PRINCIPIA

IFP Energies nouvelles

DeepLines Wind™

Offshore Wind Turbines FEA Software

Rev.01 - September 2016

Overview

Simulating the dynamic response of floating wind turbines at sea requires coupled FEA simulations that account for the combined effects of aerodynamic loads on the blades, active blades pitch control, hydrodynamic loads on the floating platform and dynamic mooring loads.

DeepLines Wind™ is a comprehensive software program designed specifically to assess the dynamic response of floating and fixed-bottom wind turbines submitted to offshore environmental loadings.

DeepLines Wind™ allows to perform fully-coupled dynamic FEA simulations of all offshore wind turbine components. These simulations provide understanding of the dynamic response of the wind turbines, the floating platform, the dynamic mooring lines and the power cable.

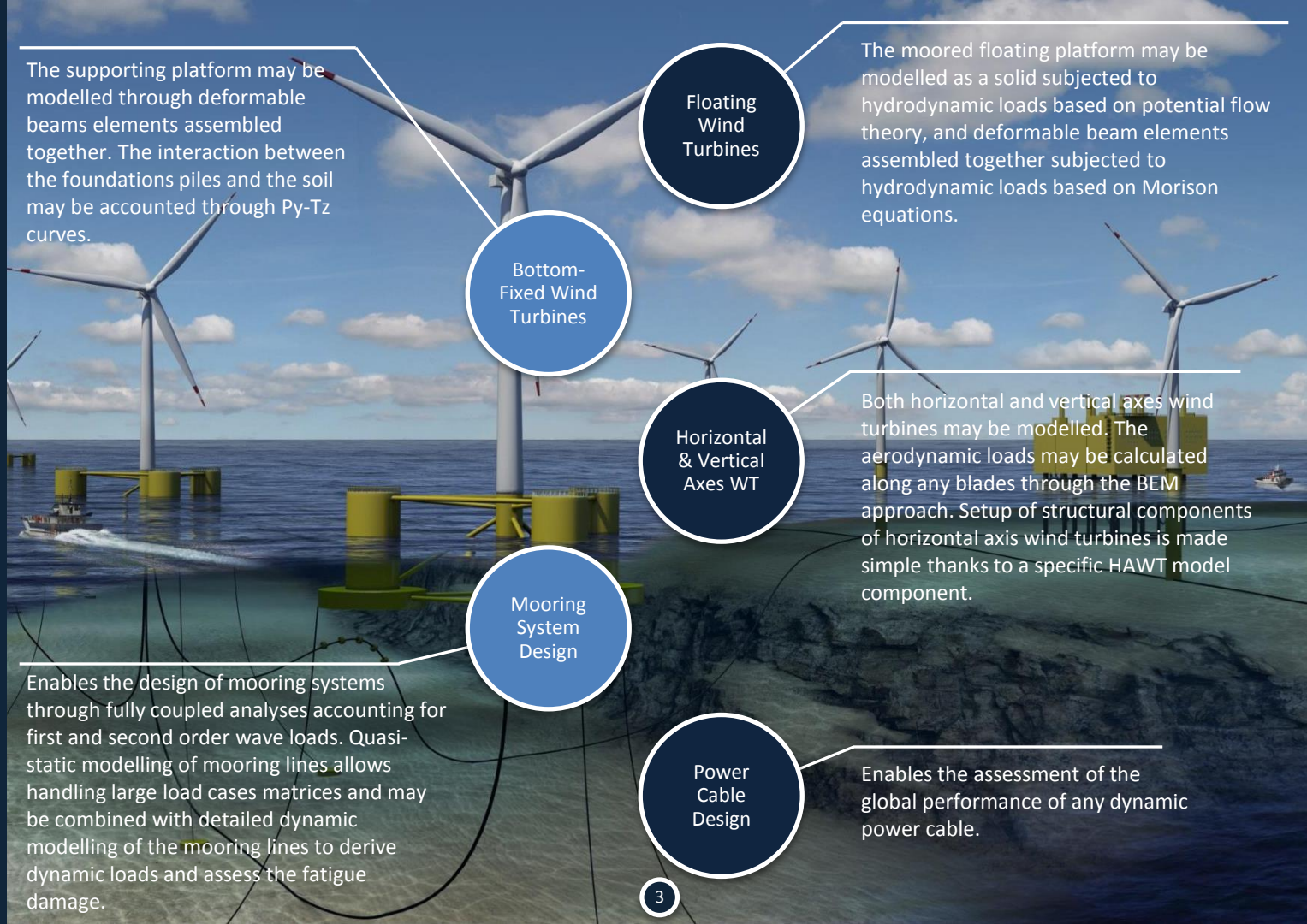
The collaborative DeepLines Wind™ software development project started in 2011 with the aim of allowing design engineers to run advanced analyses at reduced effort.

