PRINCIPIA	Principia Project No.	G214021005
	Contract Reference:	
	Client Document No.	
	Client Document Rev:	
	Principia Document No.	DSL.204.013
	Principia Document Rev:	01

Project:

DeepLines WIND

Document Title :

DEEPLINES WIND

FEATURES FOR WINDTURBINES DESCRIPTION FROM VERSION 5.6

Document Type: Integration Tests Report **Pages:** 46

Rev.	Status	Date	Purpose of Issue	Issued by	Checked by	Approved by
01	IFR	21-01-21	Issued For Review	JMH	VHN/CLC	JMH
02	IFR	12-02-21	Issued for Review	JMH	VHN/CLC	JMH

Confidentiality Category: NC ☐ CD ☐ CI ☐ DR ☐

REVISION RECORD SHEET

Rev.	Status	Date	List of Updated / Modified Sections (if any) (1)(2)
02	IFR	12-02-21	Issued For Review
01	IFR	21-01-21	Issued For Review

Notes: (1) All changes made in this document revision (as applicable) have been highlighted with a vertical black line in the document margin, next to the modified text.
(2) Answers to comments on the previous revisions (as applicable) are presented in Attachment HOLD.

HOLDS LIST

No.	Section	Description	Status (1)

Notes: (1) This document shall be re-issued once all HOLDs have been closed out.

This document was prepared by:

PRINCIPIA S.A.S
215, Voie Ariane
ZAC Athelia 1
13705 La Ciotat, France
T: +33 (0)4.42.98.11.80
F: +33 (0)4.42.98.11.89
W: www.principia.fr
E: commercial@principia.fr

ISO 9001:2015 BUREAU VERITAS Certification

TABLE OF CONTENTS

1 INTRODUCTION 6

2 HAWT DEFINITION PANEL 7

3 HAWT DEFINITION PANEL 9

3.1 HAWT folder 9

3.2 Sub-Tab: “blades” 10

3.2.1 Public Blades 10

3.2.2 Encrypted Blades 15

3.3 Aerodynamic profiles 18

3.4 TSub-Tab: Tower 20

3.5 Sub-Tab Nacelle 24

3.6 New Translation Process 25

3.6.1 Public blades HAWT 25

3.6.2 Encrypted blades HAWT 27

3.7 Windturbines Properties 28

3.7.1 Wind turbines options libraries 28

3.7.2 Control MODES libraries 29

3.7.3 Control DLL OPTIONS Libraries 30

3.8 Aero solver Options Libraries 35

3.9 Two Turbines and more 37

4 ENVIRONMENT SETS FOR HAWTS 39

4.1 Objective 39

4.2 Variations tables 40

4.3 Turbine Start-up 42

4.3.1 Individual loading 42

4.3.2 Start-Up in a EnvironmentSet 44

4.4 FF-Wind definition 45

4.4.1 Individual FF-wind 45

4.4.2 FF-Winds in an EnvironmentSet 46

LIST OF FIGURES

Figure 2-1 : Example of Wind turbine in DeepLines Wind 7
Figure 2-2 : Actual definition panel for HAWT 8
Figure 3-1 : Selection of one blade of a HAWT 9
Figure 3-2 : Shaft nodes and Nacelle reference node 9
Figure 3-3 : Blades definition panel – Public mode..... 10
Figure 3-4 : Blades properties as generic lines 12
Figure 3-5 : Associated aerodynamic properties 13
Figure 3-6 : Public Blades representation by DeepLines Wind GUI..... 14
Figure 3-7 : Encryption procedure..... 15
Figure 3-8 : Example of encrypted blade file 15
Figure 3-9 : Blades definition panel – encrypted mode..... 16
Figure 3-10 : Encrypted file loading message 17
Figure 3-11 : Encrypted Blades representation by DeepLines Wind GUI 17
Figure 3-12 : Panel to enter the Foils profiles properties 18
Figure 3-13 : Foils profiles properties..... 19
Figure 3-14 : New Tower panel – Option “conical” 20
Figure 3-15 : New Tower panel – Option “User defined” 21
Figure 3-16 : Tower properties folder 22
Figure 3-17 : New Tower panel with an External Tower object..... 23
Figure 3-18 : Nacelle new panel..... 24
Figure 3-19 : Example of HAWT.JSON file..... 25
Figure 3-20 : Example of HAWT_Blade.JSON file..... 26
Figure 3-21 : Control DLL options panel..... 28
Figure 3-22 : New Control mode panel..... 29
Figure 3-23 : HAWT object default control 29
Figure 3-24 : New Control DLL option panel – Default Option..... 31
Figure 3-25 : New Control DLL option panel 32
Figure 3-26 : Variation table for constant data exchange 33
Figure 3-27 : Writing of exchanged data 33
Figure 3-28 : Exchanged data definition..... 34
Figure 3-29 : New panel for aero solver options..... 35
Figure 3-30 : Generation of a XML file for aero solver options..... 36
Figure 3-31 : Default aero solver option 36
Figure 3-32 : Two turbines model..... 37
Figure 3-33 : Aerodynamic option for two turbines 37
Figure 3-34 : Aerodynamic loads for two turbines 38
Figure 3-35 : Updated aerodynamic option for two turbines 38
Figure 4-1 : New Environment Set panel..... 39
Figure 4-2 : Example of turbine options in an EnvironmentSet..... 40
Figure 4-3 : Variation and Env. Tables..... 41
Figure 4-4 : Example of variation table for ramp up to 20rpm in 100s..... 41
Figure 4-5 : Env. Table associated with the StartUp..... 42
Figure 4-6 : Selection of a displacement loading type “Control”..... 43
Figure 4-7 : Sub-loading “Start-up” selection..... 43
Figure 4-8 : Example of turbine “Start-up” definition..... 44
Figure 4-9 : FF-WIND new definition panel 45
Figure 4-10 : FF-WIND definition in an EnvironmentSet..... 46

LIST OF TABLES

Table 3-1 –Total Blades input data 11

1 INTRODUCTION

Following client's comments and the use of DeepLines Wind in several projects, general improvements are implemented in version V5R6 to help setting up wind turbines analyses with different set of parameters based on the same base model. In addition, for confidentiality reasons, from the version V5R6 Deeplines offers the possibility to use encrypted blades files.

This document presents the improvements introduced into DeepLines Wind V5R6 concerning the analysis of Wind turbines:

1. Improvement of the HAWT panel.
    a. HAWT folder: It is now possible to select some components of a HAWT to define a specific analysis.
    b. Sub-tab "Geometry": Control and aerodynamic sub-tabs are now considered as external loadings to avoid duplicating the same turbine model just, for instance, to switch from a production to an idle condition;
    c. Sub-tab "Blades":
        - ✓A new line type named "GENERIC" has been recently developed. This type is now used for the blades properties instead of the flexible type;
        - ✓The aerodynamic profiles can now be defined as libraries and directly defined in the GUI;
        - ✓Previous XML airfoils files are now only used to ensure compatibility with previous versions since airfoils files are now generated by the GUI in a JSON format for a public blades otherwise an encrypted file can be used;
    d. Sub-tab "Tower": towers of different shapes may be defined and the translation for the aero solver is now automatic;
    e. Sub-tab "Nacelle": the vertical drag coefficient can be defined.

b. Environment Sets geared to the wind turbines.
    a. Access to specific options has been made easier: turbine Start-up, wind ramp time.
    b. Control modes as libraries;
    c. Control options as libraries;
    d. Aero solver Options as libraries;
    e. Environment Set Combination including turbines.

2 HAWT DEFINITION PANEL

When a turbine is defined in DeepLines Wind, a specific icon is used as shown on Figure 2-1. Clicking on this icon induces the following process:

- A generic definition panel for a HAWT is open (see Figure 2-1);
- A folder is created in the model browser as shown below:

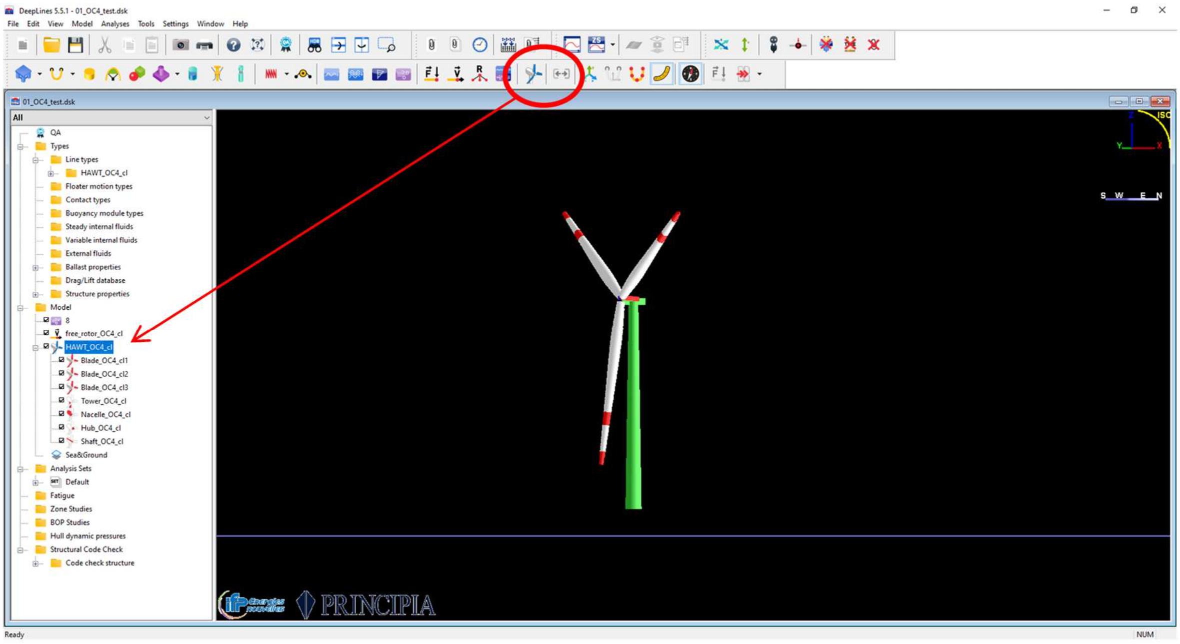


Figure 2-1 : Example of Wind turbine in DeepLines Wind

The definition panel is a user friendly shortcut to define all components of a Wind turbine. A sub-tab is associated with every component.

- ✓ Sub-Tab1: turbine general geometry,
- ✓ Sub-Tab2: components “blades”,
- ✓ Sub-Tab3: component “tower”,
- ✓ Sub-Tab4: component “nacelle”,
- ✓ Sub-Tab5: component “hub”,
- ✓ Sub-Tab6: component “power train”,
- ✓ Sub-Tab7: component “Control command”,
- ✓ Sub-Tab8: component “aerodynamic solver”.

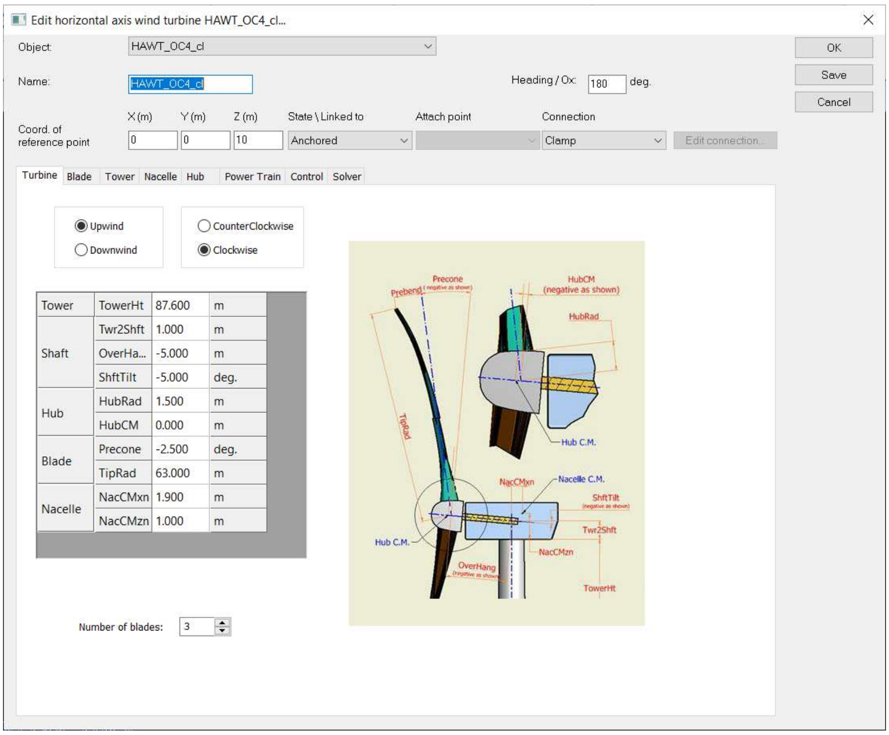


Figure 2-2 : Actual definition panel for HAWT

3 HAWT DEFINITION PANEL

3.1 HAWT FOLDER

It is now possible to introduce in an analysis only a selection of a HAWT's components. Figure 3-1 shows for instance the selection of one blade of a HAWT.

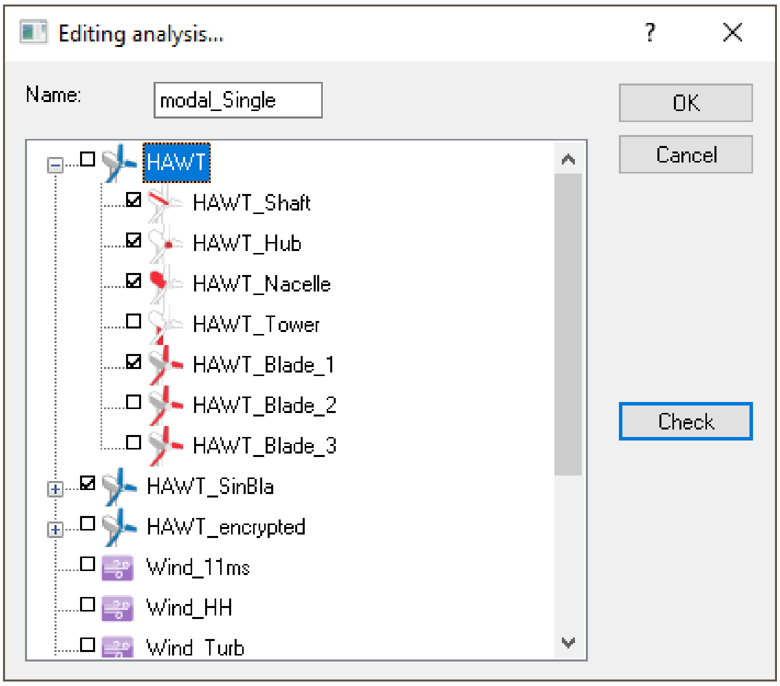


Figure 3-1 : Selection of one blade of a HAWT

For consistency of the resulting system, by default, the Shaft, the hub and the Nacelle are automatically selected.

