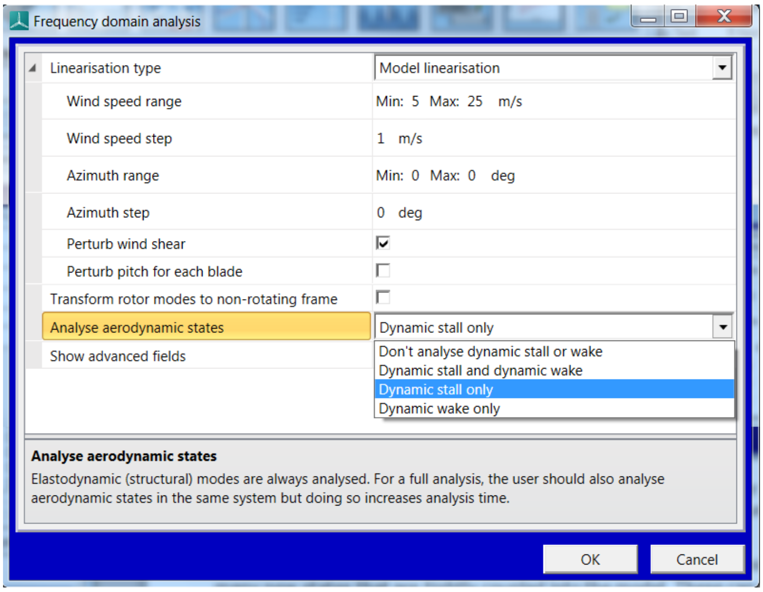

Figure 6 – New model linearisation screen including options for analysing aerodynamic states

A new consideration with linear analysis is that the new aerodynamics implementation introduces many new states that are tightly coupled into the model. These can be chosen to be analysed along with the structural modes in all frequency domain calculations. It has been observed that analysing dynamic stall can have a significant impact on coupled mode dampings and frequencies and this is recommended for Campbell diagrams. Analysing dynamic wake is important for model linearisation due to its effect on the dynamic response of modes from wind speed perturbations.

Pitch actuator

Improvements have been made to the treatment of limit switches and the actuator torque limits can now be set separately for operation under backup power.

In previous versions of Bladed, there was one definition of limit switches, which would immediately cut actuator torque and apply the pitch brake. This could sometimes result in loading spikes, particularly in safety system shutdown events. In 4.8, this functionality has now become the *safety limit switches*. Additionally there are *standard limit switches*, which limit pitch position. An additional change is that, in parked and idling simulations, the pitch brake is always applied and there is zero actuator torque.

The additional definition of actuator torque or force limits in the safety system definition has been replaced by *backup power torque/force limits* in the actuator drive details. These are activated only in a grid loss case.

Simple brake resistor model for grid loss

The existing behaviour upon a grid loss in Bladed is that the generator torque is immediately cut to zero. Now, there is an additional model to represent a simple brake resistor to allow the turbine to maintain generator torque for a period in a grid loss case. This is done by specifying an energy sink and maximum torque under grid loss in the *Additional Items* screen.

Dynamic upwind wake

A new alternative to the existing "upwind turbine wake" has been added and is available through the specify menu drop-down. The premise of the new functionality is that the user does not need to change inputs between simulations in a set of site-specific load calculations.

Based on a steady operational loads calculation and relative location of the upstream turbine, an *eddy-viscosity* wake deficit evolution calculation is performed at the start of every run, based on the mean environmental conditions of that run. This generates the wake deficit profile to be used for that run.

There is also *meandering wake* functionality, which varies the centreline of the wake deficit throughout the simulation according to an integrated meandering based on a low-pass filtered wind turbulence file.

BATCH 1.4

Bladed Cloud

Batch version 1.4 adds support for running Bladed simulations in the Cloud.

The DNV GL Bladed Cloud platform, through its tight integration with the Bladed batch framework, allows users to tap into a highly scalable compute infrastructure to achieve high throughput for their batch runs without the need to maintain expensive local IT infrastructure.