IFP Energies nouvelles developed dedicated aerodynamic loads and blades control analysis routines that were integrated into the DeepLines™ FEA software marketed by Principia to form the DeepLines Wind™ software.

The wind turbine components – including the blades, the tower, the supporting platform and the mooring system – are all modelled as beam elements and may be easily defined in a single model. This global model dataset combined with time-domain dynamic simulation or quasi-static mooring simulation capabilities provide the various levels of modelling required for basic engineering and detailed design projects.

The software may be used by wind turbine suppliers, floating platforms and foundations developers, mooring systems and power cable suppliers, at any stages of their projects

Applications



Bottom-Fixed Wind Turbines

The supporting platform may be modelled through deformable beams elements assembled together. The interaction between the foundations piles and the soil may be accounted through Py-Tz curves.

Floating Wind Turbines

The moored floating platform may be modelled as a solid subjected to hydrodynamic loads based on potential flow theory, and deformable beam elements assembled together subjected to hydrodynamic loads based on Morison equations.

Horizontal & Vertical Axes WT

Both horizontal and vertical axes wind turbines may be modelled. The aerodynamic loads may be calculated along any blades through the BEM approach. Setup of structural components of horizontal axis wind turbines is made simple thanks to a specific HAWT model component.

Mooring System Design

Enables the design of mooring systems through fully coupled analyses accounting for first and second order wave loads. Quasi-static modelling of mooring lines allows handling large load cases matrices and may be combined with detailed dynamic modelling of the mooring lines to derive dynamic loads and assess the fatigue damage.