To extract for instance the natural modes of a blade without any coupling, it is then necessary to block the Nacelle reference node and the shaft nodes with a dedicated loading (Dis/connection type) as such:

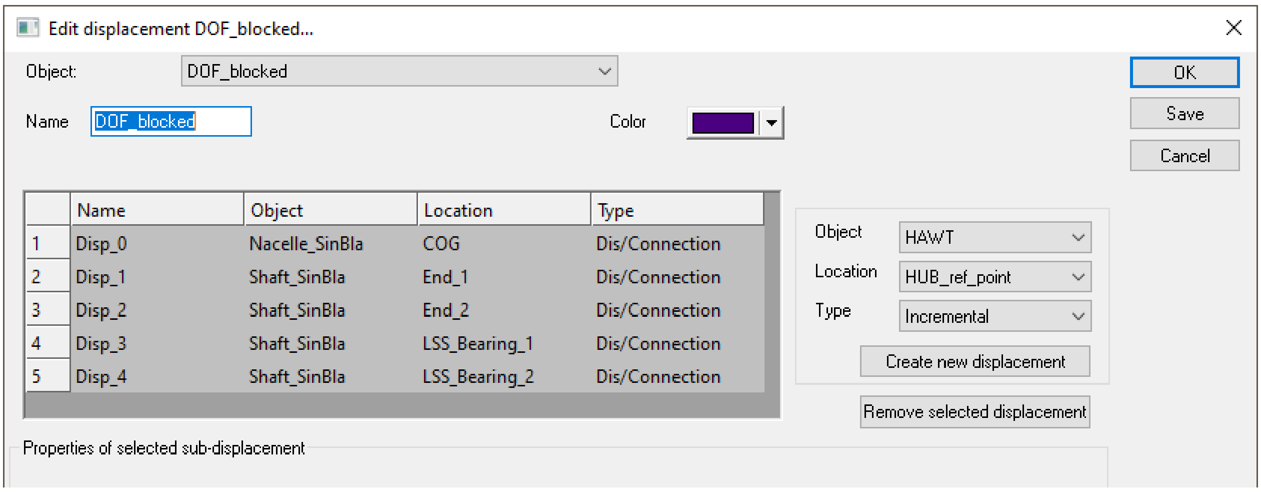


Figure 3-2 : Shaft nodes and Nacelle reference node

3.2 SUB-TAB: "BLADES"

3.2.1 Public Blades

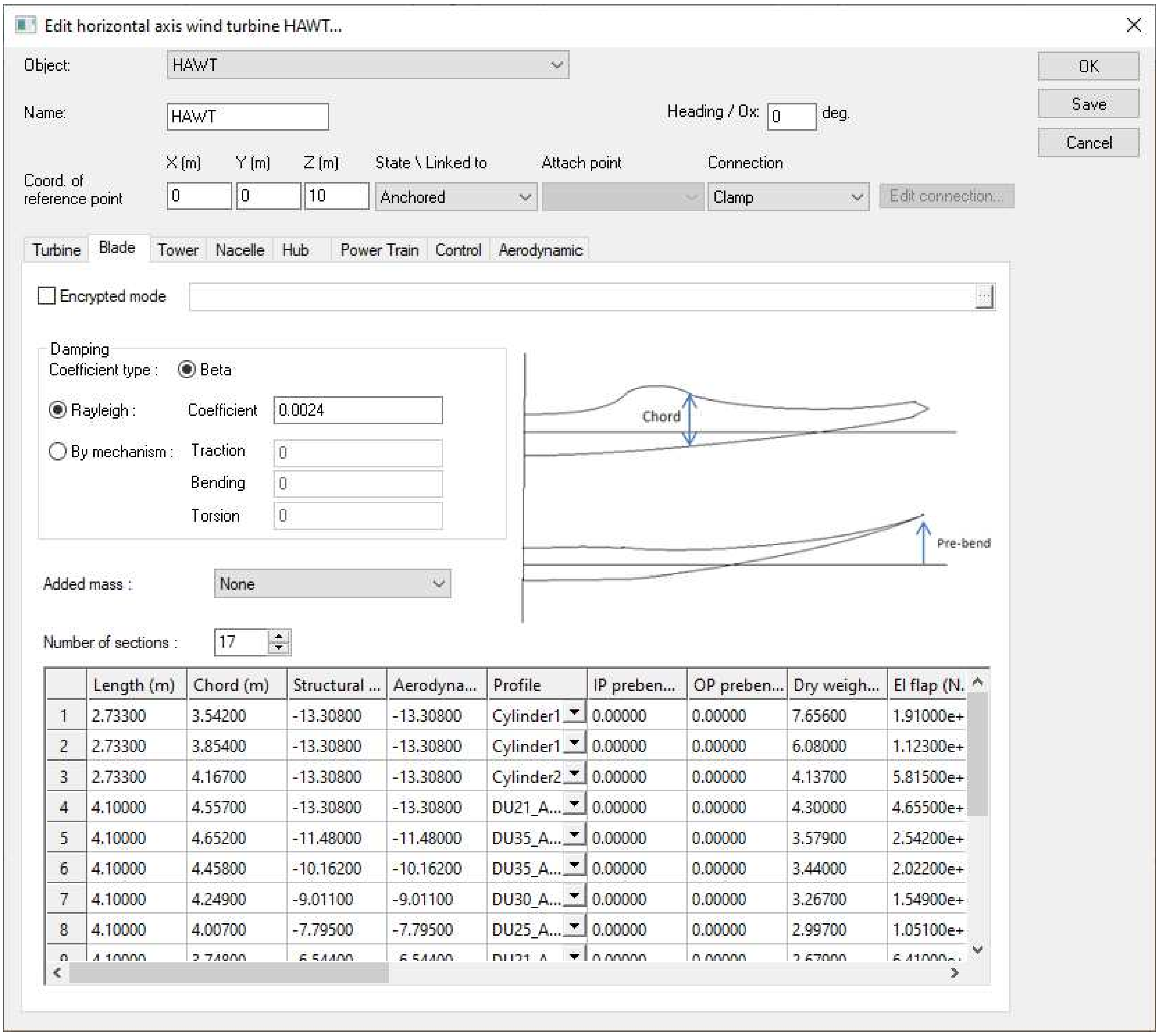


Figure 3-3 : Blades definition panel – Public mode

In DeepLines Wind V5R6, blades are modelled as series of beam finite elements with "GENERIC" type properties.

This type allows introducing new data and gathers all the input data that can now be introduced to define a blade.

Input Data for every Blade	
Number of sections	
Damping coefficients (Rayleigh coefficients)	
For every blade section	
	Section Length (m)
	Chord (m)
	Structural twist (deg)
	Aerodynamic pitch (deg)
	Profile name
	IP&OP prebend (m)
	Dry weight (kN/m)
	Flap & Edge bending stiffness (N.m^2)
	Torsion stiffness (N.m^2)
	Axial stiffness (N)
	Inertia flap and edge (kg.m)
	Torsional inertia (kg.m)
	Aero centre (X, Y) coordinates in the section (m)
	Centre of gravity (X, Y) coordinates in the section (m)
	Mass axis orientation (deg)
	Shear centre (X,Y) coordinates in the section (m)
	Flap & Edge Shear stiffness (N.m^2)

Table 3-1 –Total Blades input data

Figure 3-4 shows a blade property panel when a turbine is defined with the new GUI version.

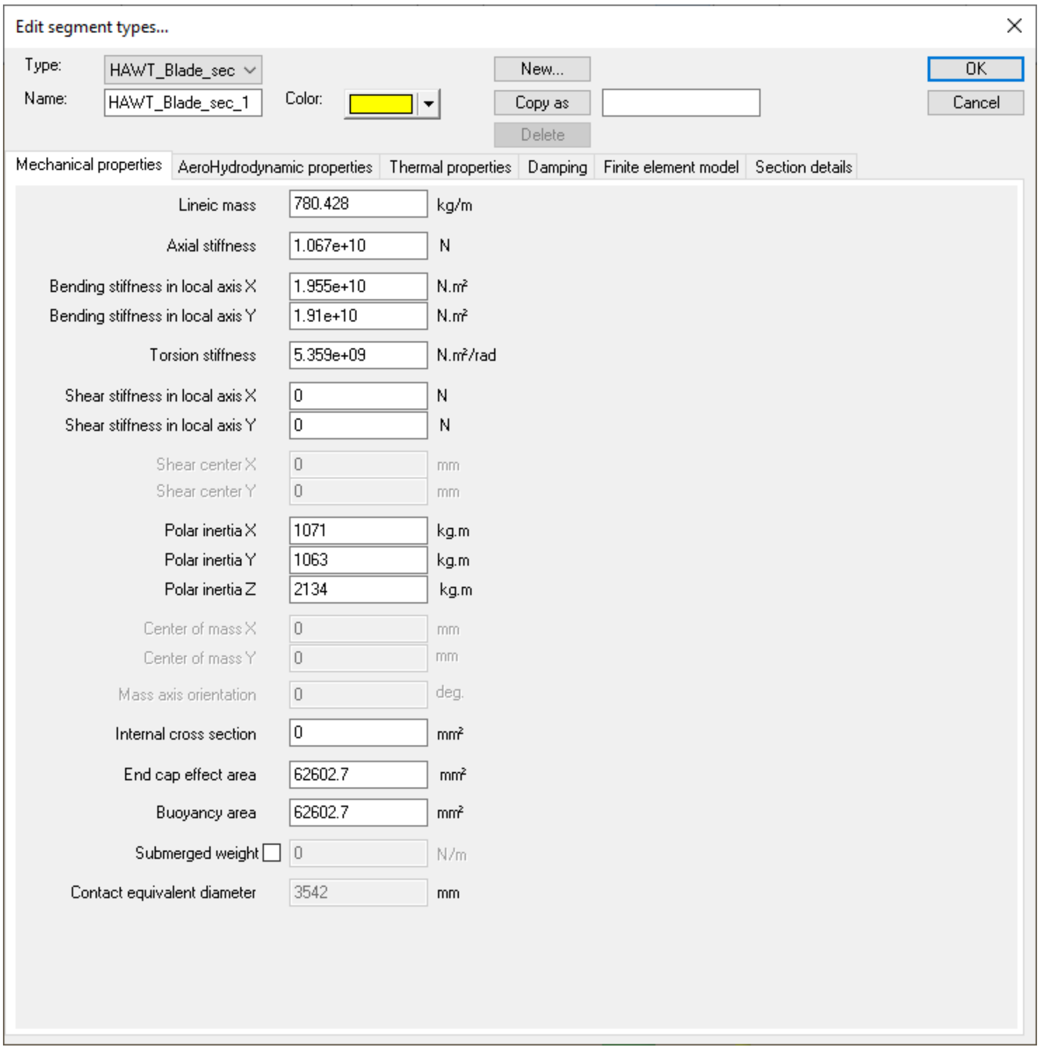


Figure 3-4 : Blades properties as generic lines

The Aero centre (X, Y) and the name of the profile shall be added in the Aero-hydrodynamic panel.

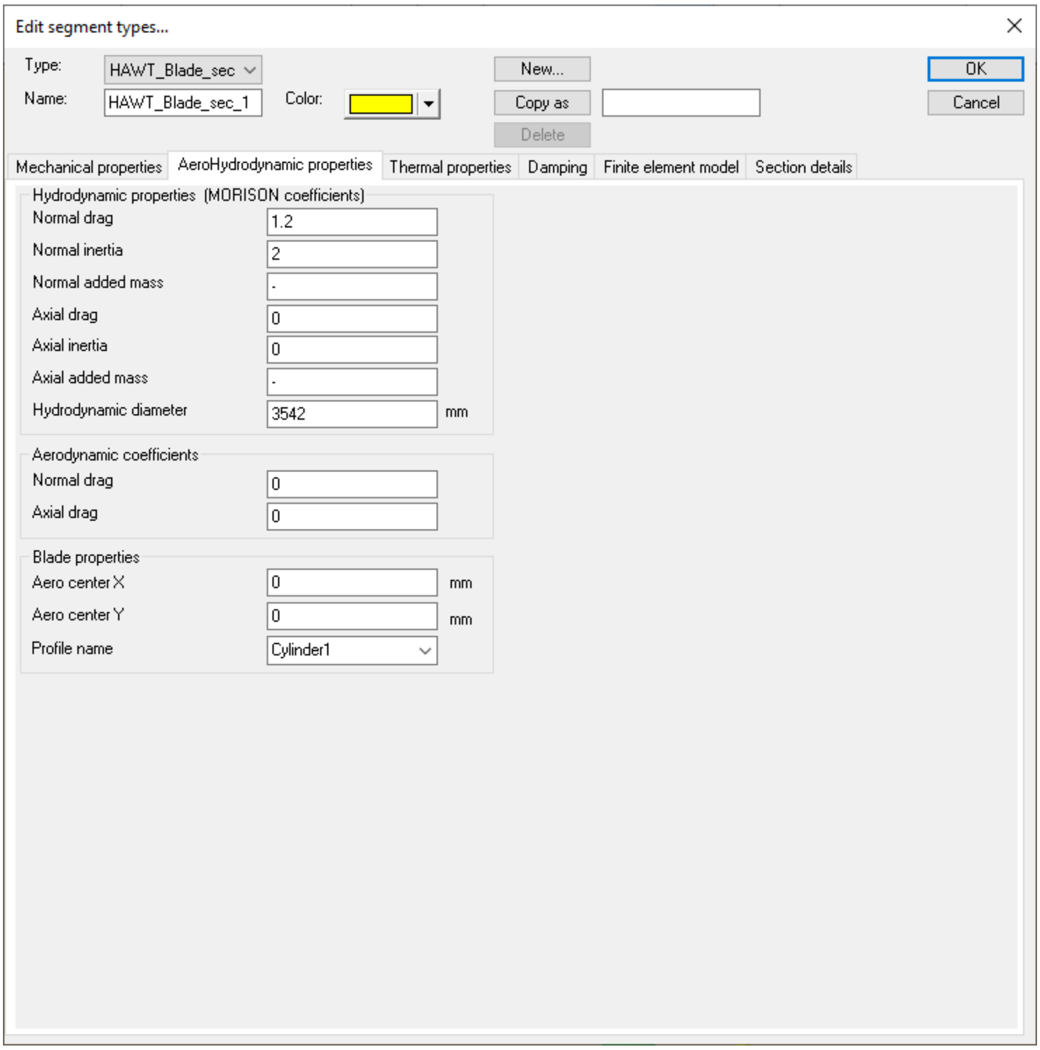


Figure 3-5 : Associated aerodynamic properties

Public blades are managed by the GUI and as a consequence, the mesh can be displayed and the chord variations can be visualized as shown below:

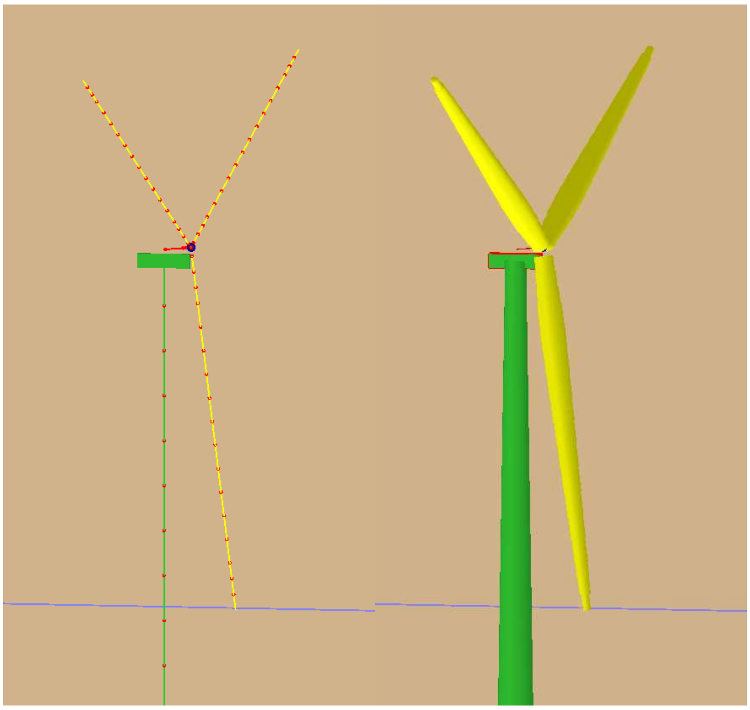


Figure 3-6 : Public Blades representation by DeepLines Wind GUI

As in previous versions, the dynamic vibrations of the blades will be visualized when looking at a dynamic simulation.