Users can setup their batch runs as per normal and at the time of initiating the run, choose to execute the jobs in the Bladed Cloud as opposed to machines within the local network. The batch framework together with its Bladed plug-in manages data preparation, encryption, upload to the Cloud, status monitoring and results download, providing a seamless user experience. This platform has built-in scaling intelligence allowing it to dynamically scale in response to fluctuations in load.

All user data is protected end-to-end using industry standard encryption technologies and all assets in the Bladed Cloud are further segregated into individual environments per customer. This allows for the best possible data security and provision of dedicated computer capability for each customer.

Access to this feature is not included as part of the standard Bladed software support and maintenance agreement. Please contact the Bladed help desk to know more about this offering and to sign up for it.

OFFSHORE SUPPORT STRUCTURE MODULE

Superelements (beta)

Bladed 4.8 supports the use of superelesments for offshore support structures, e.g. jackets. This allows a support structure designed in another code to be imported into Bladed as a reduced (modal) representation, and used in a simulation without importing any internal details of the structure. This gives the user more freedom to use Bladed in collaboration with offshore design software, which has various advantages. Foundation designers do not have to share the jacket design with the turbine designer, and complex structures, including e.g. shell elements, can be represented without having to simplify or alter them for import into Bladed. Time histories of wave loads on the jacket can be imported (in modal-reduced form) so that their effect on the turbine dynamics can still be simulated.