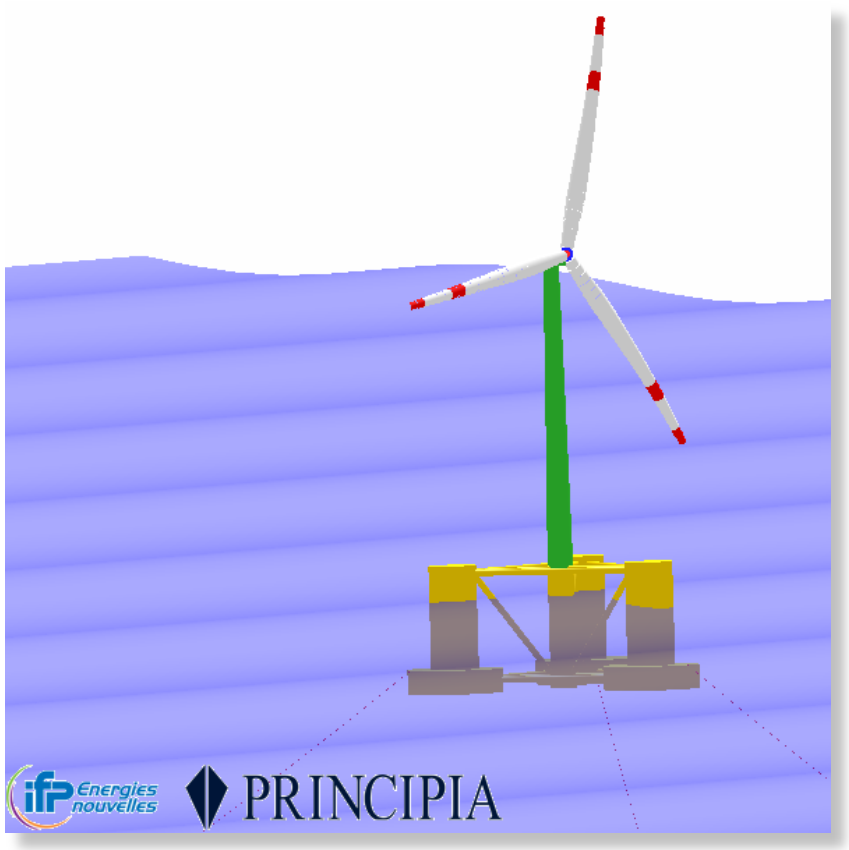
Power Cable Design

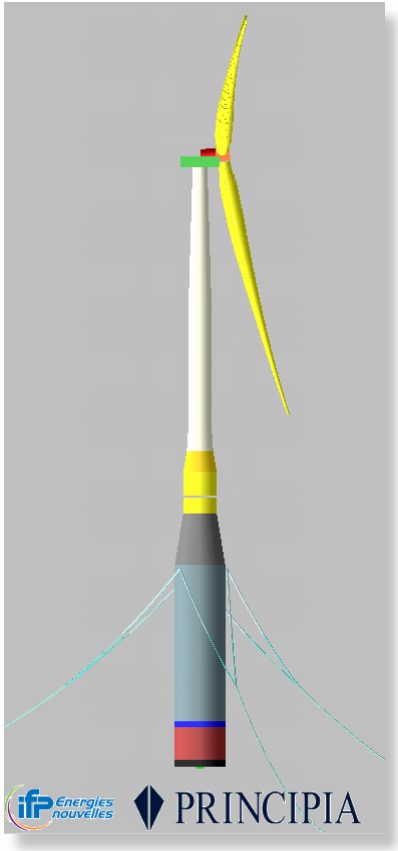
Enables the assessment of the global performance of any dynamic power cable.