3.2.2 Encrypted Blades

For the encryption of blades files, the Botan library (https://botan.randombit.net/) has been selected, which is a very well-known and strong encryption library. Figure 3-7 illustrates the encryption procedure defined in accordance with two blades suppliers:

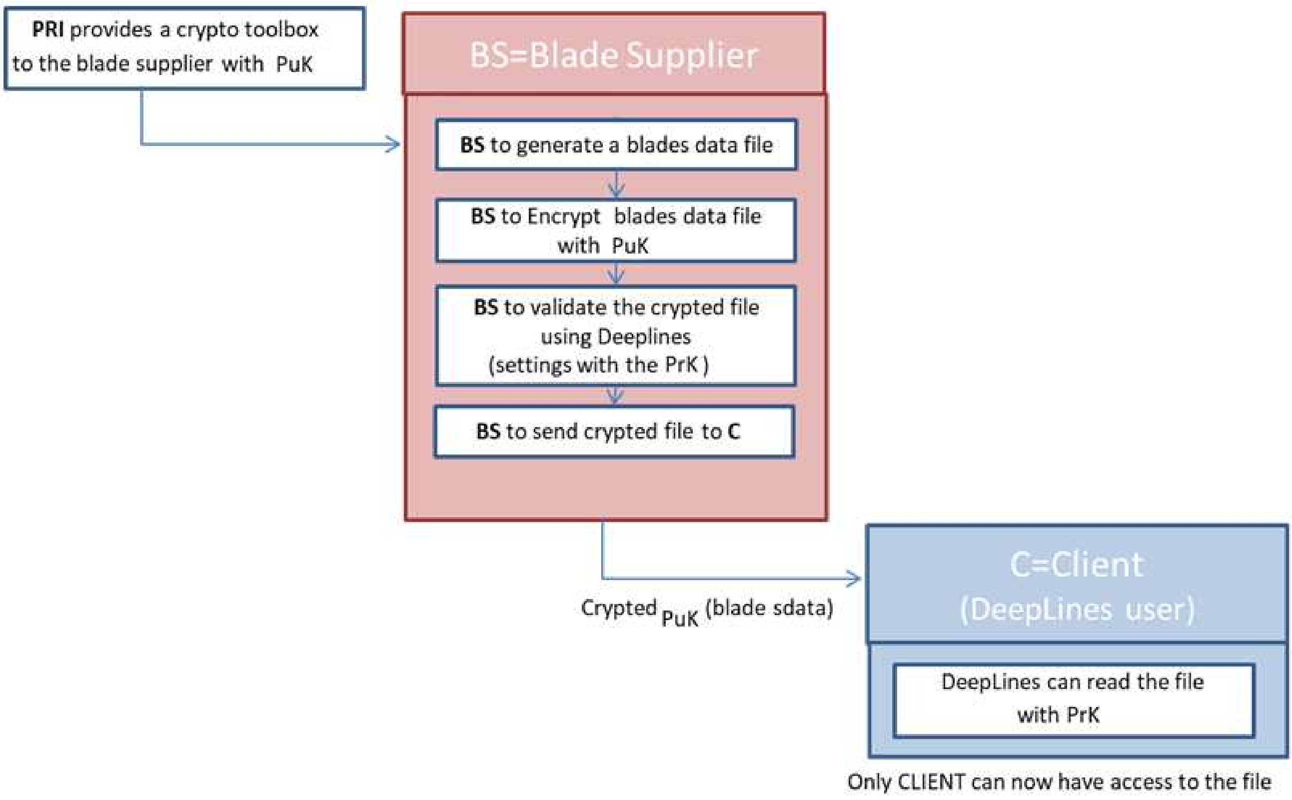
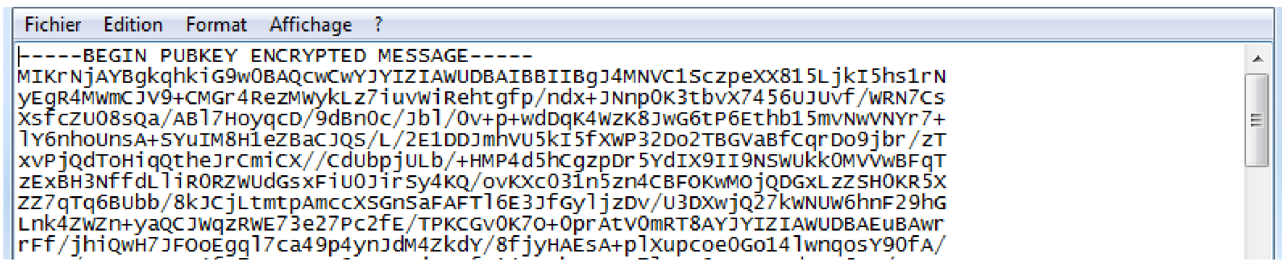


Figure 3-7 : Encryption procedure

Figure 3-3 shows an example of encrypted file.



-----BEGIN PUBKEY ENCRYPTED MESSAGE-----
MIKrNjAYBgkqhkiG9w0BAQcwCwYJYIZIAWUDBAIBBIIBgJ4MNVC1SczpeXX815LjkI5hs1rN
yEgR4MWmCJV9+CMGr4RezMWykLz7iuvWiRehtgfp/ndx+JNnp0K3tbvX7456UJUvf/WRN7Cs
XsfcZU08sQa/ABl7HoyqcD/9dBn0c/Jbl/0v+p+wdDqK4WzK8JwG6tP6Ethb15mvNwVNYr7+
lY6nhoUnsA+SYuIM8H1eZBaCJQS/L/2E1DDJmhVU5kI5fXWP32Do2TBGVaBfCqrDo9jbr/zT
xvPjQdToHiqQtheJrCmiCX//CdubpjULb/+HMP4d5hCgzpDr5YdIX9II9NSWUkk0MVVwBFqT
zExBH3NffdLliR0RZWUdGsxFiU0Jir5y4KQ/ovKXc031n5zn4CBFOKwMOjQDGxLzZSH0KR5X
ZZ7qTq6BUbb/8kJCjLtmtpAmccXSGnSaFAFTl6E3JfGyljzDv/U3DXwjQ27kWNUW6hnF29hG
Lnk4ZWZn+yaQCJWqzRWE73e27Pc2fE/TPKCGV0K7O+0prAtV0mRT8AYJYIZIAWUDBAEuBAwr
rFf/jhiQwH7JFOoEggl7ca49p4ynJdM4ZkdY/8fjyHAEsA+plXupcoe0Go14lwnqosY90fA/

Figure 3-8 : Example of encrypted blade file

Note that a limit date of validity may be defined into the encrypted file by the blades supplier.

This file shall be introduced in DeepLines Wind model as shown below:

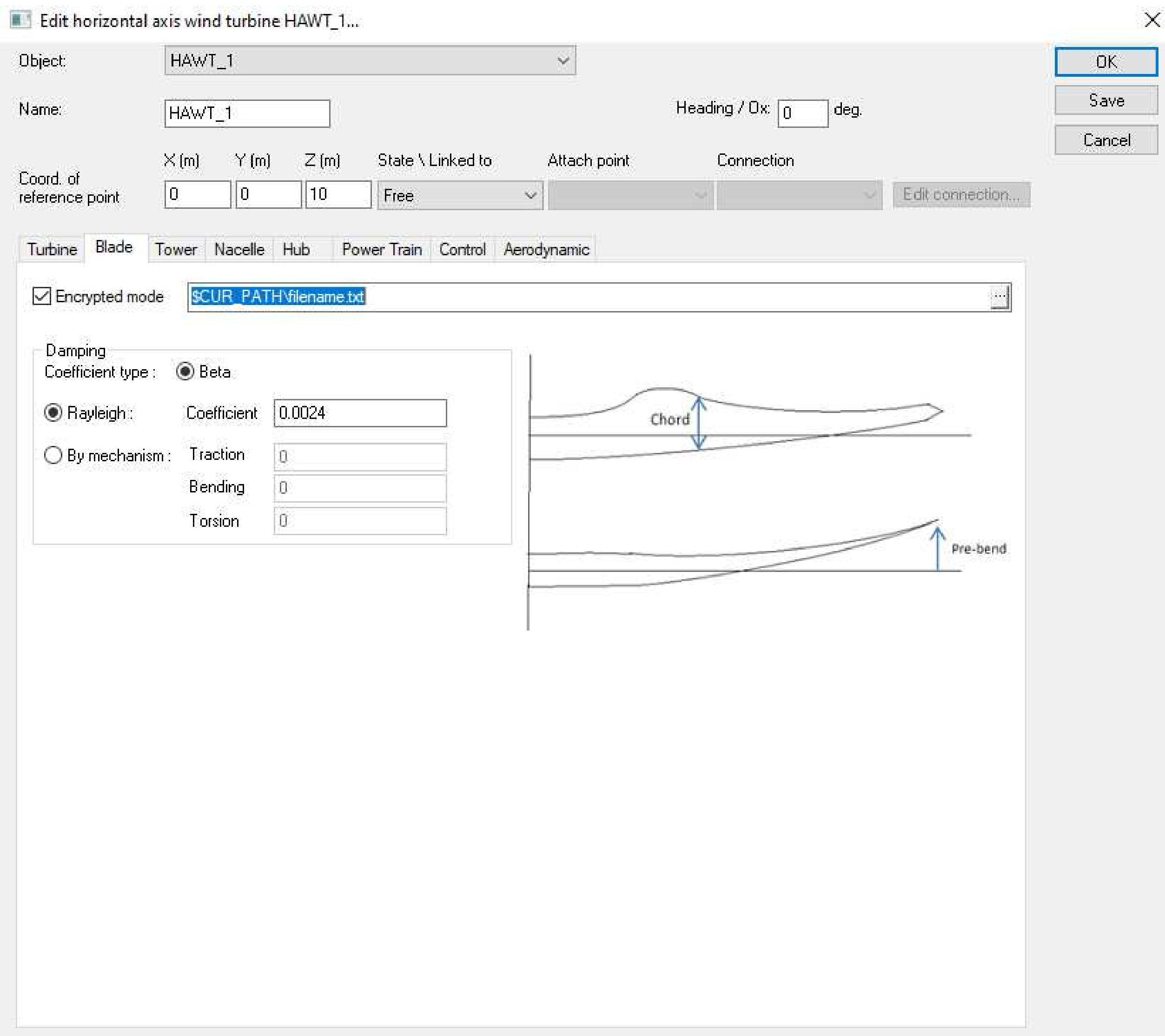


Figure 3-9 : Blades definition panel – encrypted mode

When the blades properties are correctly loaded, the following dialog box is displayed.

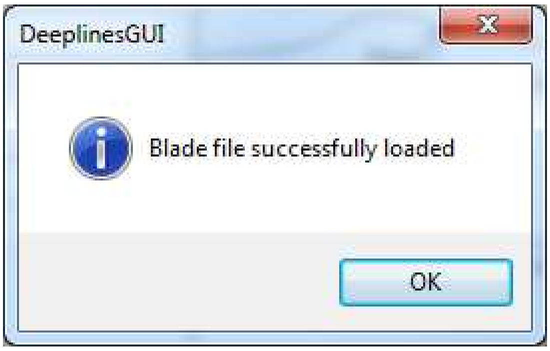


Figure 3-10 : Encrypted file loading message

In that case, the blade mesh is unknown and in Deeplines Wind GUI, every blade is simply represented by a line without any profile.

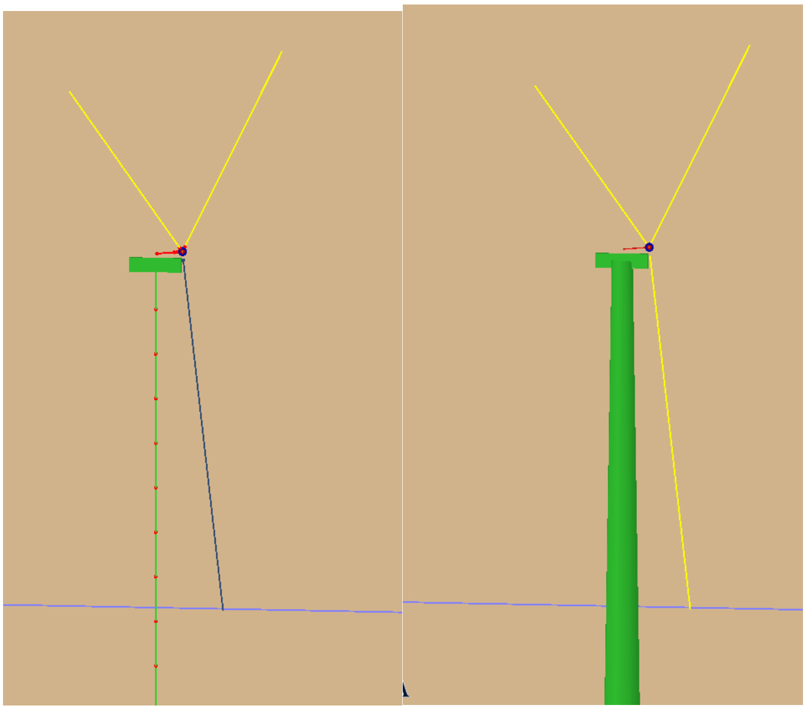


Figure 3-11 : Encrypted Blades representation by DeepLines Wind GUI

As a consequence, the blades will look like rigid blades when visualizing the dynamic animation even if the calculations actually account for their flexibility.