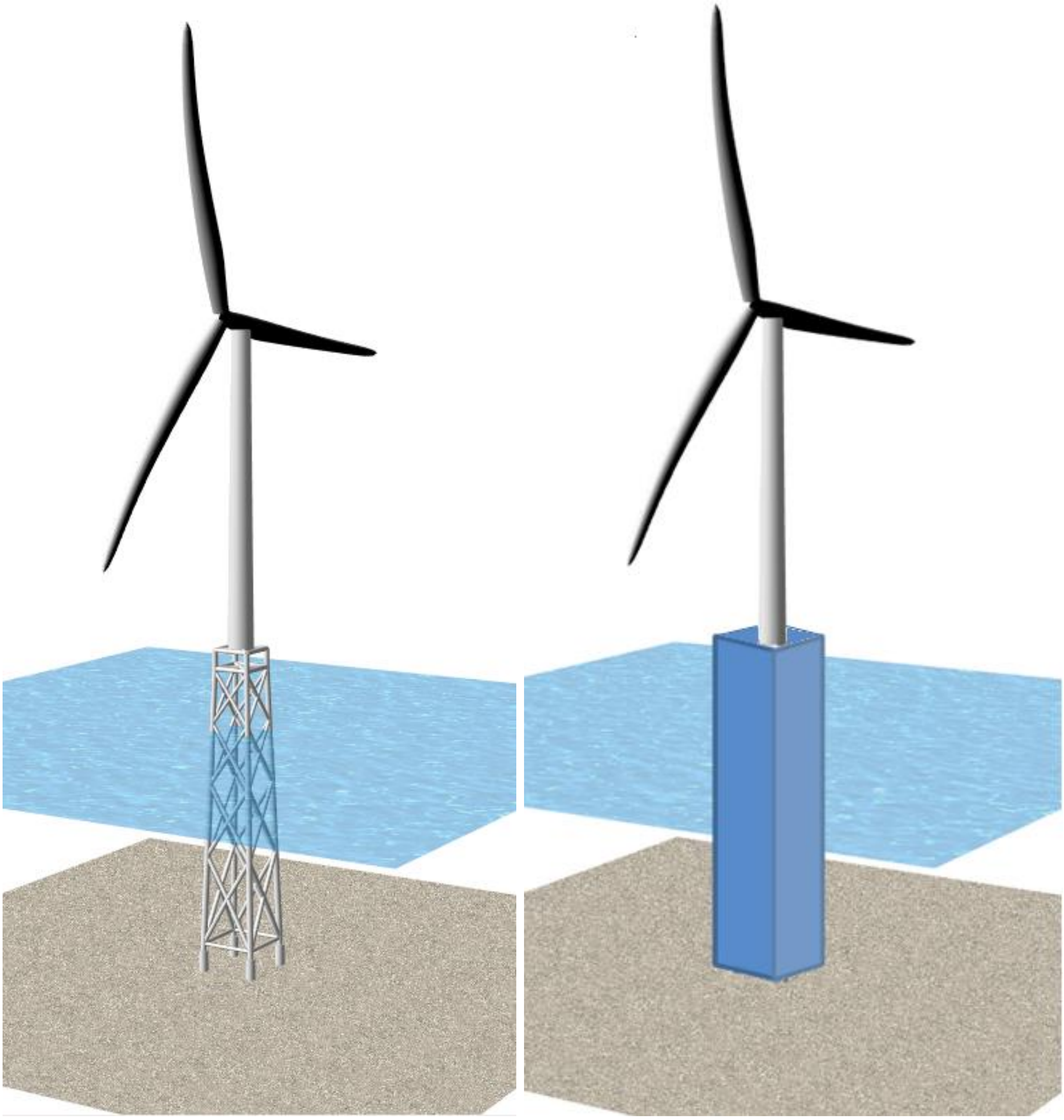

Figure 7: Superelement representation replaces jacket detail with modal information

Dynamic mooring model (beta)

This new type of mooring model offers a higher- fidelity representation of moorings, with mooring lines being represented by rigid elements (segments) connected by universal joints. These structural elements form an integral part of the multibody dynamics engine which is used to model the entire turbine. Using this mooring model, the mooring dynamics and their interaction with the environment are fully coupled with the rest of the model. The model includes the interaction of the lines with the anchors, the seabed, and hydrodynamic forces due to waves and currents. The user can control the number of segments used, allowing a trade-off between more segments (higher modelling fidelity) and fewer segments (faster simulations). It is also possible to model complex mooring arrangements featuring sections of different cable properties, as well as buoys and clump weights at arbitrary points along the line.