PRINCIPIA

Applications

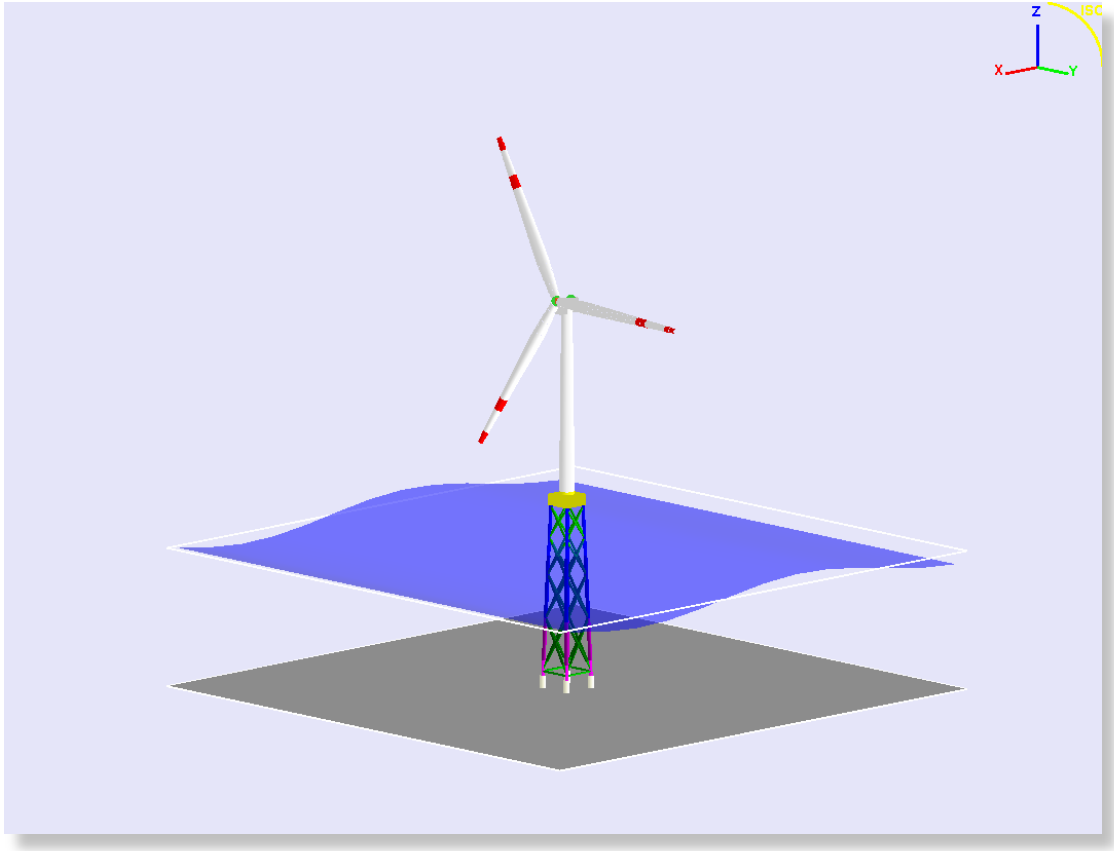
Offshore floating wind turbines





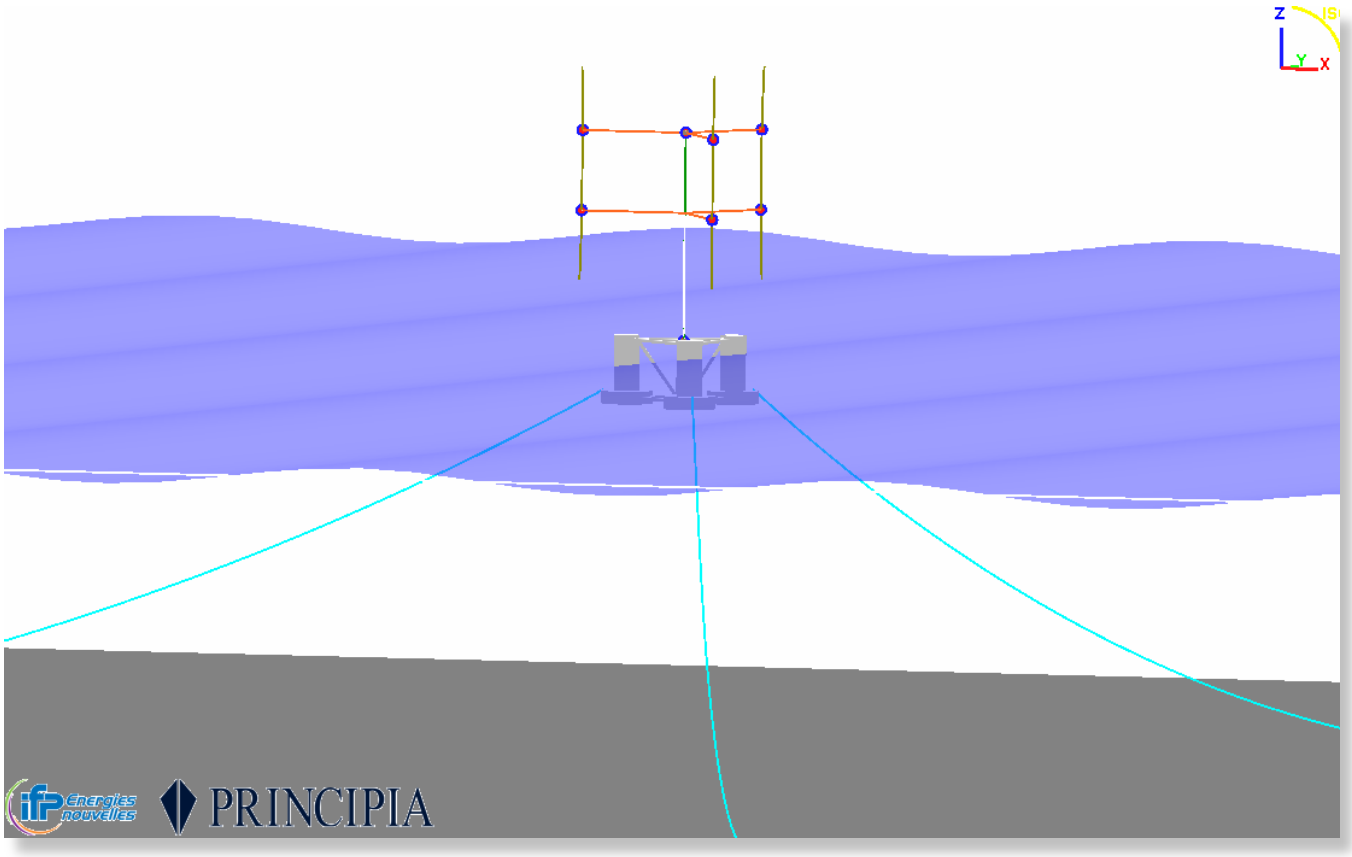
Applications

Offshore fixed bottom wind turbines



Applications

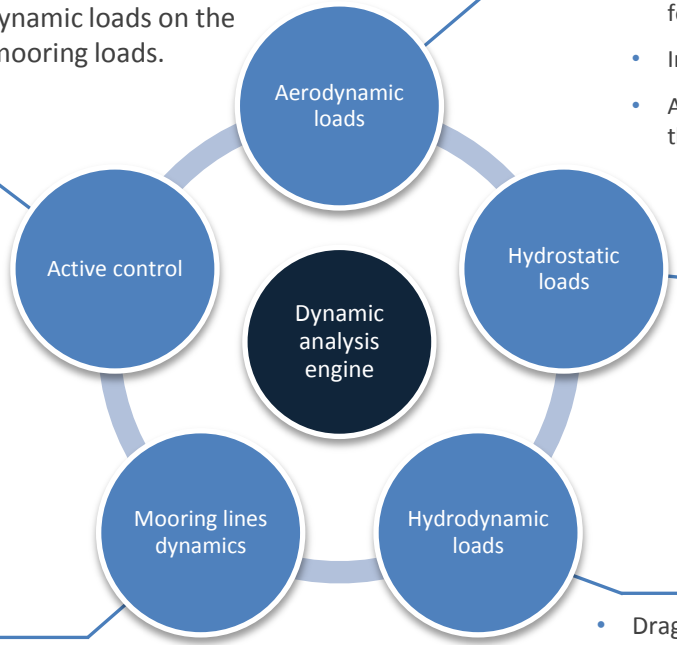
Floating vertical axis wind turbine



Key **features**

Modelling capabilities

The dynamic analysis engine offers a broad range of options to model the combined effects of the aerodynamic loads on the blades, active blades pitch control, hydrostatic and hydrodynamic loads on the floating platform and dynamic mooring loads.



- BEM + dynamic stall and losses for horizontal axis WT
- Single/Multiple Stream Tube model for vertical axis WT
- Includes tower shadow effect
- Accounts for the deflected shape of the blades

- Control algorithms available through external Dynamic Link Libraries (DLL)
- Individual pitch of blades
- Power extraction (generator)
- Nacelle orientation (yaw)
- Rotor shaft (brake)

- Hydrostatic stiffness matrix
- Non-linear hydrostatics based on pressure integrals over the hull surface
- Non-linear hydrostatics based on bar elements

- Mooring stiffness matrix
- Quasi-static modelling based on load-excursion curves
- Fully dynamic based on detailed FE modelling

- Drag and inertia Morison elements
- Diffraction/radiation loads
- First order wave loads based on potential flow calculation
- Quadratic transfer functions for 2nd order wave loads based on Newman or full-QTF

Key **features**

Blades aerodynamics

- The blades are defined using 3D beam dynamic finite elements that account for the structural twist as well as variable stiffness and structural damping along the blade.
- Both in-plane and out-of-plane pre-bends may be modelled.
- Aerodynamic loads account for the dynamic deflection of the blades.

Rotor

- Any number of blades
- Upwind & downwind horizontal axis and vertical axis