3.3 AERODYNAMIC PROFILES

In the model browser, a new type of drag/lift database named “New foil profile” has been created:

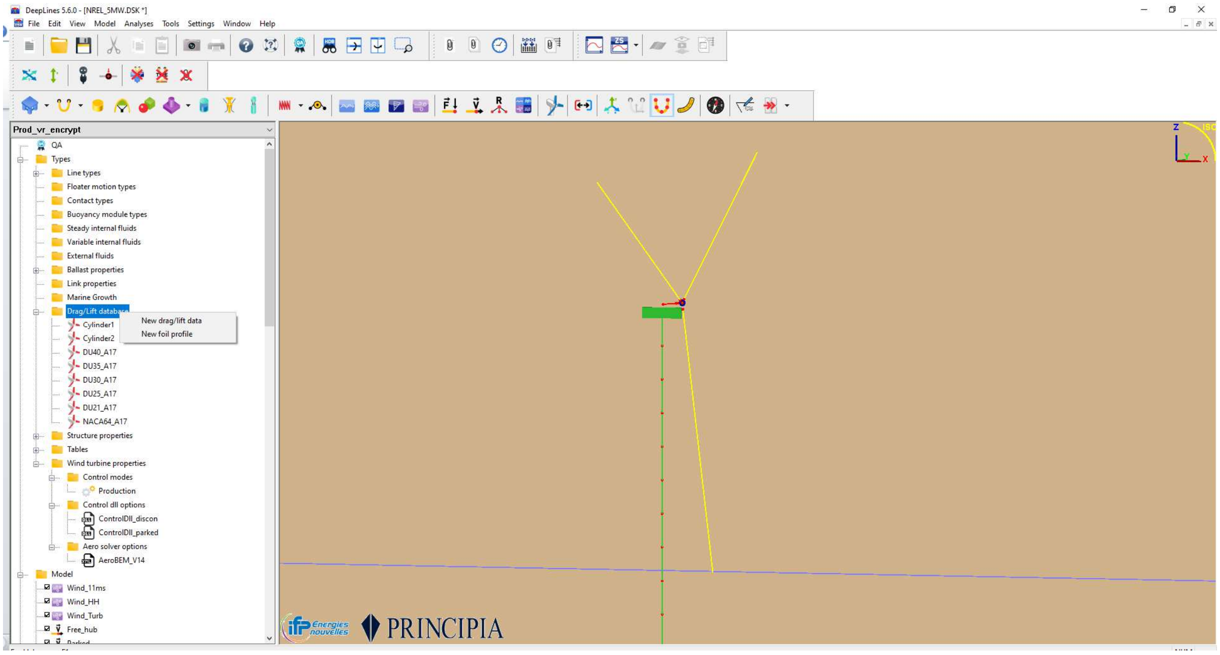
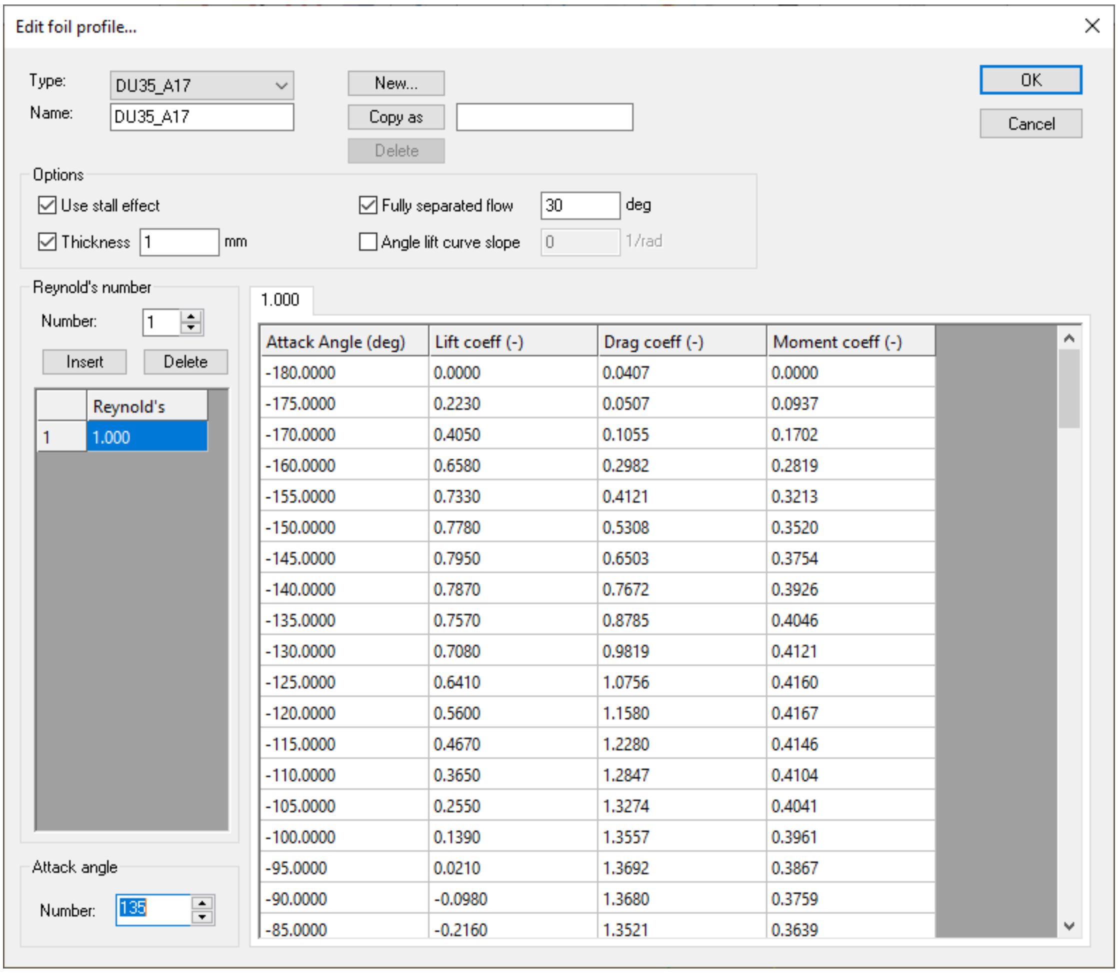


Figure 3-12 : Panel to enter the Foils profiles properties

This option allows defining airfoils properties as shown below:



Attack Angle (deg)	Lift coeff (-)	Drag coeff (-)	Moment coeff (-)
-180.0000	0.0000	0.0407	0.0000
-175.0000	0.2230	0.0507	0.0937
-170.0000	0.4050	0.1055	0.1702
-160.0000	0.6580	0.2982	0.2819
-155.0000	0.7330	0.4121	0.3213
-150.0000	0.7780	0.5308	0.3520
-145.0000	0.7950	0.6503	0.3754
-140.0000	0.7870	0.7672	0.3926
-135.0000	0.7570	0.8785	0.4046
-130.0000	0.7080	0.9819	0.4121
-125.0000	0.6410	1.0756	0.4160
-120.0000	0.5600	1.1580	0.4167
-115.0000	0.4670	1.2280	0.4146
-110.0000	0.3650	1.2847	0.4104
-105.0000	0.2550	1.3274	0.4041
-100.0000	0.1390	1.3557	0.3961
-95.0000	0.0210	1.3692	0.3867
-90.0000	-0.0980	1.3680	0.3759
-85.0000	-0.2160	1.3521	0.3639

Figure 3-13 : Foils profiles properties

Once defined, these profiles names can be selected in the blades panel (see Figure 3-6).

3.4 TSUB-TAB: TOWER

The new panel looks like as follows:

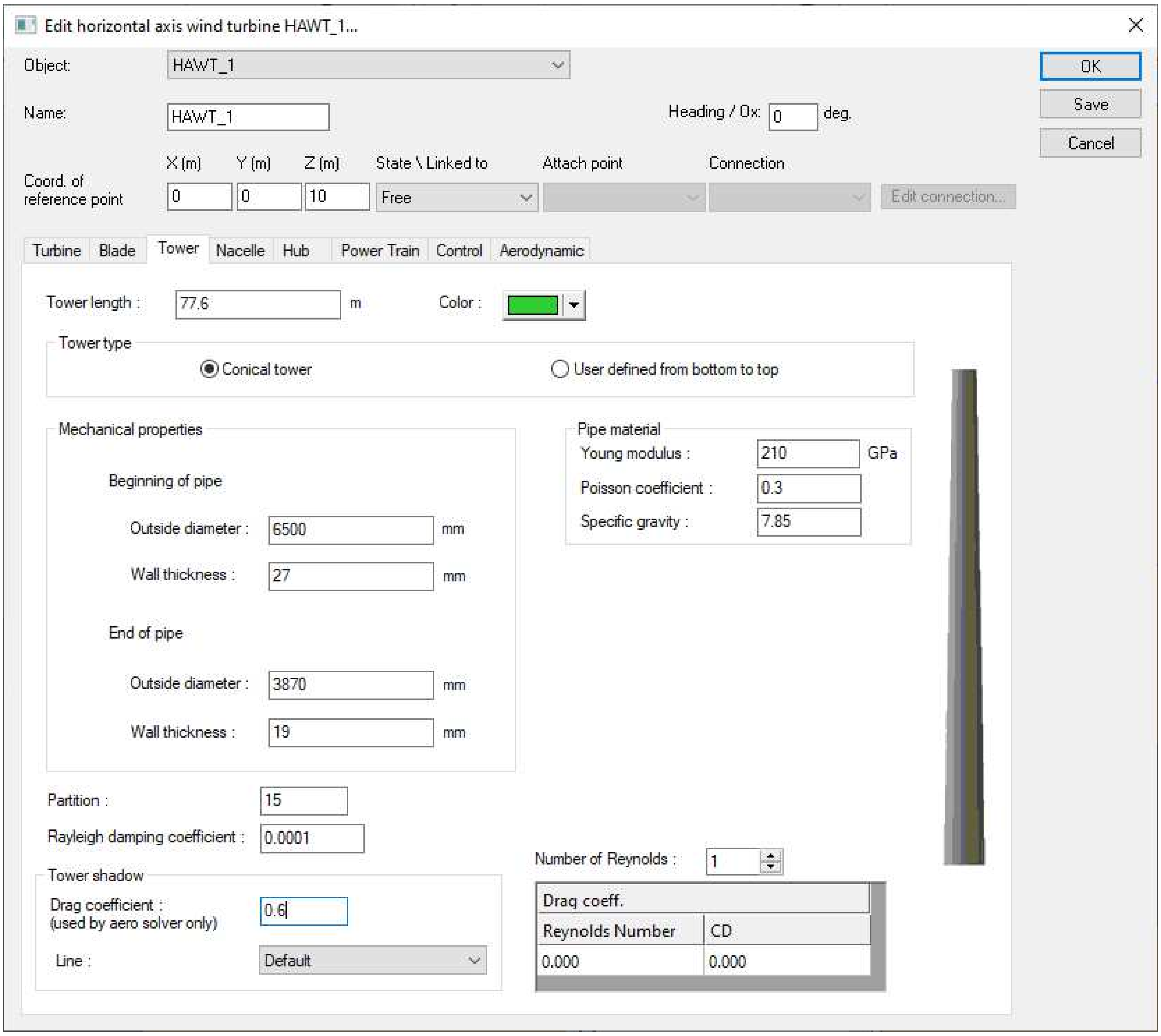


Figure 3-14 : New Tower panel – Option "conical"

In the new version, the following points have been modified:

- The option "user defined" tower has been improved to be close to a classical line definition with different types of properties as illustrated below.

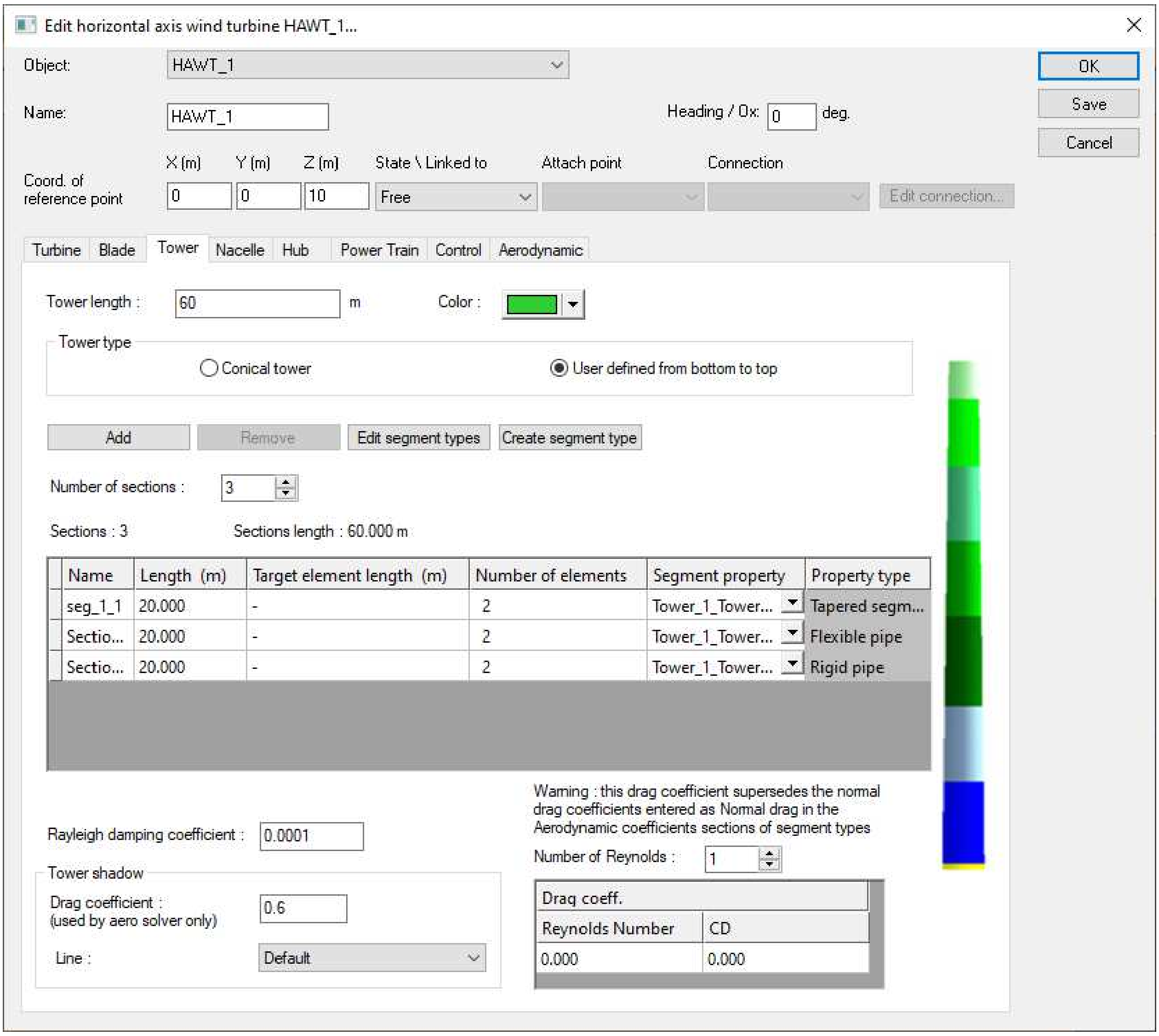


Figure 3-15 : New Tower panel – Option “User defined”

- To avoid confusion, these properties remain associated with a specific turbine and are stored in the “line type” folder associated with this turbine:

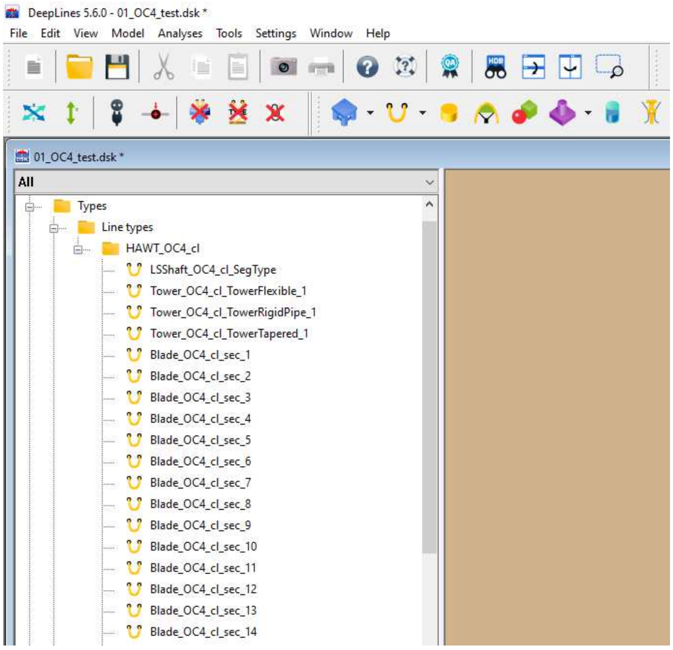


Figure 3-16 : Tower properties folder

- A global Rayleigh damping coefficient can be defined which is applied on all segments of a tower whatever their individual properties. This coefficient supersedes the coefficient that may be defined in a specific property.
- Nevertheless, in the definition panel of a HAWT, the tower component must be a vertical straight line defined from bottom to the top. For very specific tower concept, only a small top part of the tower (top flange) is to be defined in the HAWT panel and connected to the rest of the tower, defined as external object independent from HAWT panel.
- <u>Tower shadow:</u>

  The tower mesh, its outer diameters and drag coefficient will be automatically transferred to the aero-solver through the generation of a JSON file when any new analysis is run (see section 3.6 for details).