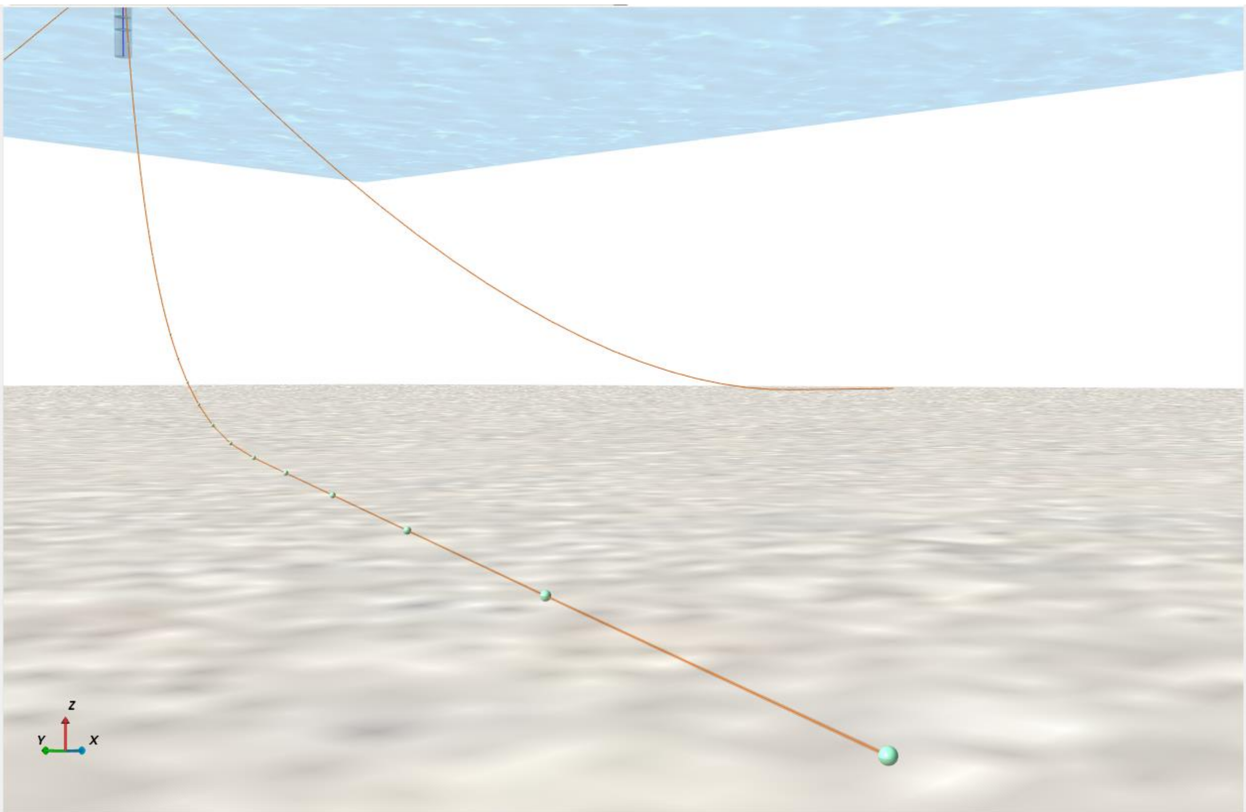

Figure 8: Dynamic mooring lines visualised in results animation

Global linear drag

This new feature may be used in conjunction with the advanced (radiation-diffraction) hydrodynamic model to specify 6-degree-of-freedom viscous drag characteristics for the hydrodynamic bodies. The new "Global linear drag" item is found in the "BEM Hydrodynamics" section for each hydrodynamic body. The velocities and loads are all expressed in global coordinates, and the loads will be applied at the support-structure node associated with the given hydrodynamic body.

BLADE STABILITY TOOL (NEW MODULE)

The blade stability tool is a new module in Bladed. It is included in the *model linearisation* screen and is a new type of frequency domain analysis where only the rotor is modelled. The frequency and damping of all rotor modes can be analysed up to high rotor speeds and wind speeds in different inflow conditions according to the user input.

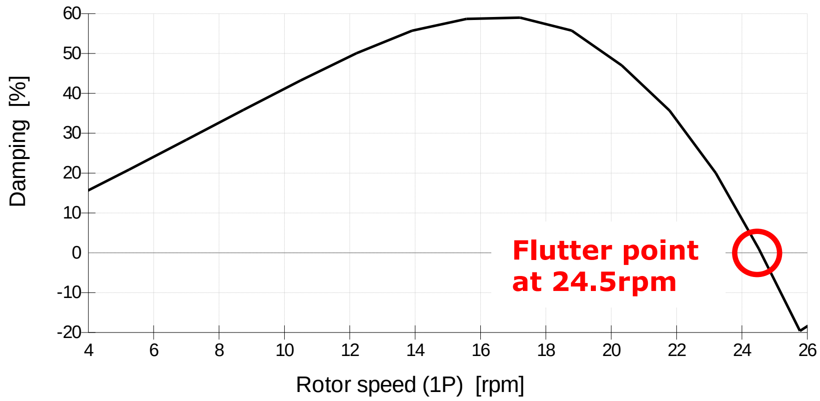

Figure 9 - Free-spin blade stability analysis identifying a flutter point

Blade stability analysis currently has two modes of operation:

- Free-spin / tip-speed ratio tracking – The rotor is analysed at many different wind speeds at which the steady-state rotor speed is found for each wind speed. This enables users to look for potential flutter points.
- Parked – Only one blade is analysed at zero rotor speed and a chosen azimuth. The user can choose wind direction and the blade is analysed at many wind speeds. This allows the user to investigate the stability of the blade in a large variety of inflow conditions.