- Clockwise & anticlockwise rotation

Blades control

- Individual or collective blades pitch control
- Constant or variable speed
- Yaw control
- Pitch control algorithms available through external Dynamic Link Libraries

Main shaft

- The main shaft is modelled as a dedicated beam element, allowing for post-processing of loads and motions

Power train

- The power train characteristics are used as input data to general control and power generation

Support structure

- Mono-pile, tri-pile, jacket or any type of floating platform can be modelled
- Accounts for hydrodynamic loads on beam elements based on Morison equations and loads on solid hull based on potential flow theory

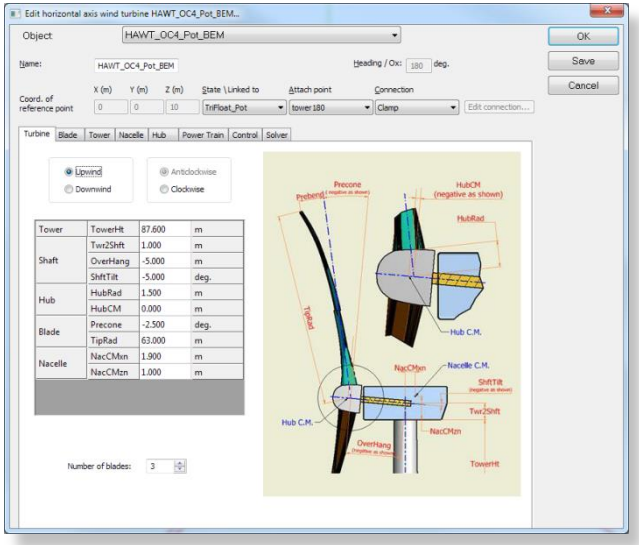


Fig. View of the HAWT model component data form

Key **features**

Analyses types

- Ultimate limit strength analysis: assessment of extreme loads along structural members
- Fatigue loads analysis: assessment of fatigue loads histograms along structural members and derivation of resulting fatigue damage through S-N curves
- Installation & decommissioning: towing, crane and barge operations
- Assessment of export cable configuration performance and stability on the seabed
- Interference analysis: assessment of the clearance between the dynamic power cable and the mooring lines

Environmental loads

- Constant winds, unsteady winds gusts, conventional wind spectra, hub height winds and full field turbulent wind
- Linear (Airy) and non-linear wave theories (Stokes, Dean Stream) for modelling extreme regular waves
- Large range of random wave spectra (JONSWAP, Ochi-Hubble, Pierson-Moskowitz, Gaussian and user-defined)
- Steady and unsteady current profiles with variable direction over the water column

HAWT model component

A specific HAWT model components is included in the GUI to help setting up all data related to the wind turbine.