  This ensures the full consistency between the tower mechanical model used by DeepLines Wind solver and the computation of the tower shadow effect by the aero-solver.

  For specific cases when the tower is an object external to the HAWT panel, this line object must be selected as illustrated by Figure 3-17

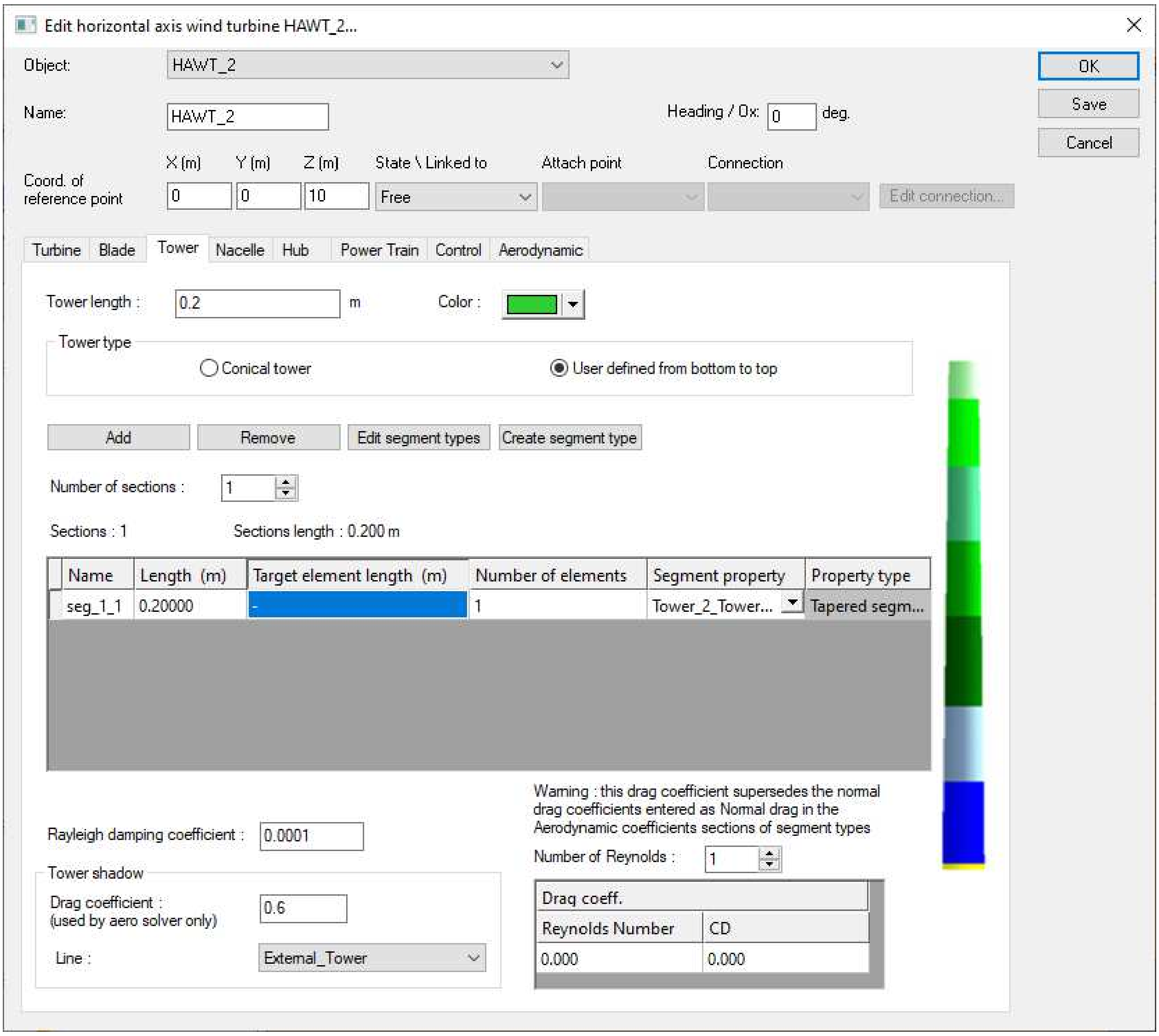


Figure 3-17 : New Tower panel with an External Tower object

3.5 SUB-TAB NACELLE

For the Nacelle, the drag coefficient in the vertical direction was missing. It can now be entered in the panel.

As shown below, the input value corresponds to Cd_vertical*Area; the area depends on the nacelle shape and is an input data for DeepLines Wind.

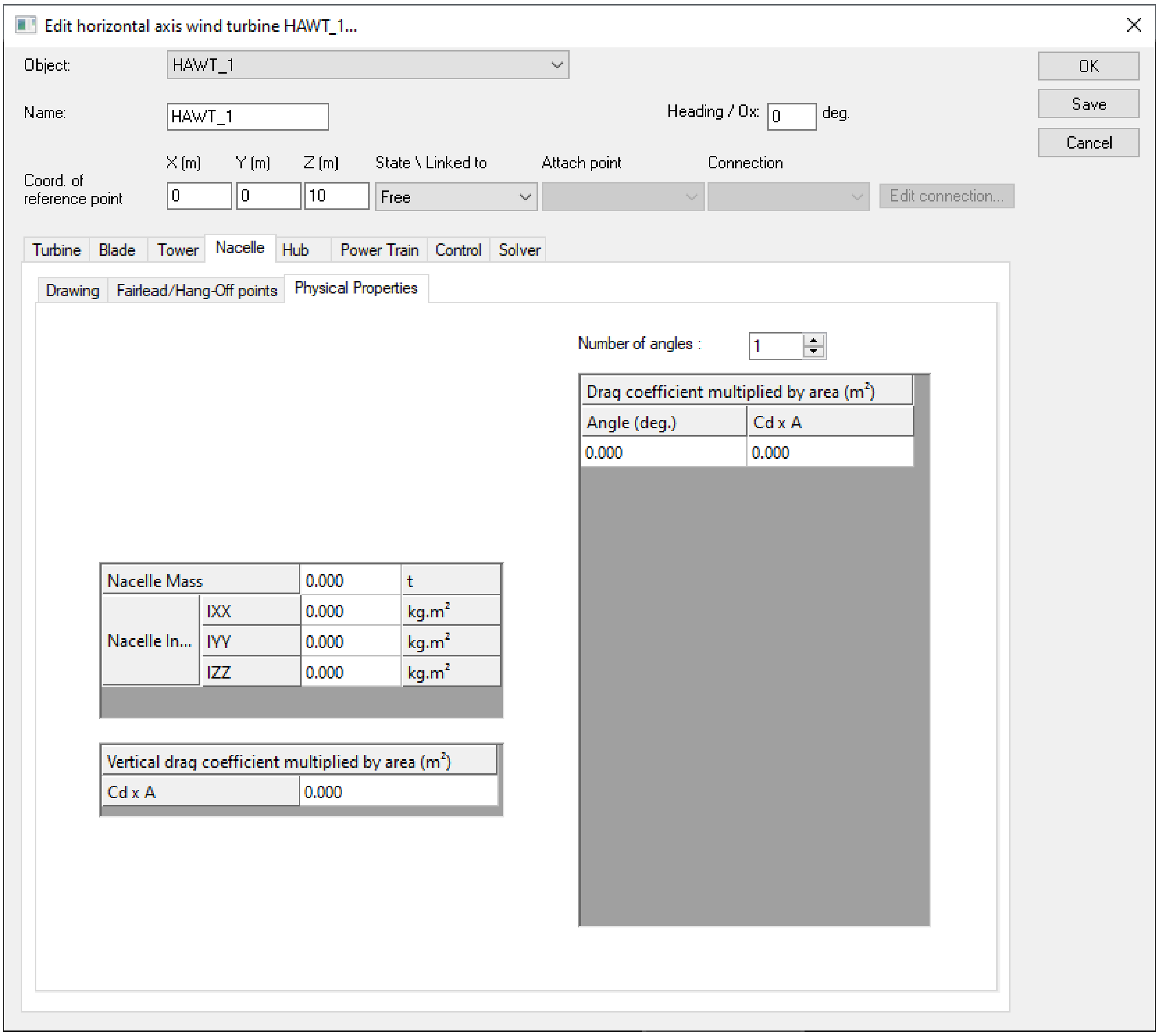


Figure 3-18 : Nacelle new panel

3.6 NEW TRANSLATION PROCESS

3.6.1 Public blades HAWT

Let's consider that a turbine, named ***HAWT_1***, is created in DeepLines Wind GUI. When an analysis is launched including this turbine, the following process is done:

- A specific repertory 00-AERO\ is created (for the first time);
- Two JSON files named ***HAWT_1.JSON*** and ***HAWT_1_Blade.JSON*** are translated into this directory;
- The translation of the LOG file is kept unchanged except keyword *AEROFILE:

```
*AEROFILES,NAME=HAWT_1
AeroFile=..\00-AERO\aeroBEM_V14.xml
ProfilFile=..\00-AERO\HAWT_1.json
```

- DeepLines Wind solver copies these files into the analysis directory;
- Computations can start.

Note:

- The same logic as for the HDB file is followed here when RAO data are entered through GUI. As a consequence, the JSON file in the 00-AERO\ repertory corresponds to the last definition of the turbine that may have changed. Therefore, the JSON files are copied by the solver into the working directory;
- ***HAWT_1.JSON*** contains data about the hub, the tower and the nacelle:

```
{
    "DEEPLINES": "DeepLinesGUI Application 5.6.0.0",
    "WINDFARM": {
        "ROTOR": {
            "name": "HAWT",
            "Hub": [
                {
            ],
            "Tower": [
                {
                    "center (m)": "3.8799999999999999",
                    "radius (m)": "3.25",
                    "drag (-)": "0"
                },
                {
                {
                {
                {
                {
                {
                {
                {
                {
            ],
            "Nacelle": [
                {
                    "center (m)": "0",
                    "radius (m)": "0",
                    "drag (-)": "0"
                }
            ]
        }
    }
}
```

Figure 3-19 : Example of HAWT.JSON file

- ***HAWT_1_Blade.JSON*** gathers the blade mechanical and aerodynamic data:


```
{
    "DEEPLINES": "DeepLinesGUI Application 5.6.0.0",
    "LimitDate(DD-MM-YYYY)": "",
    "WINDFARM": {
        "ROTOR": {
            "name": "HAWT",
            "BladePart": {
                "Blade": {
                    "Mesh": [
                        {
                            "length (m)": "2.7330000000000001",
                            "chord (m)": "3.5419999999999998",
                            "Str-twist (deg.)": "-13.308",
                            "Aero-pitch (deg.)": "-13.308",
                            "Mass-orien (deg.)": "0",
                            "profile": "Cylinder1",
                            "IPprebend (m)": "0",
                            "OPprebend (m)": "0",
                            "Dryweight (kN/m)": "7.6559999999999997",
                            "FlapBending Stif. (N.m2)": "19100000000",
                            "EdgeBending Stif. (N.m2)": "19550000000",
                            "Torsion Stif. (N.m2)": "5359000000",
                            "Axial Stif. (N)": "10670000000",
                            "FlapShear Stif. (N)": "0",
                            "EdgeShear Stif. (N)": "0",
                            "Bend-Tors Stif. (N.m2)": "0",
                            "FlapInertia (kg.m)": "1071",
                            "EdgeInertia (kg.m)": "1063",
                            "TorsInertia (kg.m)": "2134",
                            "AeroCenterx (m)": "0",
                            "AeroCentery (m)": "0",
                            "COGx (m)": "0",
                            "COGy (m)": "0",
                            "ShearCenterx (m)": "0",
                            "ShearCentery (m)": "0",
                            "YoungModulus (GPa)": "210000000000",
                            "PoissonCoef (-)": "0.0001",
                            "SpecGravity (-)": "7.8499999999999996"
                        },
                        {
```


...


```
                        {
                        {
                        {
                    ]
                },
                "Airfoils": [
                    {
                        "Name": "Cylinder1",
                        "thickness": "",
                        "use_Stall": "No",
                        "separated_flow_aoa": "",
                        "lift_slope": "",
                        "Profiles": [
                            {
                                "angle": "-180",
                                "reynolds": "1",
                                "lift": "0",
                                "drag": "0.5",
                                "moment": "0"
                            },
                            {
                            {
                        ]
                    },
                    {
                    {
                    {
                    {
                    {
                    {
                ]
            }
        }
    }
}
```


Figure 3-20 : Example of HAWT_Blade.JSON file

- With version V5R6, the XML airfoils files are not used any longer unless an old model is used;
- On the contrary, the XML file defining the aerodynamic options is unchanged (see section 3.8 for details).

3.6.2 Encrypted blades HAWT

For an encrypted blades turbine, the process is as such:

- A specific repertory 00-AERO\ is created (for the first time);
- The same file HAWT_1.JSON is generated as well as a file named HAWT_1_Blade.txt, which is a copy of the external file referred to in the blade panel;
- The translation of the LOG file greatly changed:
  - Blades are defined with two nodes; the blade root node connected to the hub and an end node rigidly linked to the hub. This end node is located using TipRad, Precone and Prebend defined in Figure 2-2.

```
C -- Begin Blade(s) :
C -- Begin line : Blade_encrypted1
*NODES
90 000000 5.111707 0.000000 88.501487
91 000000 12.147623 1.000000 27.397101
*BLADE,NAME=Blade_encrypted1,type=ENCRYPTED
8 90 0.0024 0 0 0
C
C -- Connections
C -- <Blade_encrypted1::End_1> is connected to <Hub_encrypted:Blade hang-off 0> with a clamp
```

  - keyword *AEROFILE:

```
*AEROFILES,NAME=HAWT_encrypted,type=ENCRYPTED
AeroFile=..\00-AERO\aeroBEM_V14.xml
ProfilFile=..\00-AERO\HAWT_encrypted.json
```

- DeepLines Wind solver copies these files into the analysis directory;
- Computations can start.

Note:

- The blades nodes are invisible in the LOG file and no specific results may be post-processed on the blades except on the blades root node.

3.7 WINDTURBINES PROPERTIES

3.7.1 Wind turbines options libraries

The control mode, the DLL used to control a turbine as well as numerical options for the aero solver are equivalent to motions types for the floaters. In V5R6, a specific folder has been created in the GUI that allows defining three types of libraries:

- Control modes,
- Control DLL options,
- Aero solver options.

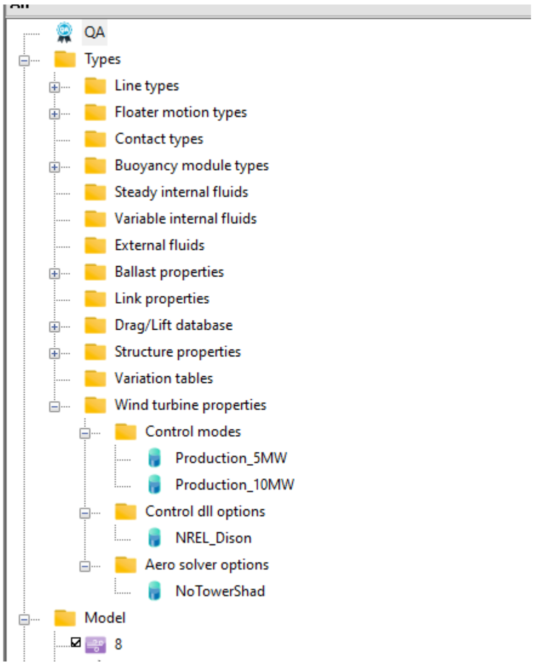


Figure 3-21 : Control DLL options panel

Once created, these options may be directly selected when a new HAWT is created but they can also be defined in an EnviromentalSet to define different analyses with different options for the same HAWT object.

