

European Bladed User Conference 2016

10th November 2016

Ungraded

-
- Introduction
 - Bladed Cloud
 - Results animation
 - Superelement
 - Dynamic wake

The team



Paul Martin



**William
Sardar**



**William
Collier**



**Philip
Bradstock**



**Douglas
McCowen**



Jamie Badar



**Andrew
Cordle**



**Menno
Kloosterman**



Alec Beardsell



**Oscar
Hugues Salas**

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Agenda

Registration and coffee		
Bladed 4.8 – what's new?	Patrick Rainey	DNV GL
Multi-part blade: validation and loads study	William Collier	DNV GL
Multi-part blade modelling and blade stability	Jelmer Cnossen	GE
Coffee Break		
New blade stability tool	Philip Bradstock	DNV GL
Bladed 5	Patrick Rainey	DNV GL
Workshop 1 / discussions on selected topics	All	
Lunch		
New Aerodynamics verification	Menno Kloosterman	DNV GL
Trailing Edge Flaps on Multi-MW Turbine Blades	Sebastian Perez-Becker	WINDnovation
Floating wind and new dynamic mooring line model in Bladed	Douglas McCowen Andrew Cordle	DNV GL
LiDAR simulation and hardware testing in Bladed	Oscar Hugues Salas	DNV GL
Coffee Break		
Earthquake simulation in Bladed	Alfredo Martinez Cia	Acciona
Workshop 2 / discussions on selected topics	All	
Closing presentation	Patrick Rainey	DNV GL
Drinks Reception		

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Bladed 4.8

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Bladed 4.8

- Multi-part Blade
 - Work begun 2013
 - Working model 2015
 - New integrators 2015
 - GUI 2016
- New Aerodynamics
 - Work begun 2011
 - Working model 2013
 - Optimised and beta released in 2015
 - Verification and testing continued – official release in 4.8
- Dynamic Wake Meandering
- Dynamic mooring line
- Superelements

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Bladed 4.8

Defining modes:

Flexibility Modeller

Flexibility Model inputs

Run modal analysis

Blade

Flexibility Enabled ☒

Modal reduction on blade parts Modal reduction

Add blade part Delete selected blade parts

First station	Last station	Maximum allowed modes	Number of modes on part
1	10	36	4

Tower

Flexibility Enabled ☒

Number of modes 6

Maximum allowed modes 28

Modal analysis results and damping inputs

Whole-blade modes Tower modes

View blade mode

Modes with damping defined 4

ID	Damping Ratio (%)	Name	Modal Frequency (Hz)
1	1		0
2	1		0
3	1		0
4	1		0

Simulation flexibility settings

Use cached mode shapes ☐

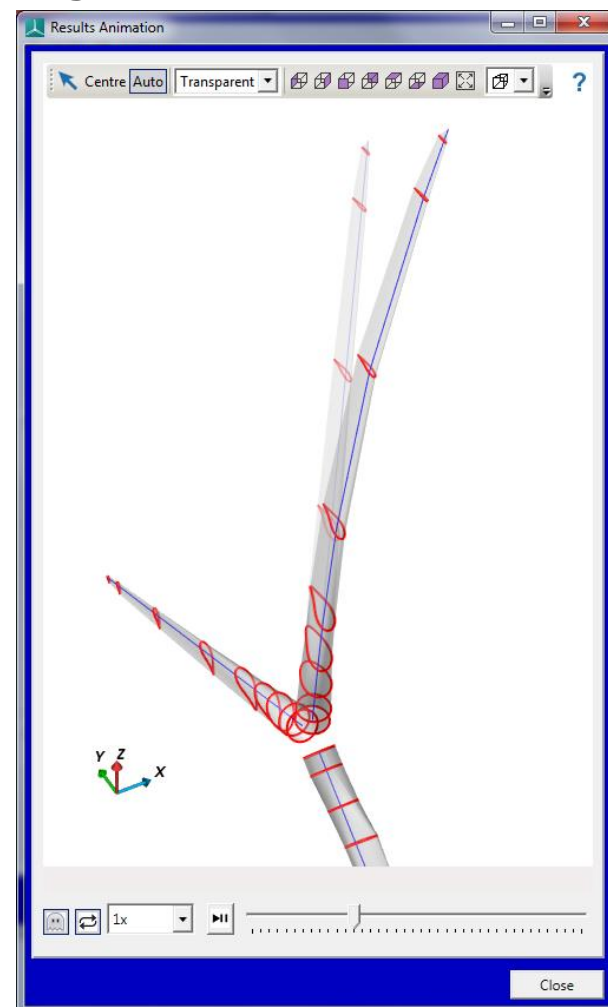
Blade geometric stiffness model Axial loads only

Support structure geometric stiffness model Axial loads only

OK Cancel

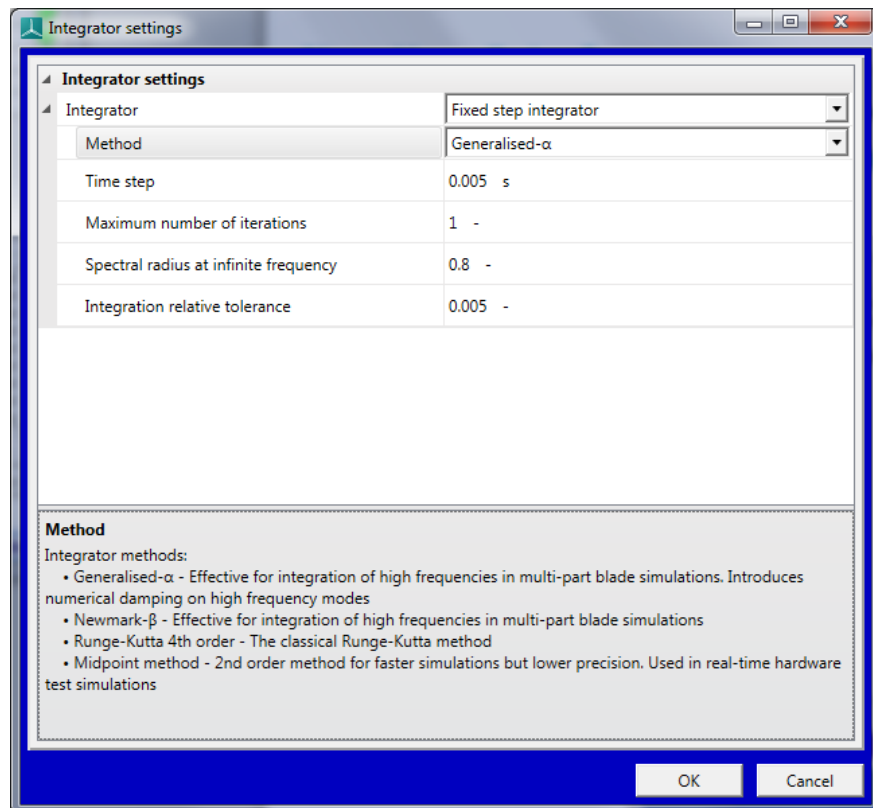
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Viewing modes:



Bladed 4.8

Integrator settings:



The Integrator settings dialog box contains a table for configuration and a detailed method description.