Finite elements

- Beam elements (6 DOF per node): used to model any structural member featuring axial, bending and torsion loads
- Bar elements (3 DOF per node): used to model any structural member featuring axial loads only.
- Cable elements (3 DOF per node): used to model any structural member featuring axial loads only without compression.

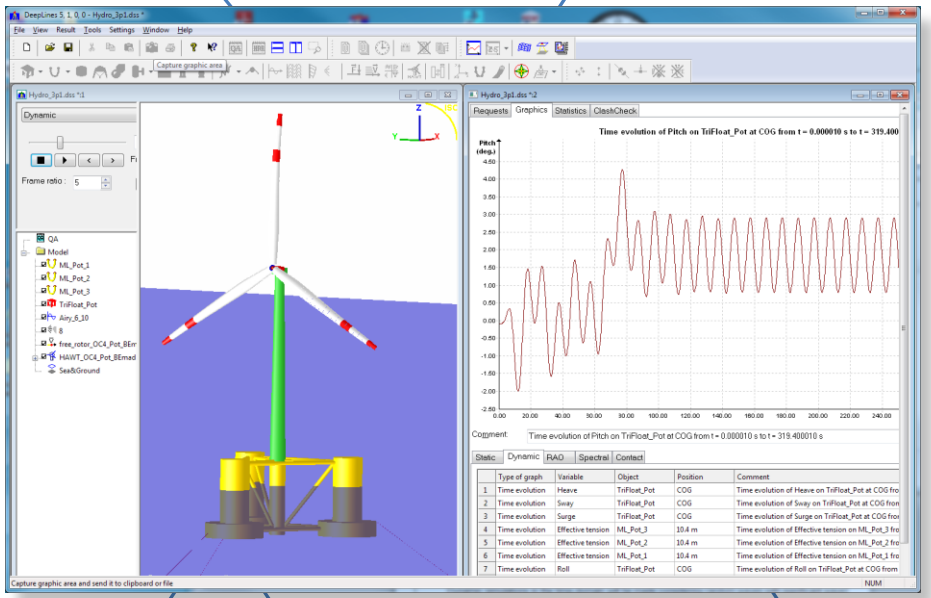
Seabed interaction

- Able to handle any bathymetry through meshing of the seabed surface
- Linear and non-linear normal contact force models
- Standard Coulomb friction with specific coefficients along the axial and lateral directions
- Berm effect and non-linear friction laws
- Able to model the interaction between the foundation and the soil through Py-Tz curves

User **interface**

- Modular working environment
- Multiple windows GUI
- Unattended batch processing features with multi-tasking capabilities
- Comprehensive help system

- Wide range of structural model components
- Wide range of environmental loadings
- Designed to handle large set of load cases
- Copy/paste and import/export features are available for any model components



- Direct control of all components and loads from a unique model file
- Includes HAWT model component

- Displays animations and numerical outputs
- Video files export
- Export to Excel

- Large sets of static and dynamic outputs available
- Includes plots and statistics
- Fatigue analysis through RFC method

PRINCIPIA

Batch & **productivity**

Offshore engineering is continuously raising its standards thus also increasing the required number of analysis cases all of which need to be completed within challenging projects' schedules. Answering these needs implies enhancing automation of analyses setup and optimizing the use of computer capacity.

Analyses sets

Any model may include several Analyses Sets which typically correspond to the load case matrices that need to be considered within the design. These Analyses Sets are based on series of environmental loads that may be conveniently defined within the Environment Sets components.

Batch processing

The Batch Processing is designed to answer users demand and helping completing thousands of analysis cases at limited effort. The Batch Processing form is fully integrated into the GUI and is directly available from the Tools menu.

The form consists in a list of tasks to be performed, and includes controls to setup the list and run the tasks. Each task is defined through an input file and a job type which defines the type of command to be executed.

The batch processing facility may be used to perform tasks that go from analysis files setup to analysis results export to Excel.