3.7.2 Control MODES libraries

The control mode allows defining the control on the Generator and the blades pitch as well as the main parameters of the control.

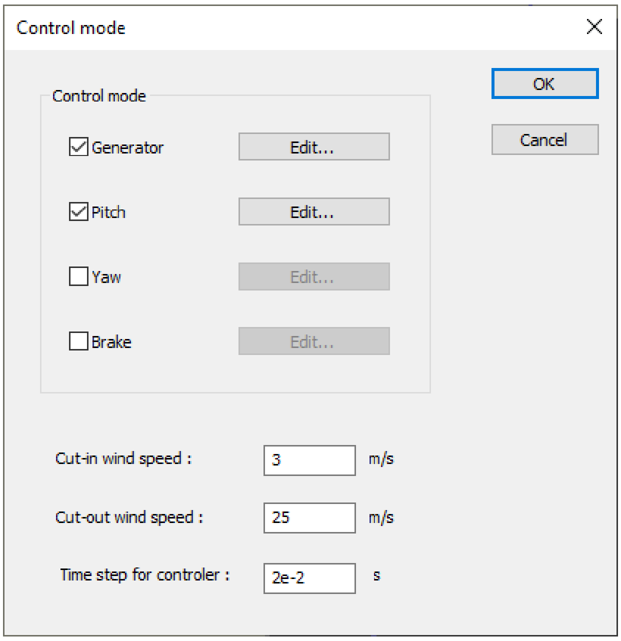


Figure 3-22 : New Control mode panel

When a HAWT is created, by default no control mode is defined.

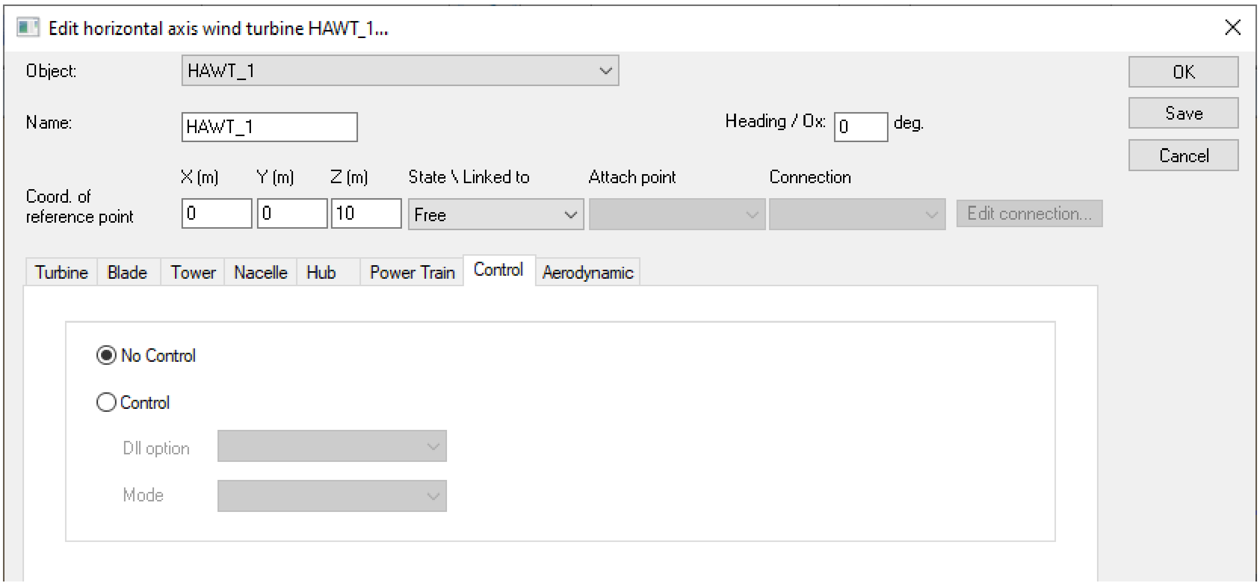


Figure 3-23 : HAWT object default control

As already mentioned, specific control options may be associated with each turbine or redefined in an EnvironmentSet.

3.7.3 Control DLL OPTIONS Libraries

The control DLL options define the exchanges of data between the controller and DeepLines Wind solver. These options are translated in the LOG file with the keywords *WTCONTROL and *WTOPCONT, file=

Data exchanges are all based on the same format referred as “Bladed API”. Nevertheless, experience shows that every control DLL usually created by a third party may have some specificity:

- The DLL may require specific input data files in which parameters are defined which correspond to a specific state of the turbine and specific Load Cases;
- The data exchange may be performed in a specific reference frame: most of the time, the reference frame is defined by the mean wind direction, but some controllers are using the nacelle or the rotor frames;
- In addition, the Bladed API allows introducing “reserved data” and these data may be different for every controller.

In version V5R6, a library of DLL options has been created which allows defining:

- A list of input files required by the DLL; these files will be copied by the solver in the Analysis directory;
- The main coordinate system used to define the input data exchanged with the DLL. This can be relative to the Wind mean direction, the Nacelle orientation or the rotor local frame.
- At last, series of data can be defined in the same way as post-processing requests. Each data is defined by a name, a location in the model, eventually a specific correction factor to cope with the units system used by the DLL and the channel number of the Bladed API.

The variable name corresponds to the internal name used by DeepLines Wind to define an output result. To make the definition easier, it is possible to first create a “fake” Batch post processing file in which the variable is requested and to load this Batch file.

<u>Default Option: No specific data exchange</u>

Figure 3-24 presents the simplest form of the definition panel.

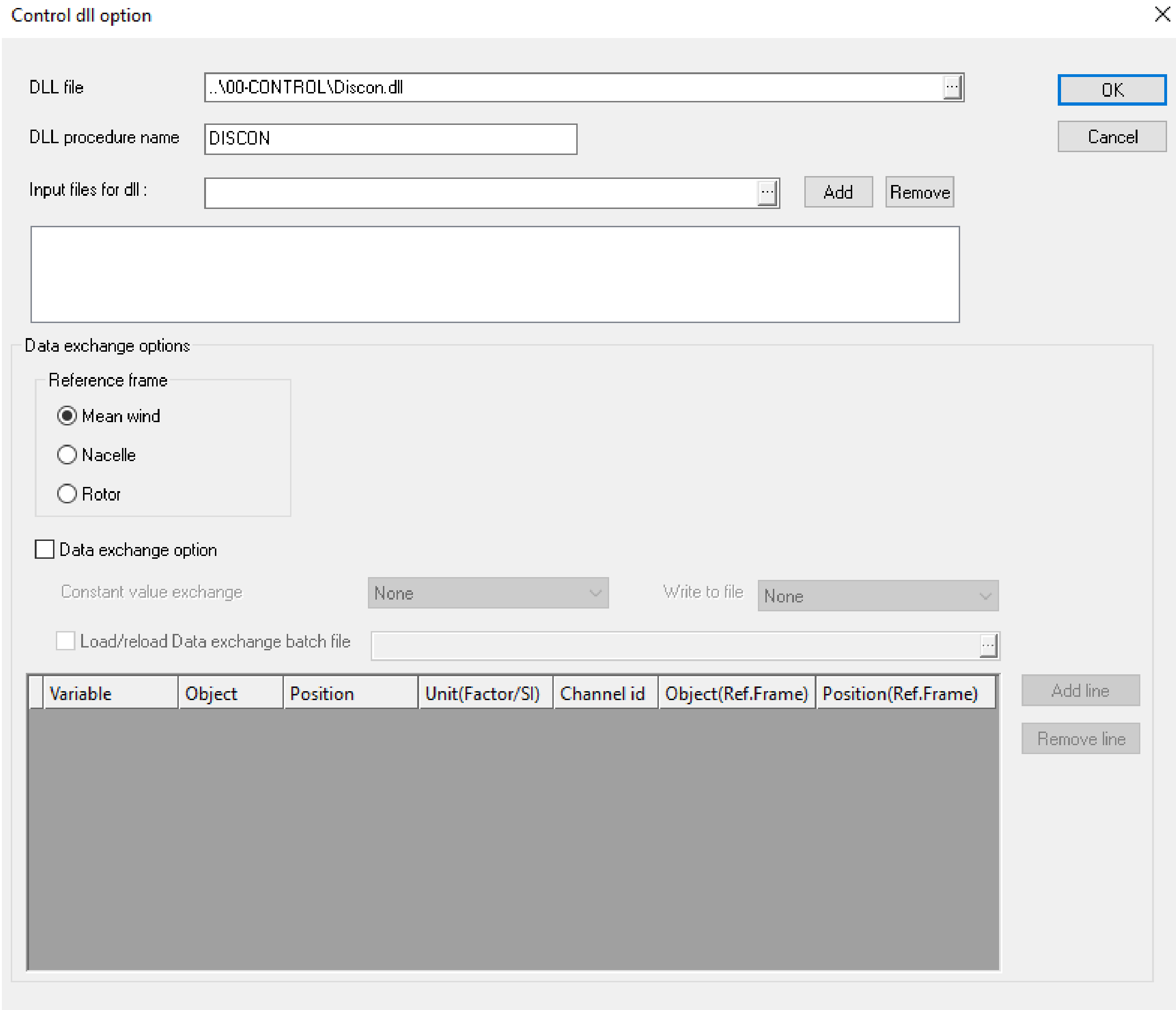


Figure 3-24 : New Control DLL option panel – Default Option

<u>Example of DATA Exchange:</u>

An example of a more complete exchange with the controller is provided with the “Data exchange option” activated.

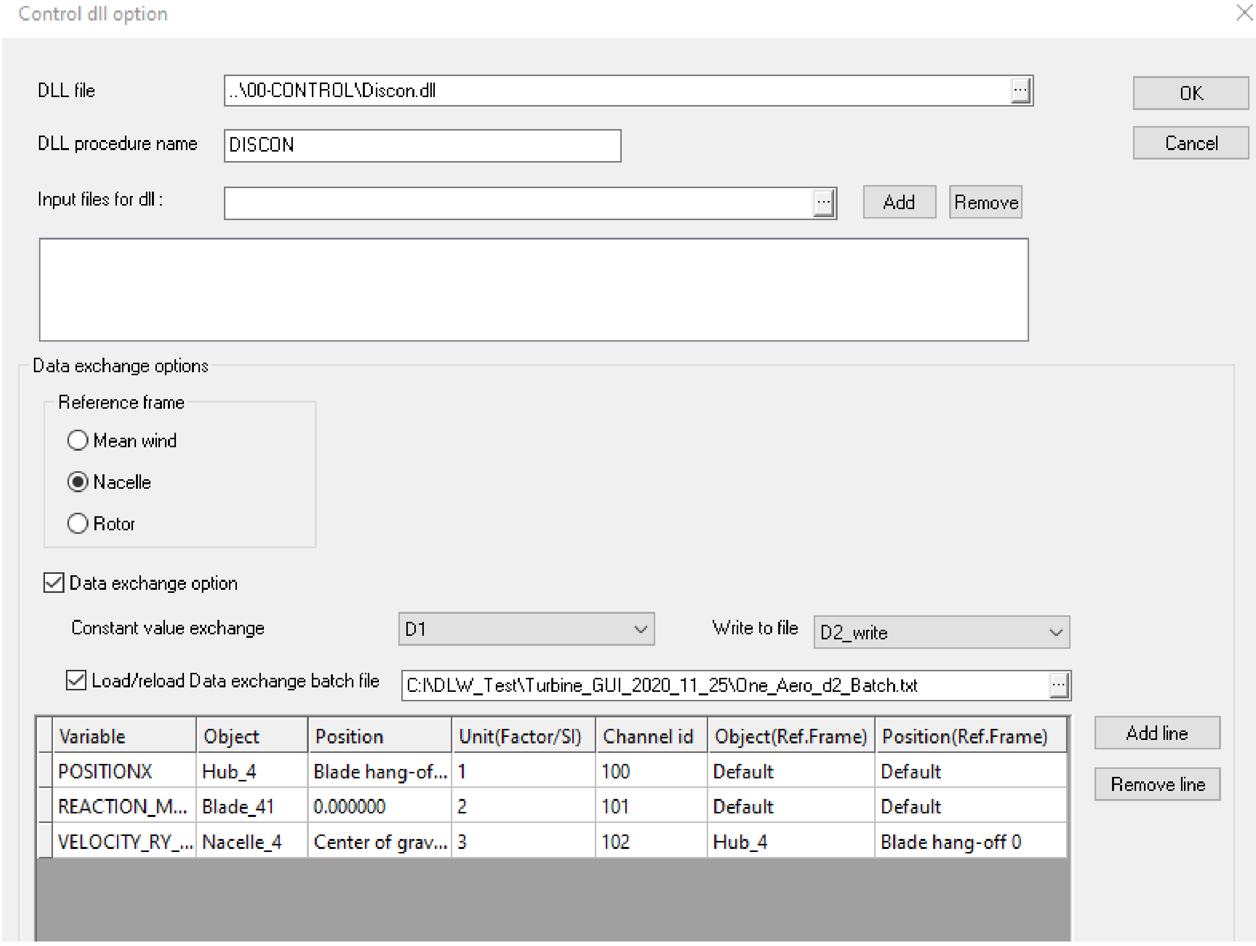


Figure 3-25 : New Control DLL option panel

- A table (D1) is provided for constant value exchange. This sends initial data to the controller. The table is a two columns table defined in Variation table:

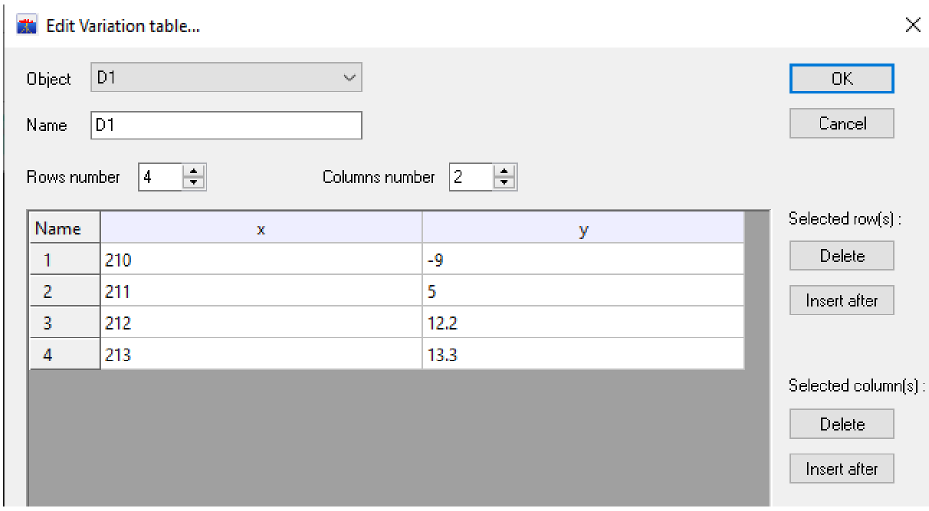


Figure 3-26 : Variation table for constant data exchange

This indicates that value -9 will be provided at initial value at line 210, value 5 is provided at line 211 and so on…

- A table D2_write is provided in the “write to file” option. The table is a two columns table defined in Variation table. At each saved timestep, the value exchanged after the controller call are written in file ‘`turbctr_TurbineName.txt`’. With the table below, the data stored in channel 2, 10 to 12, 100 to 103 and 210 to 214 are written in the file.