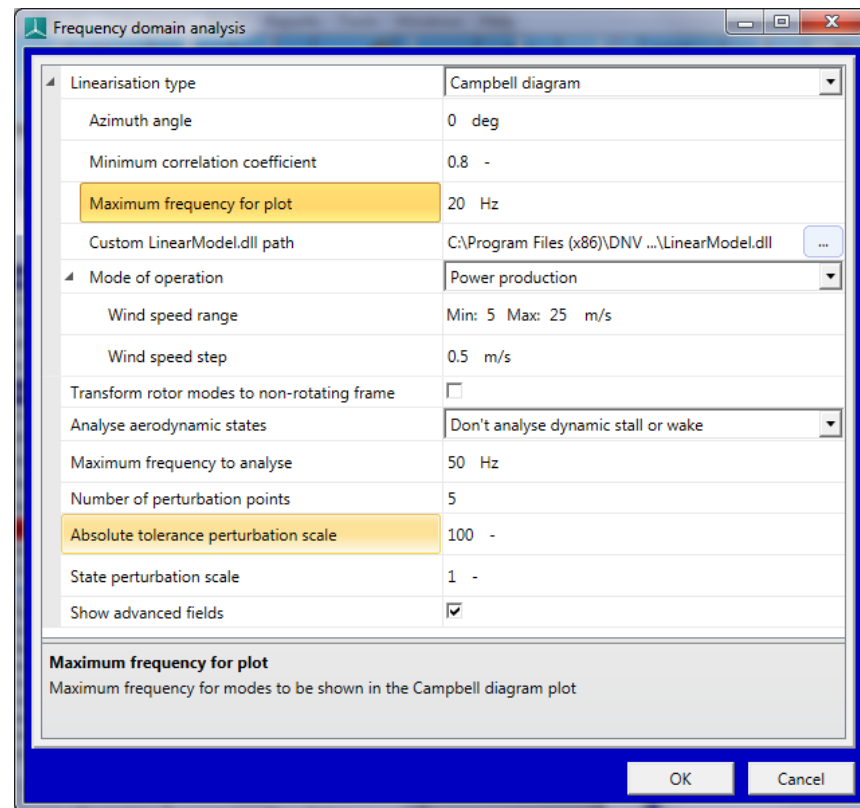
Integrator settings	
Integrator	Fixed step integrator
Method	Generalised- α
Time step	0.005 s
Maximum number of iterations	1 -
Spectral radius at infinite frequency	0.8 -
Integration relative tolerance	0.005 -

Method
Integrator methods:

- Generalised- α - Effective for integration of high frequencies in multi-part blade simulations. Introduces numerical damping on high frequency modes
- Newmark- β - Effective for integration of high frequencies in multi-part blade simulations
- Runge-Kutta 4th order - The classical Runge-Kutta method
- Midpoint method - 2nd order method for faster simulations but lower precision. Used in real-time hardware test simulations

OK Cancel

Frequency domain analysis:



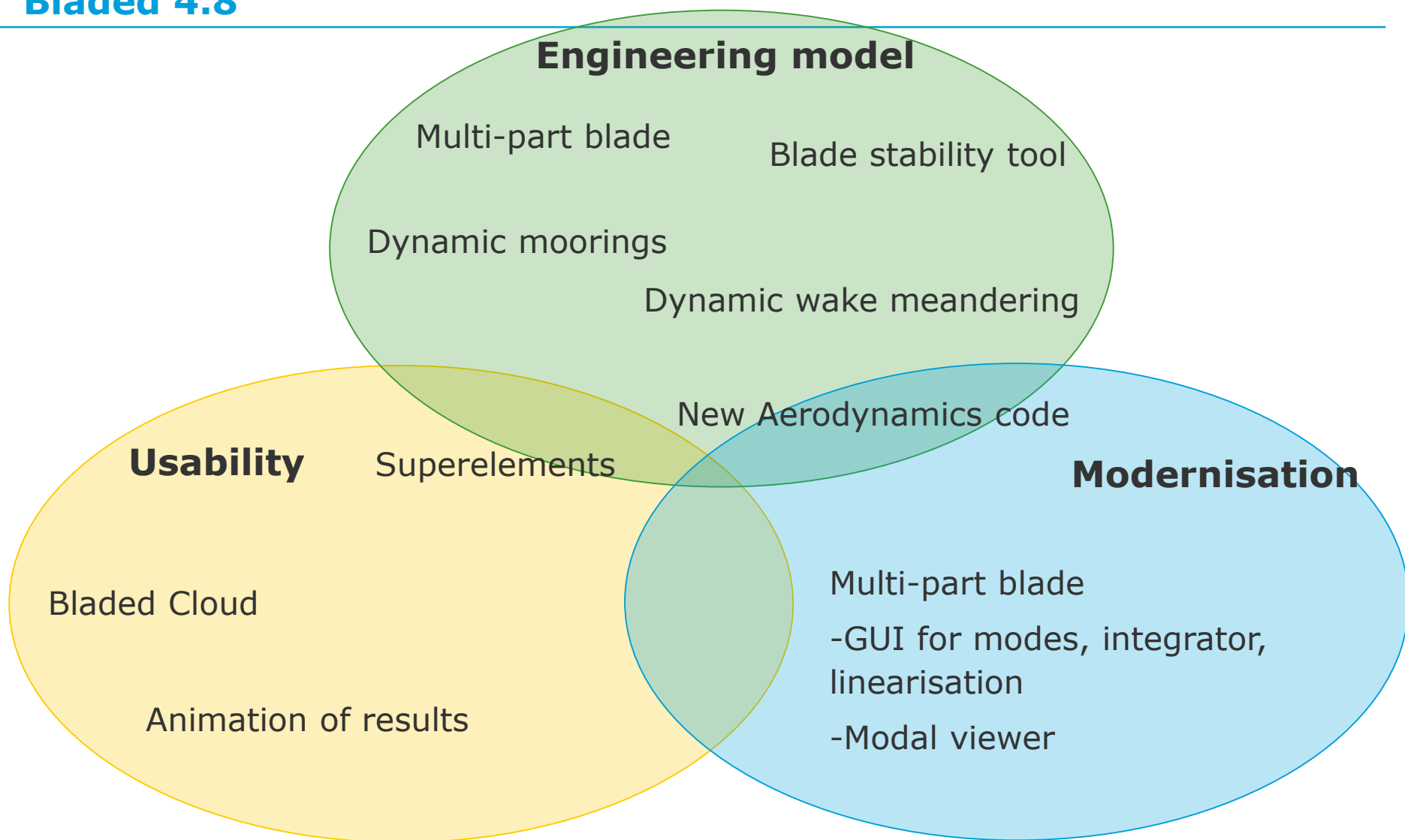
The Frequency domain analysis dialog box contains a table for configuration and a note about the maximum frequency for plot.