Tasks such as fatigue analysis, zones study post-processing, export of results statistics, and clearance check analysis may also be included in the list of tasks.

The batch processing interface finally provides a better control over the analyses as it reports the current status of every tasks, indicating whether it is successfully completed, running or failed.

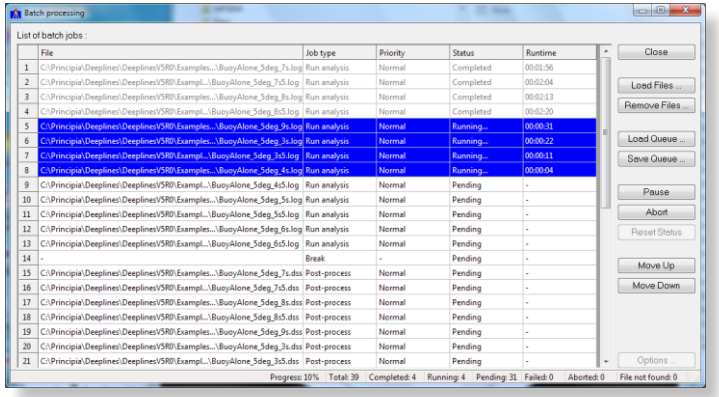


Fig. View of the Batch processing data form

Multi-tasking

Multi-tasking is available through the Batch Processing form. Users may run up to 8 tasks concurrently and take advantage of multiple-cores processors capacities, still using a single license key.

Validation & support

Validation

Validation of wind turbine features is mostly based upon IEA Wind programs OC4 and OC5. Validation of other modelling features was performed as part of the DeepLines's validation program.

Selected references

- **OMAE 2013-10780** - "Fully coupled floating wind turbine simulator based on non linear finite element method – Part 1 : methodology" - Le Cunff, Heurtier, Piriou, Berhault, Perdrizet, Gilloteaux, Teixeira, Ferrer
- **OMAE 2013-10785** - "Fully coupled floating wind turbine simulator based on non linear finite element method – Part 2 : validation results" - Perdrizet, Gilloteaux, Teixeira, Ferrer, Piriou, Cadiou, Heurtier, Le Cunff
- **OMAE 2014-24040** - "OC4 within IEA wind task 30: Phase II results regrading a floating semisubmersible wind system"
- **OMAE 2014-24396** - "Influence of hydrodynamic modeling assumptions on floating wind turbine behaviour" - Le Dru, Le Cunff, Perdrizet, Poirette

Documentation

The documentation provided with the software includes a comprehensive help system, an example manual, a theory manual and a range of presentations extracted from our training courses material.

Technical support

Both technical software support (for problems with creating a model or performing an analysis) and systems support (for installation, licensing, and hardware-related problems) are offered through email at deeplines@principia.fr.

Training courses

Principia deliver both in-company courses and public courses open to multiple companies. In-company courses may be scheduled at your convenience and run at your business premises or at a local venue if you prefer it off-site.

Our software training courses include both a general training with DeepLines™ FEA software which provides an overview of the software capabilities, and a course dedicated to DeepLines Wind™ which details how to build wind turbines models and perform fully coupled dynamic simulations accounting for aerodynamics, blades control, platform hydrodynamics and mooring line dynamics.

Open courses are regularly scheduled at our facilities and announced on our website.

Contact

Please email our software team at deeplines@principia.fr if you wish to learn more about DeepLines Wind™, request for a free evaluation license or a quote.

Licensing options

One-time purchase

The software is available for perpetual purchase. The price for perpetual purchase includes maintenance, upgrade and support (MUS) services for a duration of 12 months. MUS services fees apply for the following years.

Long-term rental

The software is available for long-term rental. The duration of long-term rental is 12 months. The price for long-term rental includes maintenance, upgrade and support (MUS) services.

Short-term rental

The software is available for short-term rental with a minimum duration of 1 month. The price for short-term rental includes maintenance, upgrade and support (MUS) services.

Lease-to-purchase option

You can convert lease into purchase at any time over the rental period. A significant proportion of the rental fees can be reimbursed upon conversion to purchase.

Multi-copy discount

We offer multi-copy discounts on DeepLines licenses. These discounts apply to multiple licenses orders made for use by the same organization at the same site.

Network and node-locked licenses

Network licenses let any user connected to your local area network access the software. DeepLines network licensing uses the FlexNet network license manager from Flexera Software to control a DeepLines license server. Node-locked licenses can also be provided at a reduced rate against network licenses.