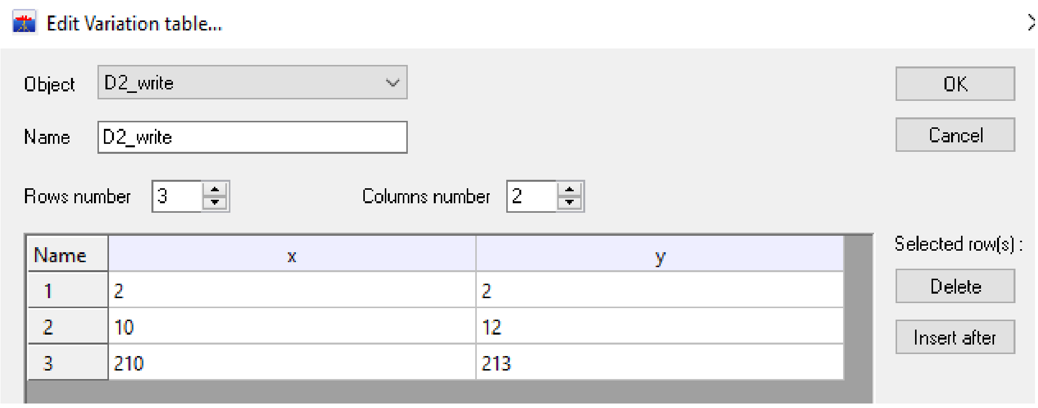


Figure 3-27 : Writing of exchanged data

- A batch file was loaded to provide specific data to the controller at specific points. The batch file can be generated by defining time series of pre-defined results and exporting the corresponding batch file. It can then be loaded as illustrated by Figure 3-28.

  The user then needs to provide a factor to multiply the value computed by DeepLines Wind and the channel at which the data is exchanged. Also potentially when data are required in a local frame other than the node frame, the user can provides the reference node to be used to derive the local frame. In the example the position in the X global frame is provided at channel 100 as is since the multiplication factor is 1. On the other hand at channel 102, the pitch velocity measured at nacelle reference is computed with respect to the blade hang-off point frame.

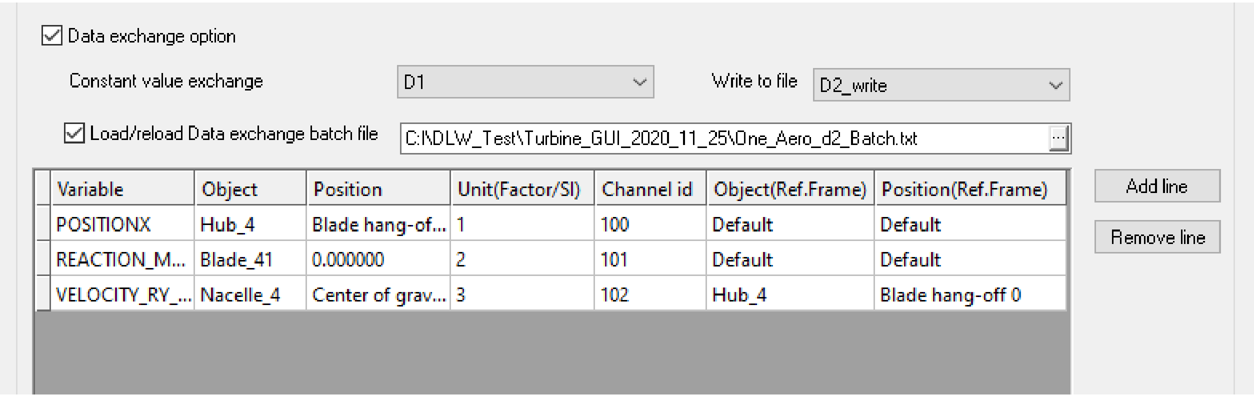


Figure 3-28 : Exchanged data definition

3.8 AERO SOLVER OPTIONS LIBRARIES

The aero solver is using a XML file in which different options are defined to compute the aerodynamic loads on the blades. This is still the case in version V5R6.

When a XML file is already generated or provided by others, the associated aero solver option is simply defined as shown by Figure 3-29.

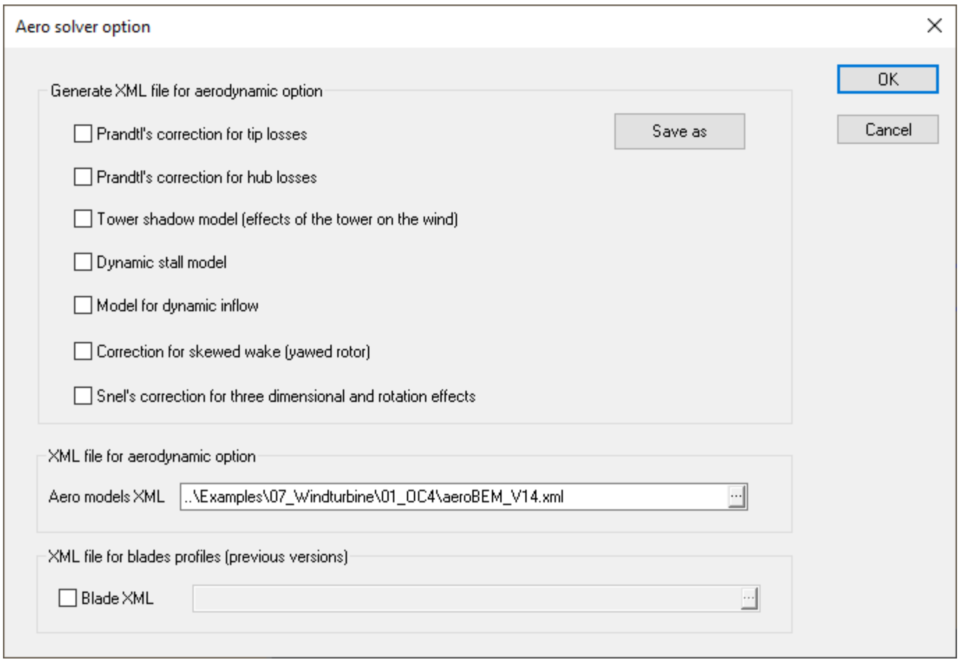


Figure 3-29 : New panel for aero solver options

In case the XML is to be generated, the process is as such:

- Select different solver options among the proposed list;
- Click on “save as” to generate the XML file;
- Select the new XML file in the menu “xml file for aerodynamic option”.

Note:

- Only classical options may be selected. For more advanced options, the XML file shall be created by hand and loaded afterward.
- On Figure 3-30, it can be seen an example where blades air foils are introduced through an old XML file. This configuration represents the default configuration when loading and DSK built-up with previous versions.

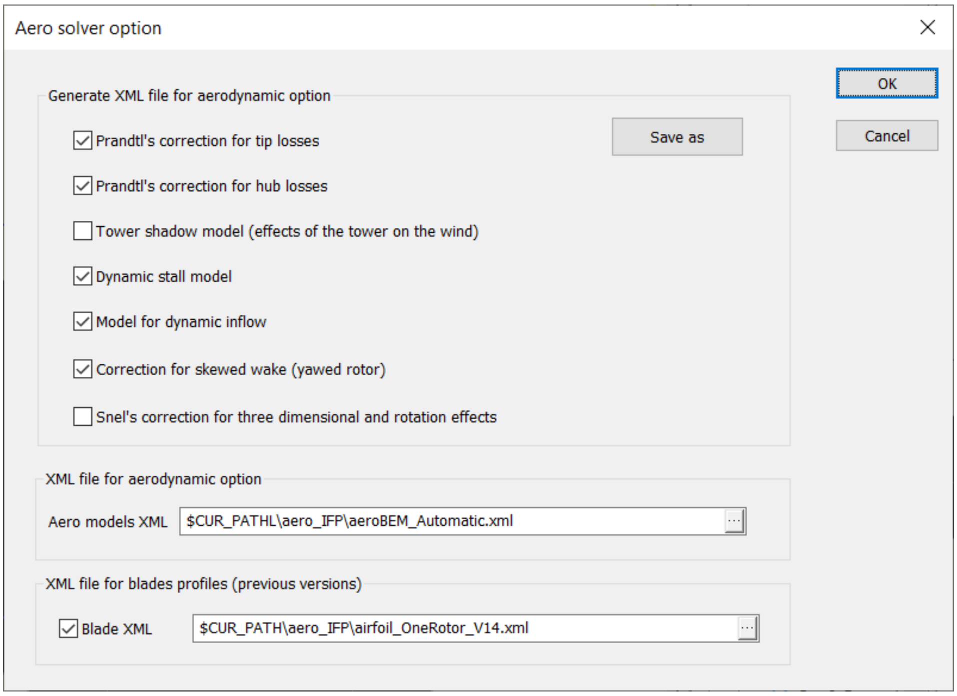


Figure 3-30 : Generation of a XML file for aero solver options

When a HAWT is created, by default no aerodynamic option is defined.

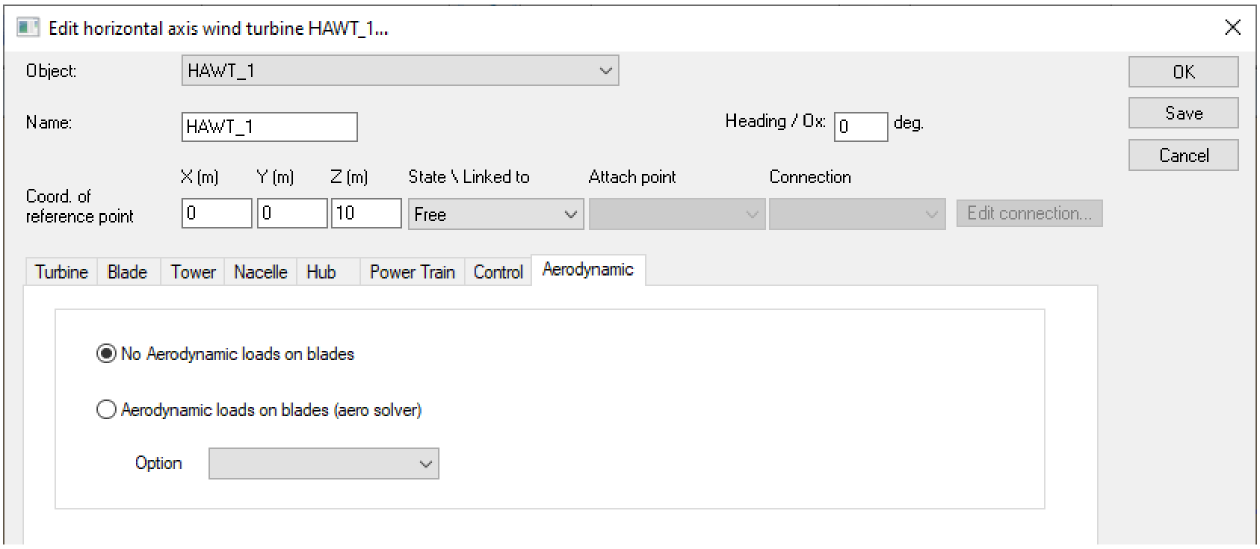


Figure 3-31 : Default aero solver option

3.9 TWO TURBINES AND MORE

If more than one turbine is needed in your analysis, it remains possible.

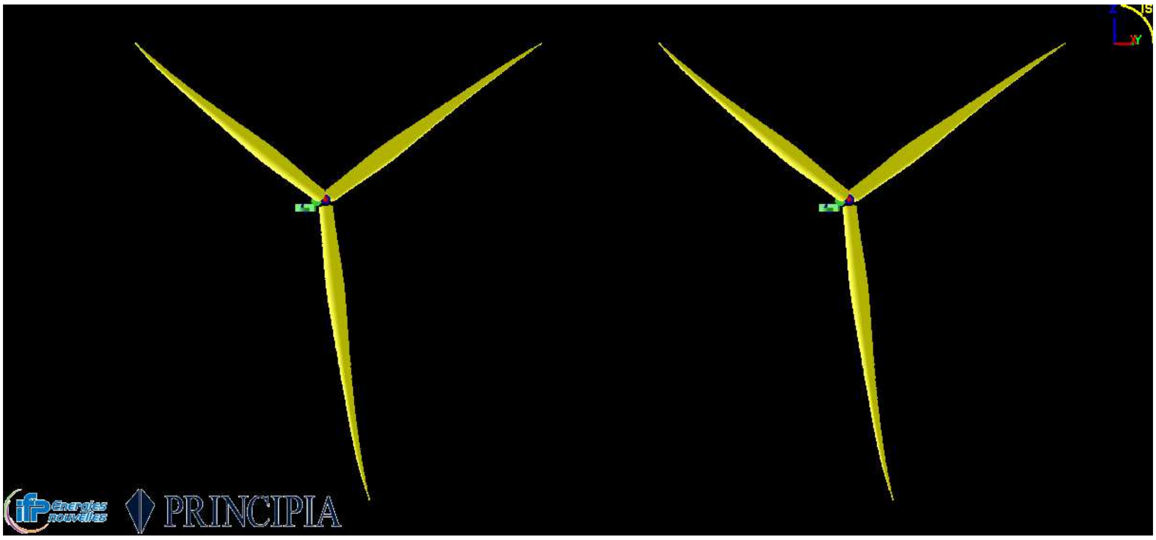


Figure 3-32 : Two turbines model

The old option of having a single .xml file to define the turbine profile is still available. Define an Aerodynamic solver option which points towards the common .xml file airfoil_IEATASK37_2rotors.xml as shown on Figure 3-33.