Frequency domain analysis	
Linearisation type	Campbell diagram
Azimuth angle	0 deg
Minimum correlation coefficient	0.8 -
Maximum frequency for plot	20 Hz
Custom LinearModel.dll path	C:\Program Files (x86)\DNV ...\LinearModel.dll ...
Mode of operation	Power production
Wind speed range	Min: 5 Max: 25 m/s
Wind speed step	0.5 m/s
Transform rotor modes to non-rotating frame	<input type="checkbox"/>
Analyse aerodynamic states	Don't analyse dynamic stall or wake
Maximum frequency to analyse	50 Hz
Number of perturbation points	5
Absolute tolerance perturbation scale	100 -
State perturbation scale	1 -
Show advanced fields	<input checked="" type="checkbox"/>

Maximum frequency for plot
Maximum frequency for modes to be shown in the Campbell diagram plot

OK Cancel

Bladed 4.8

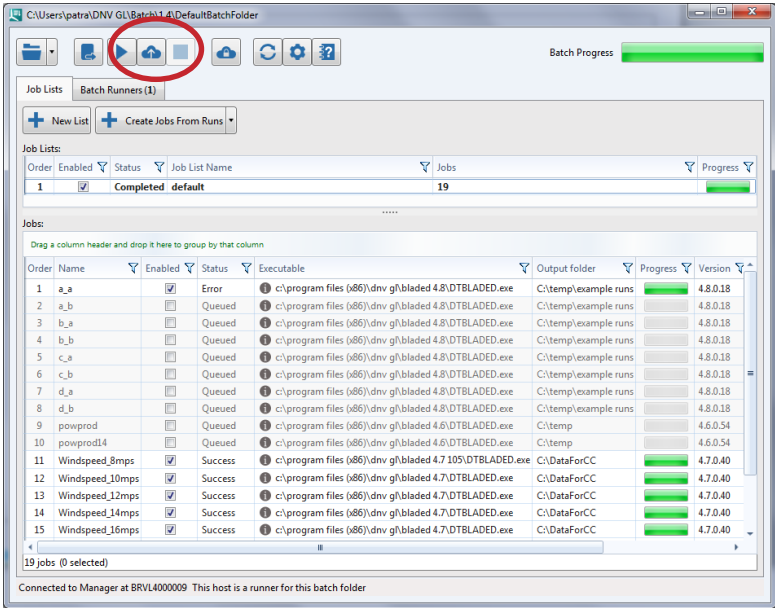
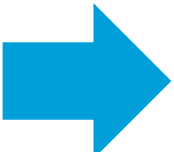
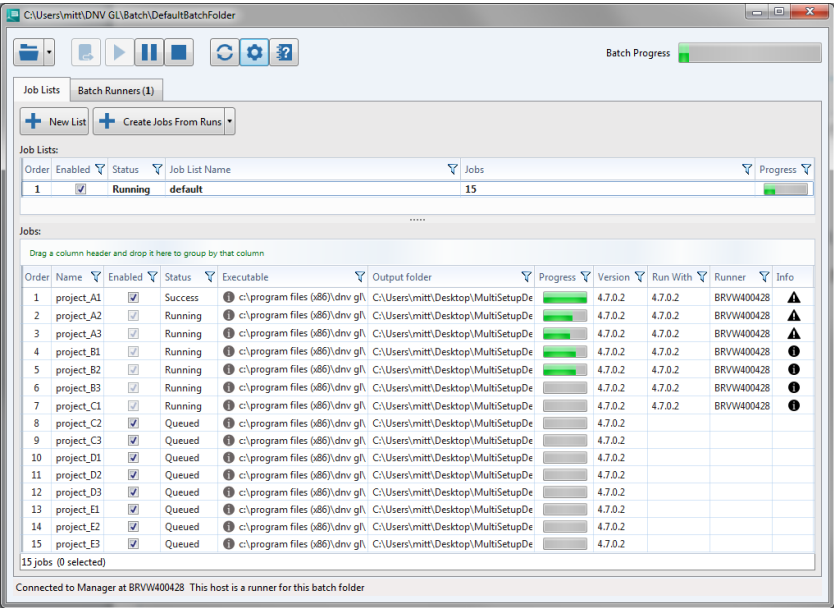


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Bladed Cloud

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Bladed Cloud User Interface



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Bladed Cloud User Interface

Batch Settings

General

Manager

Runner

Runs in the Cloud

Max Calculation Duration (minutes) 180

Max Time Without Progress (minutes) 10

Max Calculation Duration (minutes)

Maximum allowed calculation duration for Cloud jobs. Individual jobs within the batch are expected to finish within this time from when they start running. Calculations that do not finish within this period are terminated to avoid incurring unacceptable costs. Note that the time taken to prepare and upload the job inputs are not included in this duration.

OK Cancel

Bladed Cloud - Usage Reporter

[Enter BladedCloud credentials](#)

User administration

Create user Create credentials from AWS key

Enter the criteria for the query:

Environment menno01

Company Code GL Garrad Hassan

Dongle Ids 1237907357 • 1692333034

Jobs Processed From: 01/11/2016 To: 01/12/2016

Query Usage

Total Usage: 635 Hours

Usage Breakdown

☒ Daily Summary ☐ Full List of Jobs

Export Results

Date dd/mm/YYYY	Total Usage [hrs]:[mins]:[secs]
01/11/2016	75:38:36
07/11/2016	559:05:09