License borrowing

To provide license mobility, DeepLines supports FlexNet license borrowing. This capability lets you use DeepLines on computers that do not have a continuous connection to the license server.

Academic licenses

Academic pricing is available for educational use at accredited academic institutions only.

Free evaluation version

Temporary licenses required for potential users to evaluate the software can be issued for free upon request. The validity of these licenses is generally 1 month.

Local **agents**

South Korea

Balance Marinetek Inc. (BMI)
Suite 1506, Centum Green Tower.,
78, Centum Jungang-ro, Haeundae-gu
Busan, 612-020 Rep. of Korea
W: www.bmigroup.co.kr
E: deeplines-contact@bmigroup.co.kr

BMI is an independent offshore and marine engineering consultancy organization, providing high quality services to the offshore oil & gas and renewable energy industries.

Italy

Oceanira s.r.l.
Via Ilva 2/9
16128 Genova, Italy
W: www.oceanira.com
E: deeplines-contact@oceanira.com

Oceanira is a highly specialized company providing design and technical consultancy services in the oil & gas, naval, shipping, transportation and energy sectors

Vietnam

Petropartner Partnership Company Ltd.
Suite 141, 14th Floor, Ree Tower
9 Doan Van Bo Street, Ward 12, District 4,
Hochiminh City, Vietnam
E: hanhph@petropartner.vn

Petropartner is a leading oil and gas service company operating in Vietnam. Products and services range from upstream such as seismic to drilling.

China

Beijing Deding Jijie Technology Co. Ltd.
Room 612/C, Caizhi Guoji Building, No.18,
East Zhongguancun Road, Haidian District,
Beijing 100083
W: www.ddjjchina-bj.com
E: yilibin@vip.sina.com

Beijing Dedingjijie Technology Co. Ltd. is a high-tech company focusing on exploration and development of oil and gas with purpose of serving clients. The company is engaged in the exploration and development of oil, software research and development, sales, technical support and service

About us

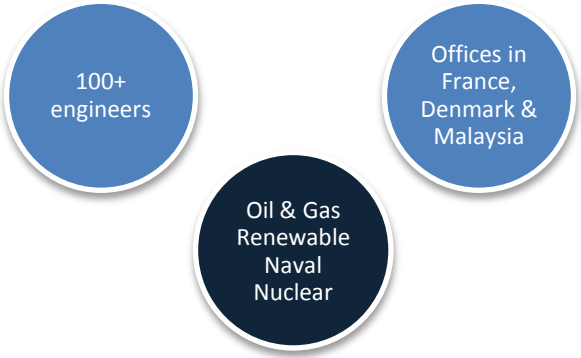
Principia

Principia is an independent engineering, consultancy and software development company active in the fields of energy, oil & gas, naval and offshore renewables.

Our track record covers projects from equatorial swamps to polar deepwater, from oil production facilities to LNG developments.

We deliver expertise and ground-breaking engineering design services applied to floating facilities, subsea modules, umbilicals, risers and flowlines, fixed platforms, offshore service vessels and LNG terminals.

With a workforce of over 100 engineers and offices in France, Malaysia and Denmark , we can provide expertise and engineering services worldwide.



IFP Energies nouvelles

IFP Energies nouvelles (IFPEN) is a public-sector research and training center. It has an international scope, covering the fields of energy, transport and the environment.

From research to industry, technological innovation is central to all its activities.

As part of the public-interest mission with which it has been tasked by the public authorities, IFPEN focuses on providing solutions to take up the challenges facing society in terms of energy and the climate, promoting the emergence of a sustainable energy mix, and creating wealth and jobs by supporting French and European economic activity, and the competitiveness of related industrial sectors.

www.principia.fr
deeplines@principia.fr

France (Head Office)
PRINCIPIA SAS
Zone Athelia 1
215 voie Ariane
13705 La Ciotat Cedex
Tel. +33 4 2 981 180
Fax. +33 442 981 189

France
PRINCIPIA SAS
Technocampus Océan
5 rue de L'Halbrane
44340 Bouguenais
Tel.+33 2 40 14 50 14
Fax. +33 240 143 400

Denmark
PRINCIPIA North A/S
Gronlandsvej 10
DK-5700 Svendborg
Denmark
Tel. +45 72 301 855

Malaysia
PRINCIPIA ASIA Sdn Bhd
Level 32
Menara Binjai No. 2 Jalan Binjai
50450 Kuala Lumpur, Malaysia
Tel. +60 321 660 400