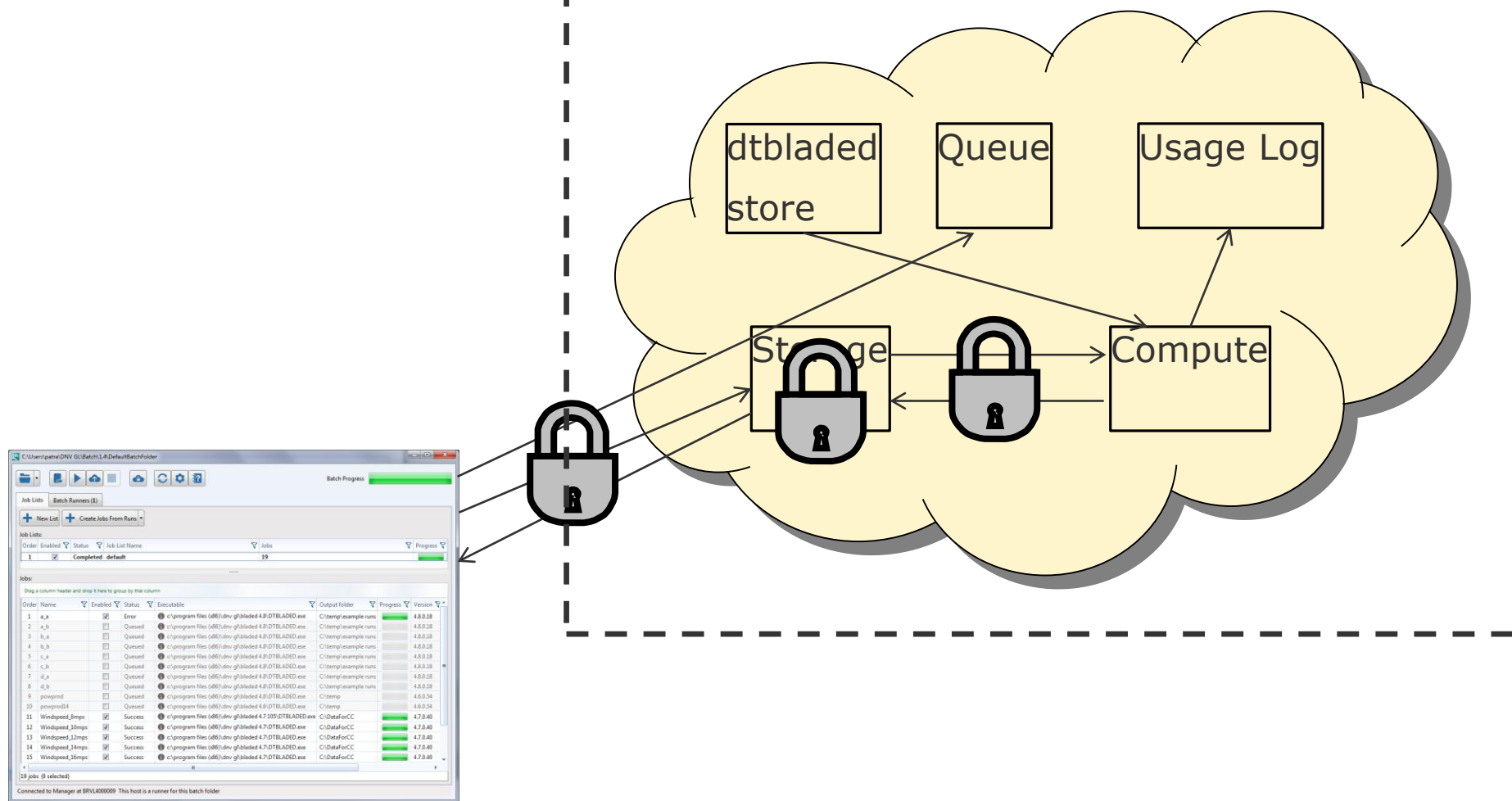
Number of jobs found: 746

Results are in sync

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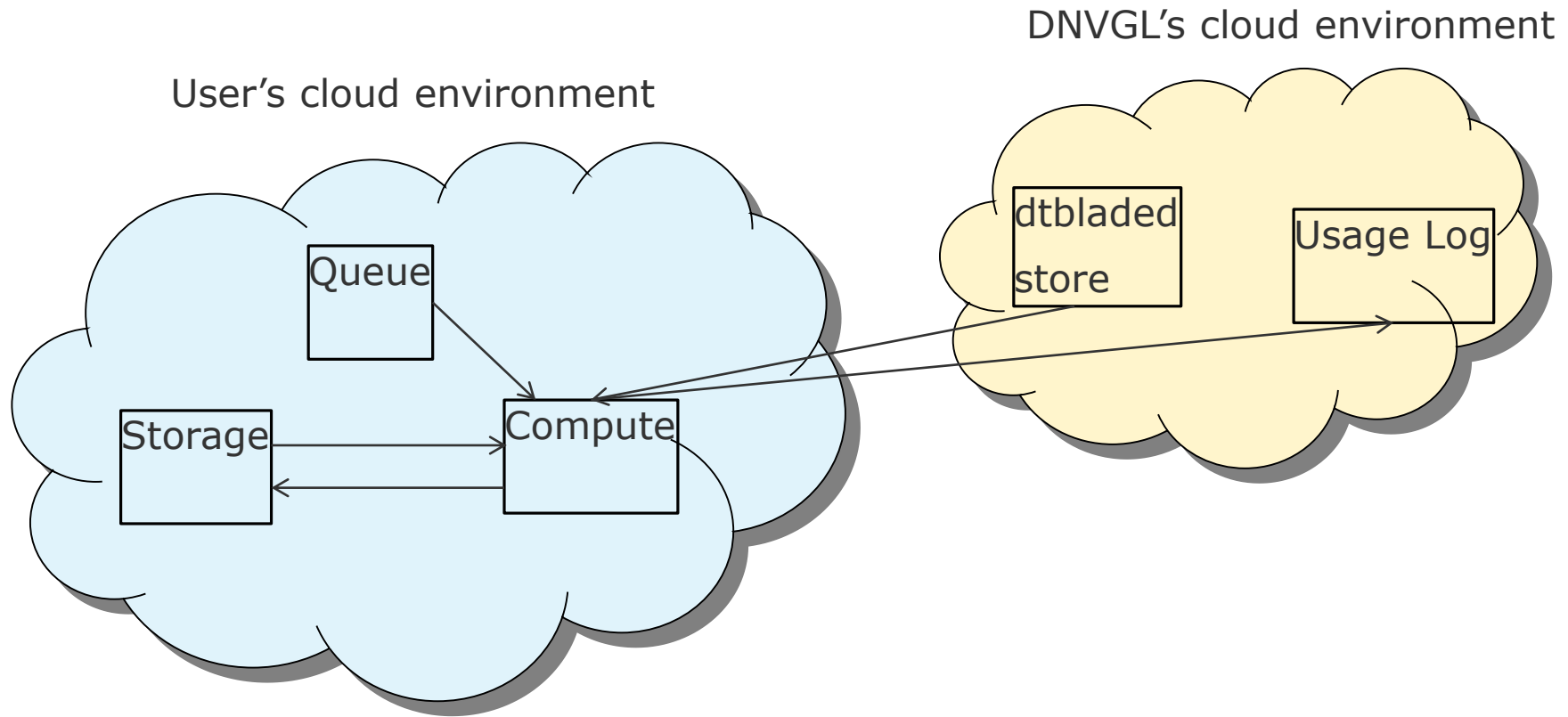
Bladed Cloud

Unique cloud environment for each Bladed customer



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Build your own Bladed Cloud



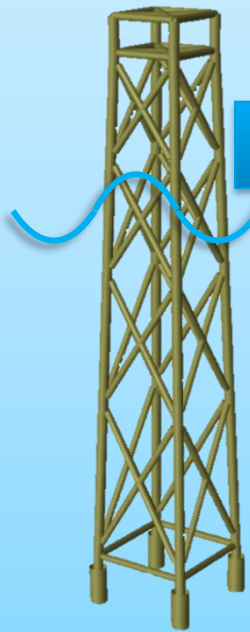
Superelements

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Creating a Superelement

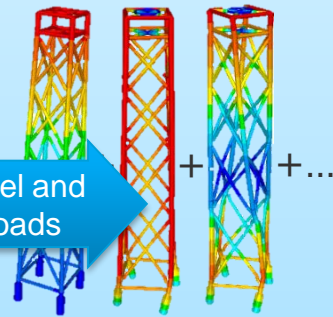
Offshore Code

Jacket design
+ waves loads



Offshore Code

Reduction into
superelement and
load files



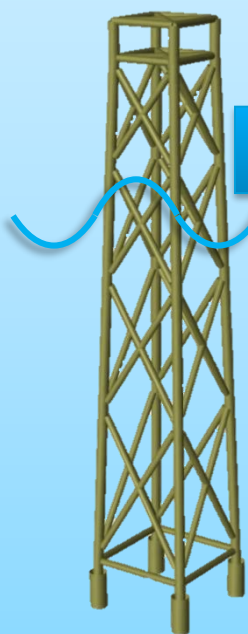
↓
 $[K], [M], [F]$

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- Superelement created using Craig-Bampton reduction
 - **Constraint modes:** applied displacements at jacket top
 - **Normal models:** Eigen modes with jacket top constrained
 - Modes give reduced $[K]$, $[M]$, $[F]$ for use directly in Bladed

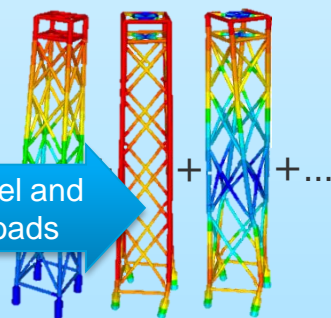
Superelement Analysis

Offshore Code
Jacket design
+ waves loads



Full model and
wave loads

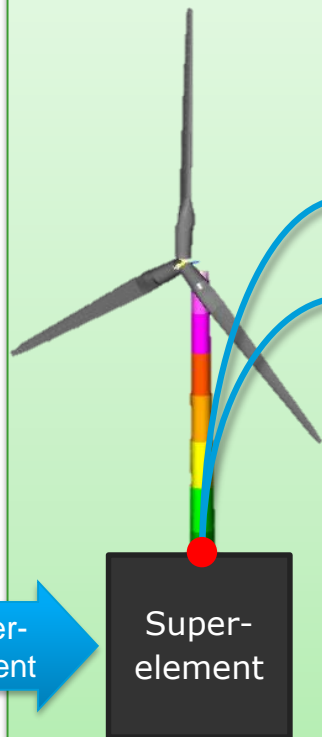
Offshore Code
Reduction into
superelement and
load files



$[K]$, $[M]$, $[F]$

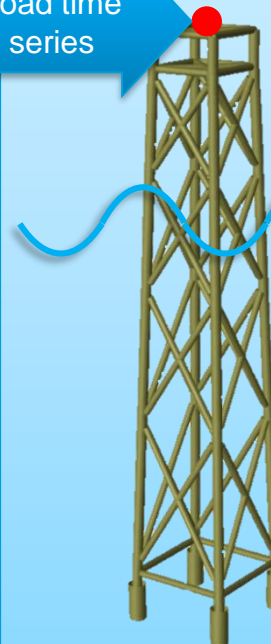
Super-
element

Bladed
Wind loads
Structural analysis



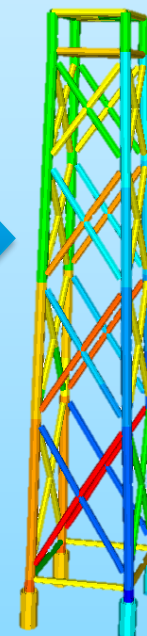
Load time
series

Offshore Code
Re-use wave loads
Structural analysis



Results

Offshore Code
FLS and ULS
analysis



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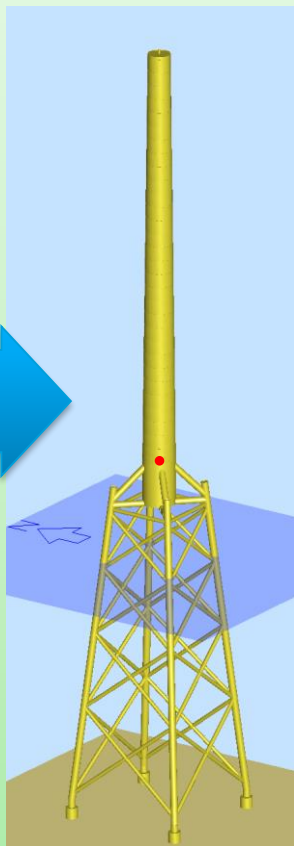
Superelement testing 1 – test integrated model

SESAM



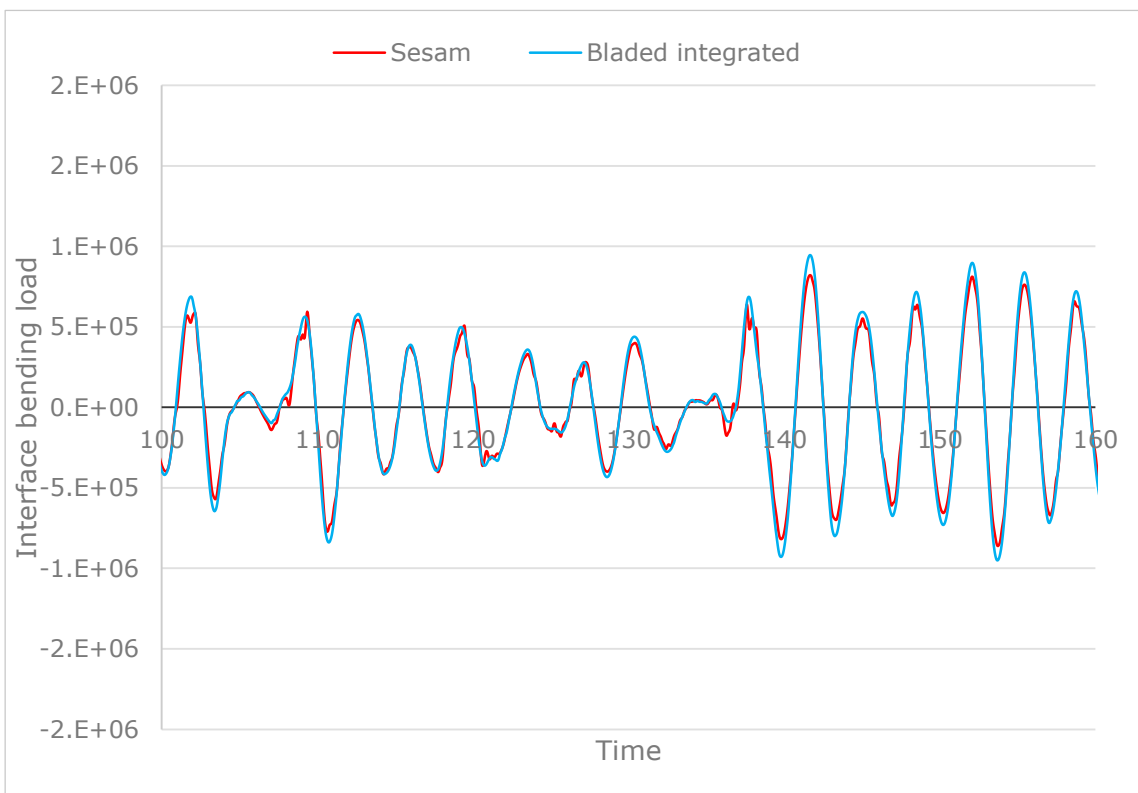
Ungraded

Bladed



Model

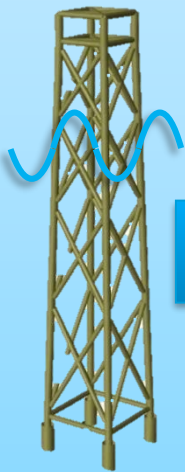
1. Check for equivalent modelling in Bladed / SESAM
2. Take full model & sea surface (waves) SESAM -> Bladed
3. Compare interface loads



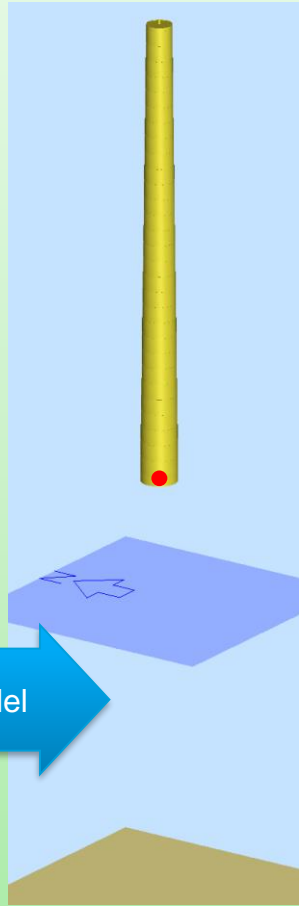
Superelement testing 2 – test superelement model

SESAM

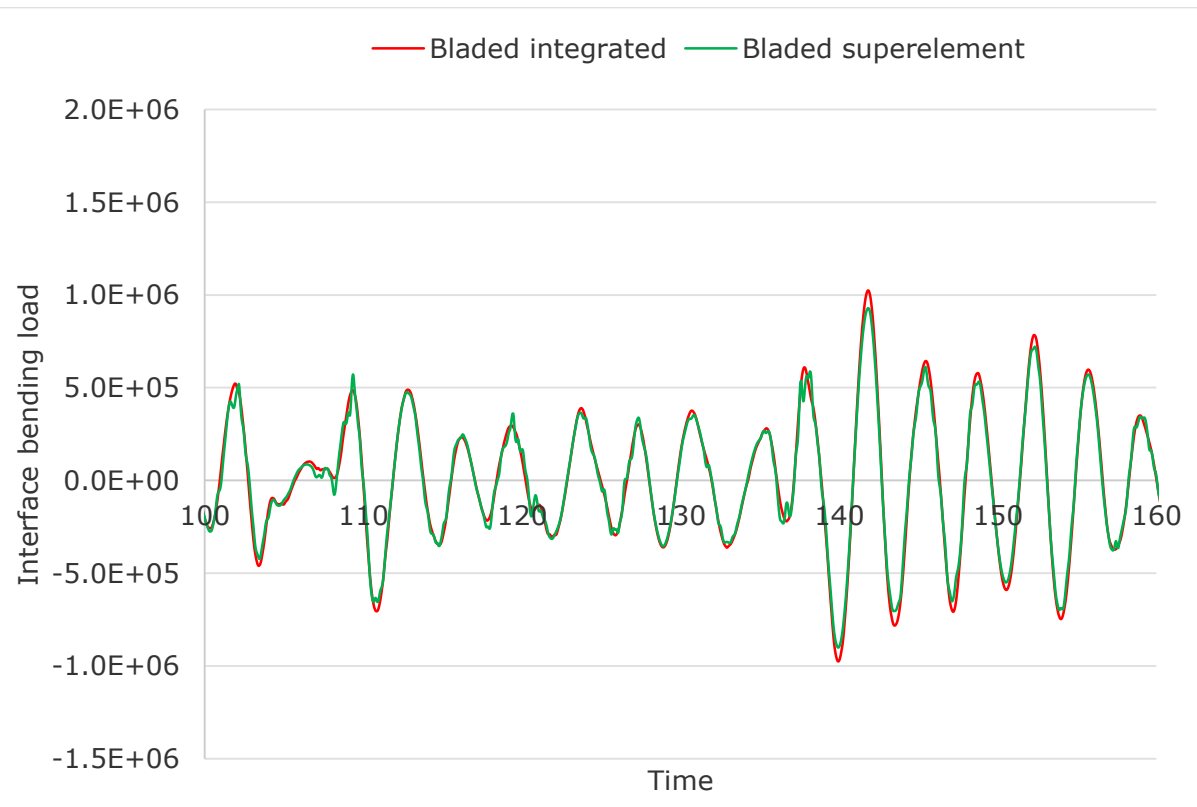
Bladed



Model



1. Compare Bladed integrated and Bladed superelement
2. Take jacket and wave loads SESAM -> Bladed
3. Compare interface loads to integrated case



Results animation

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Live Demo

Dynamic Wake Meandering

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Dynamic Wake Meandering

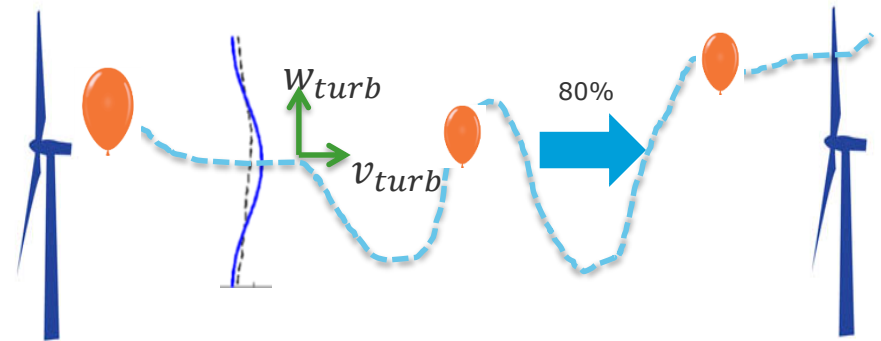
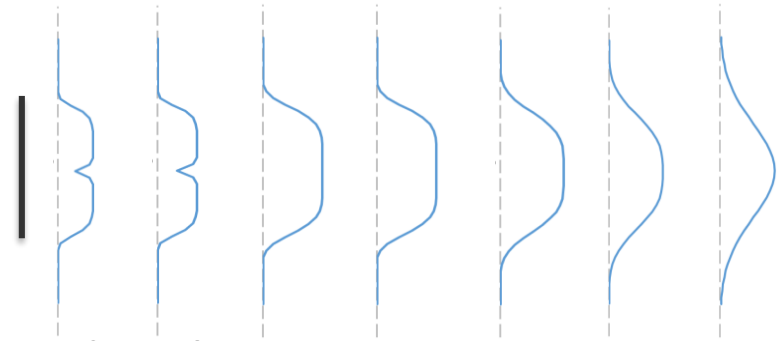
■ Eddy viscosity model

- Navier-Stokes model of how the wake propagates downstream
- Steady wake profile calculated for mean wind conditions of simulation



■ Meandering wake

- Variation of wake position with simulation time
- Due to ambient turbulence
- Assumed independent of wake deficit profile



How is it “dynamic”?

1. The “meandering” wake means position of wake dynamically varies with simulation time. (Wake deficit profile is static)
2. Load-case dynamic – don’t have to change the properties for every simulation!

Legacy Bladed model:

Wake Model

☐ None

☐ Gaussian wake

☒ Eddy viscosity model

Not used for simulations with

Only used for simulations with

Centre Line Velocity Deficit	%	0
Wake half-width (from centreline to $\exp(-0.5)$)	m	0

Upwind turbine: Diameter	m	0
Upwind turbine: Thrust coefficient	-	0
Upwind turbine: Tip speed ratio	-	0
Upwind turbine: Number of blades	-	0
Upwind turbine: Distance upstream	m	0
Default ambient turbulence intensity	%	0

Added turbulence

Applied to all components

Horizontal offset of wake centre-line from hub	m	0
Vertical offset of wake centre-line from hub	m	0

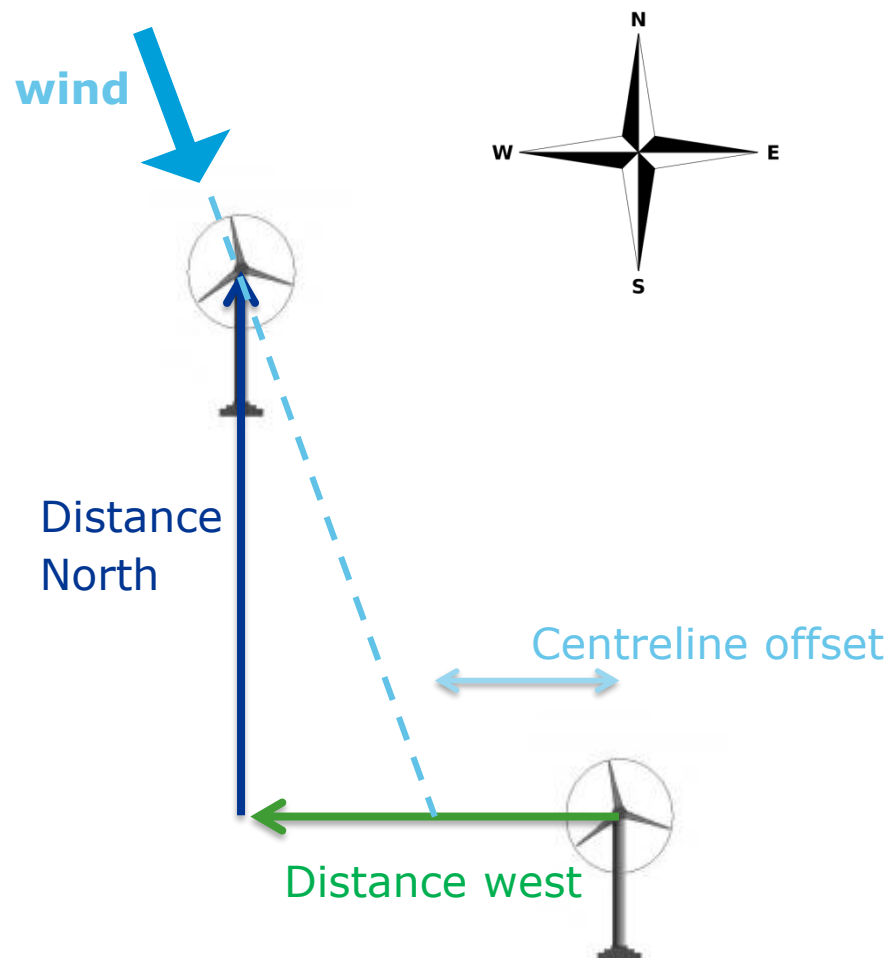
Depend on
wind speed/file

Depend on
wind direction

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Bladed 4.8 - Set up in terms of eternal constants

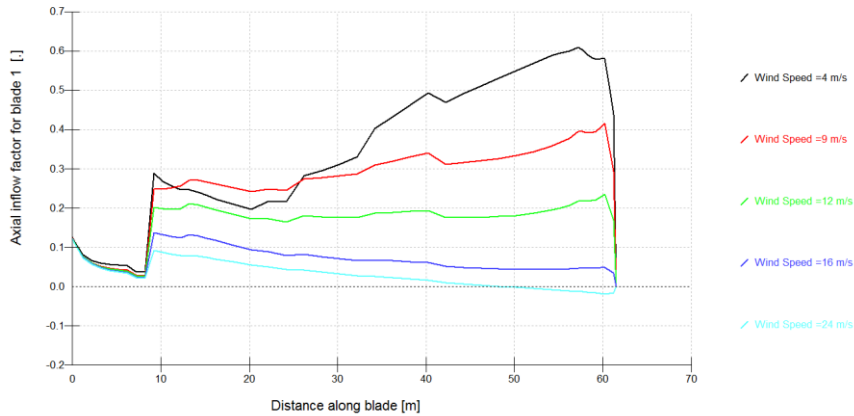
Wake Definition	
Enable dynamic wake	<input checked="" type="checkbox"/>
Distance of upstream turbine North	800 m
Distance of upstream turbine West	200 m
Relative hub height of upstream turbine	0 m
Use steady operational loads for wake deficit	<input checked="" type="checkbox"/>
Aerodynamic information results set	
Steady operational loads aerodynamic information	P:\STP\Bladed\Dyna...
Meandering Wake	
Enable wake meandering	<input type="checkbox"/>
Wind file for meandering wake	
Speed of wake propagation relative to ambient wi	80 %
Distance of upstream turbine West	
Distance of turbine generating the wake relative to the modelled turbine in t	



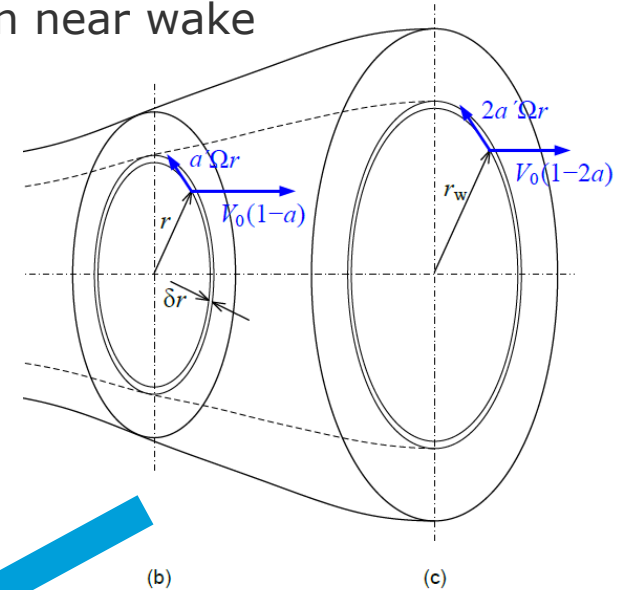
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Wake Profile Propagation (Eddy-Viscosity)

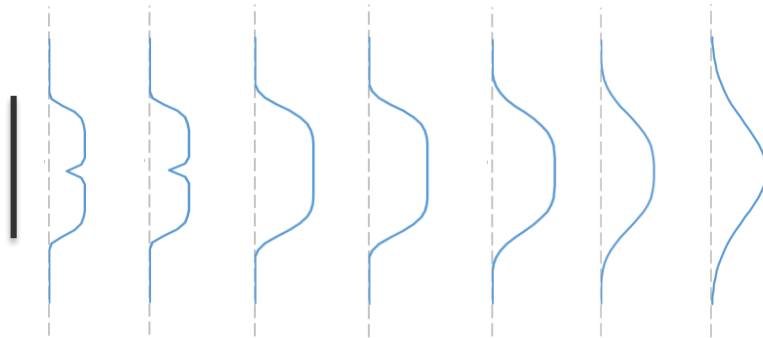
Initial wake profile generated from steady operational loads calculation



Expand in near wake



Propagate in far wake

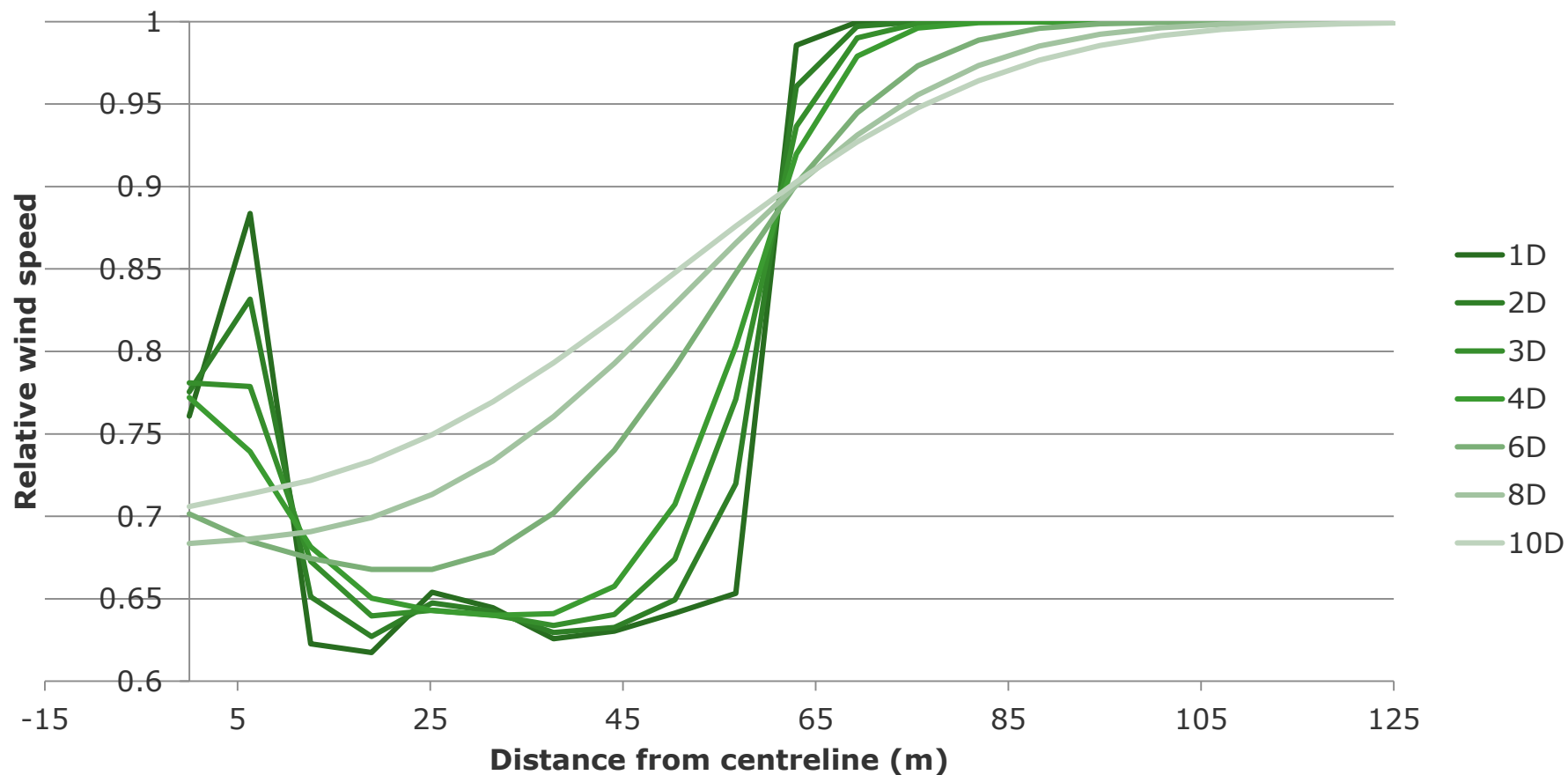


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Eddy-viscosity model – thin-shear layer approximation of Navier-Stokes equation

$$u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial r} = \frac{1}{r} \frac{\partial}{\partial r} \left(\epsilon r \frac{\partial u}{\partial r} \right)$$

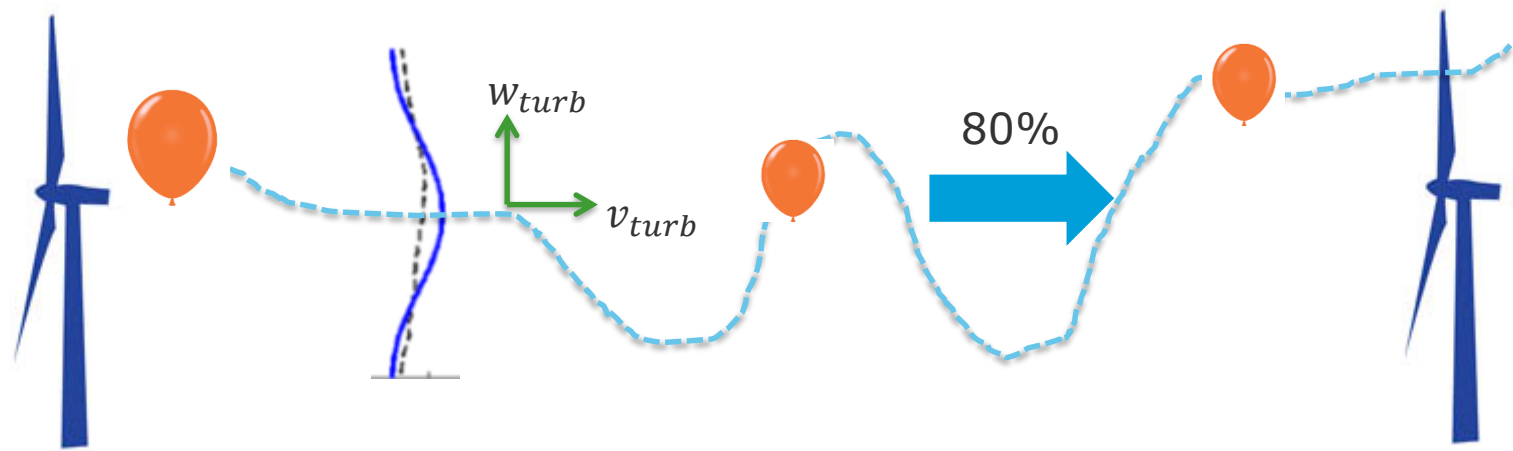
Example Wake Propagation



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Meandering Wake

- Use low-pass filtered wind file to fluctuate the entire wake around in wind field
- Doesn't modify wake profile shape



$$\int \begin{aligned} dx &= (U_{wake} + u'_{wake})dt \\ dy &= v'_{wake}dt \\ dz &= w'_{wake}dt \end{aligned}$$

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Thanks you for attending

Keep in touch!

www.dnvgl.com

SAFER, SMARTER, GREENER

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