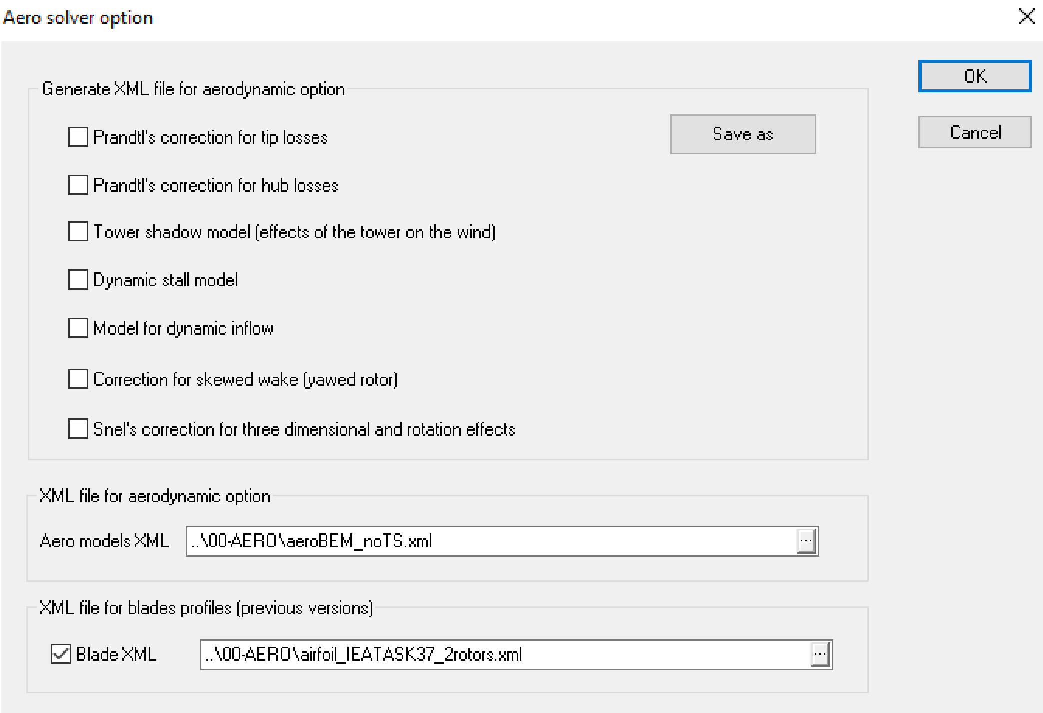


Figure 3-33 : Aerodynamic option for two turbines

Then use this option for both turbines in the aerodynamic loads:

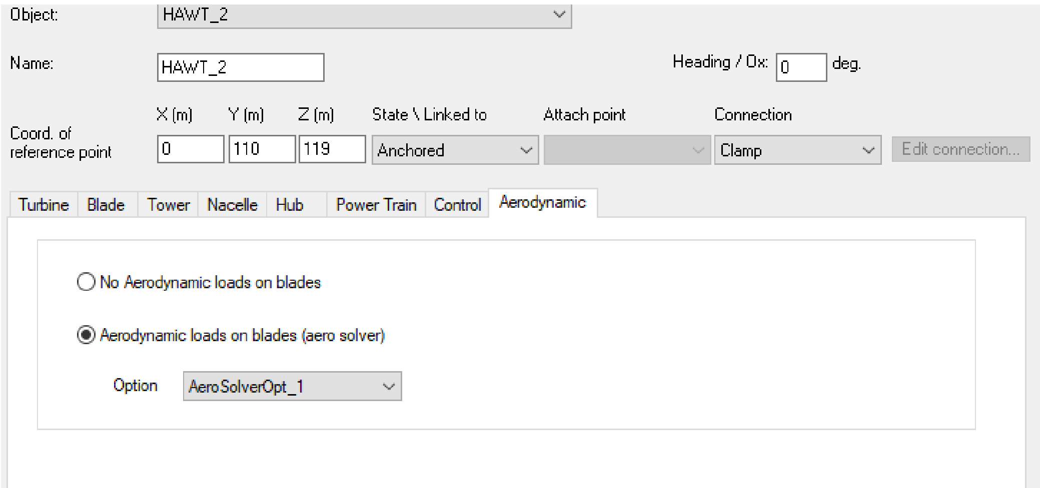


Figure 3-34 : Aerodynamic loads for two turbines

If now you have an updated model with the aerodynamic profile defined in the interface, the GUI will automatically generate independent .json files that the solver will handle. The Aero solver option will then not have the Blade XML option as shown in Figure 3-35. There is nonetheless one restriction: at this point the Aero models .xml file must be the same for all turbines used in the same analysis. It is therefore recommended to use the same Aero solver option for all turbines defined to be used together. Control is another matter and can be different from one turbine to another in the same analysis.

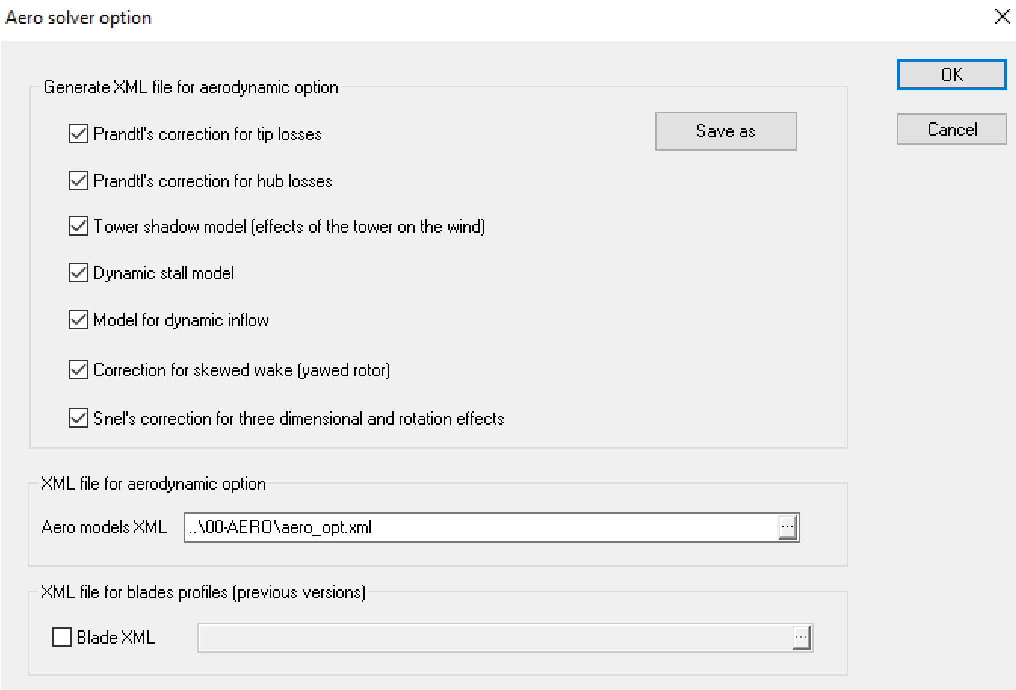


Figure 3-35 : Updated aerodynamic option for two turbines

4 ENVIRONMENT SETS FOR HAWTS

4.1 OBJECTIVE

With the experience acquired on projects, series of convenient keywords have been created in the solver input file. These keywords have been implemented into the GUI and integrated in the Load Cases combination matrix.

The options associated with the turbine can now be defined in the Environmental Set.

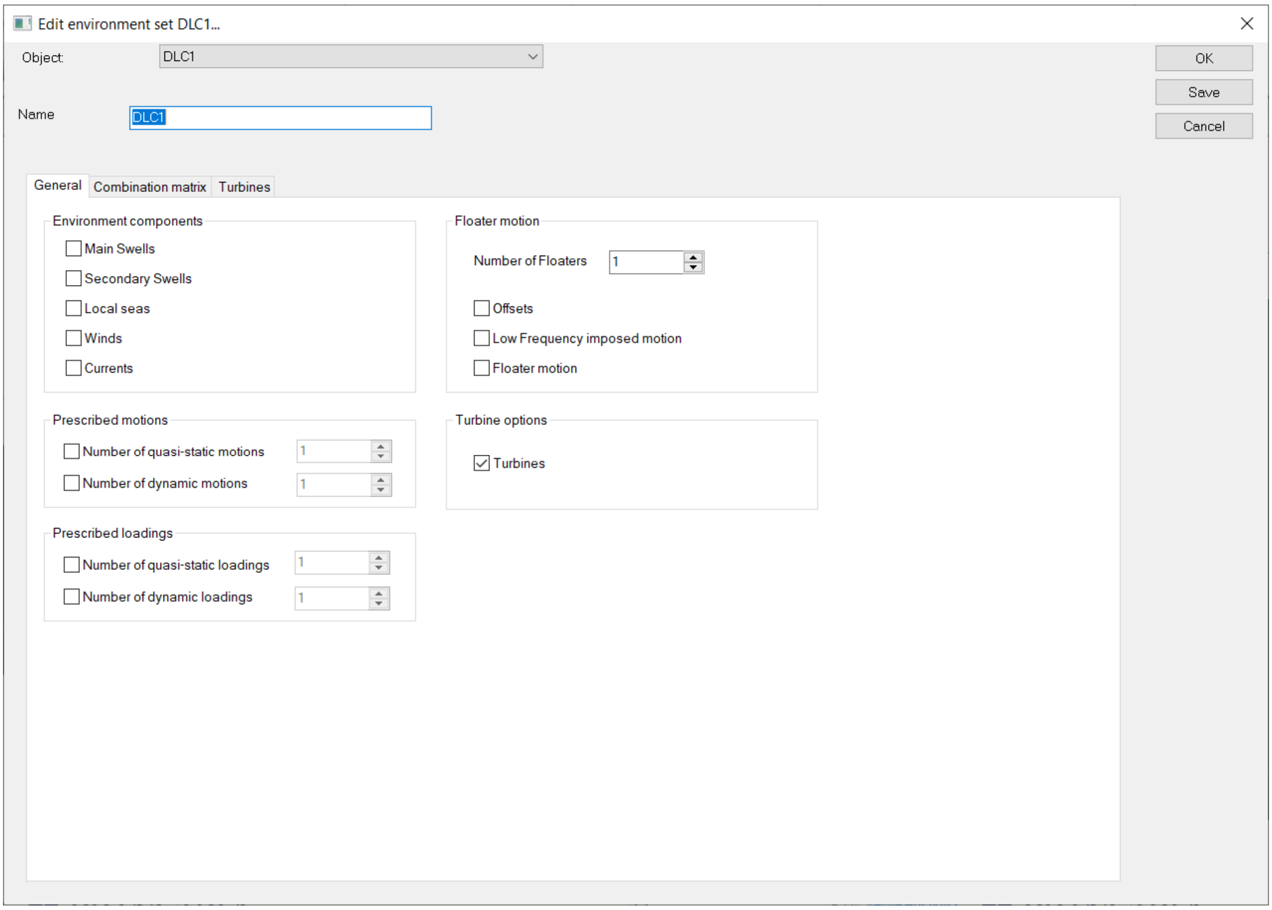


Figure 4-1 : New Environment Set panel

As shown on Figure 4-2, every turbine load case is defined by:

- **Name**: the user may gives a specific name to every case;
- **HAWT**: turbine object to be selected among the objects already defined in the model browser;
- **Start-Up**: "start up" loading already defined in the model browser. Even if this loading has been defined with another turbine object, the sub-loading "start-up" is associated with the selected HAWT.
- **StartUp VAr Table**: In the same way, the variation table defined here supersedes the table initially used to create the subloading "Start-up" (see section 4.2).
- **Control mode**: controle mode already defined in the "turbine properties" menu;

- **Control options**: already defined in the "turbine properties" menu;
- **Aerodynamic solver Options**: already defined in the "turbine properties" menu.

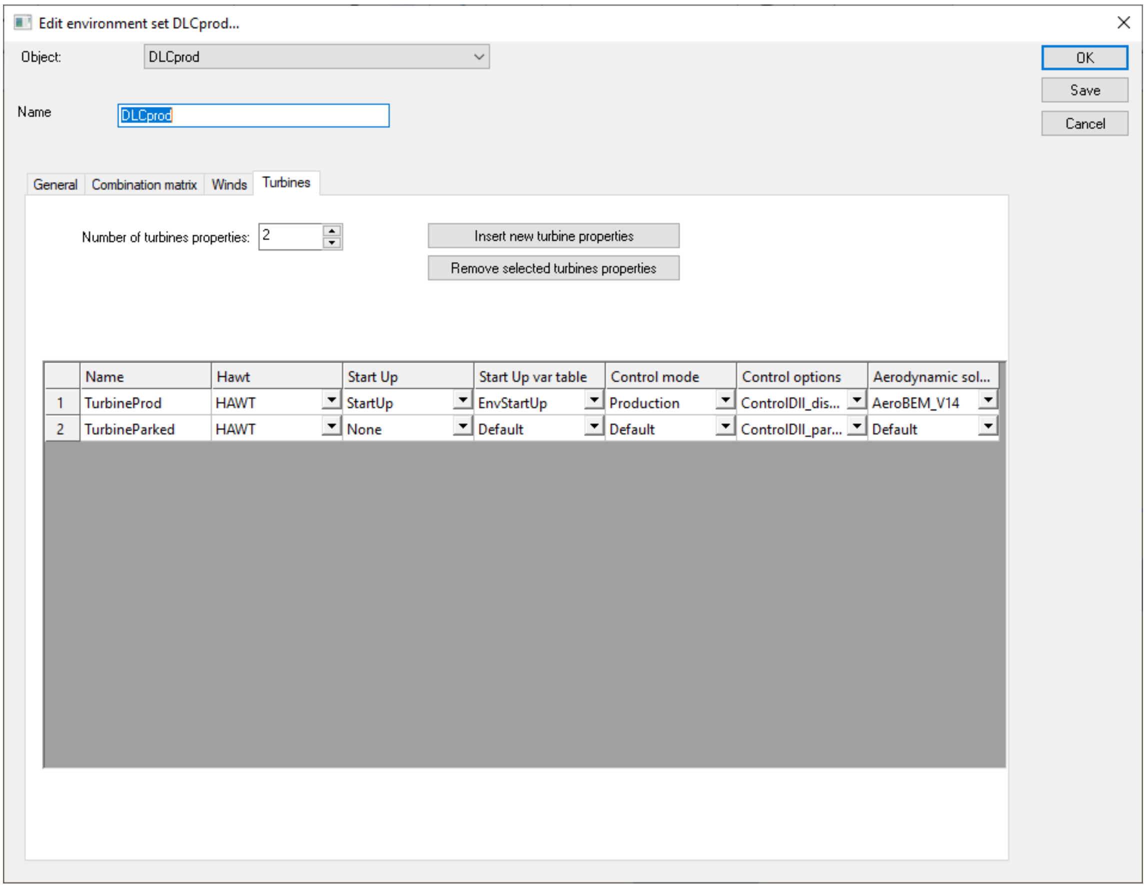


Figure 4-2 : Example of turbine options in an EnvironmentSet

4.2 VARIATIONS TABLES

The notion of "tables" has been introduced into the GUI with a new folder in the model tree called "Tables".

When a new table is created, the user may define:

- The new table name,
- The number of rows and columns
- The unit of every column: NONE can be selected meaning that no specific unit is defined.

Once created, the tables are stored in the model tree:

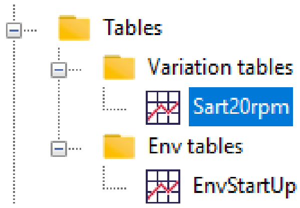


Figure 4-3 : Variation and Env. Tables

It is possible to define two kinds of tables:

- Variation tables: these tables define a set of parameters as function of a specific variable: quasi-static step, time, arc length, water depth etc…

  It is important to note that values in these tables must be given in **SI units**.

  On Figure 4-4, an example of StartUp for a Clockwise turbine is provided relative to a ramp up of 100s to achieve 20rpm, i.e. 2.0944rad/s.

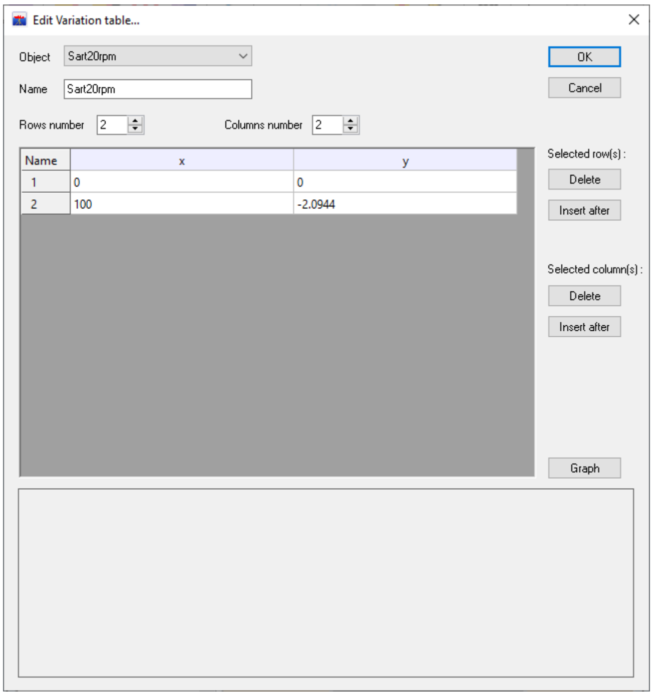


Figure 4-4 : Example of variation table for ramp up to 20rpm in 100s

- Environmental Tables: this kind of tables is to be used in an EnviromentSet to redefine the main parameters of a variation table with respect to the Analysis number.

  In the previous example, the StartUp is defined by two main parameters: the duration of the transient phase (in seconds) and the final rotation speed (in rmp). The following Environmental table can then be defined:

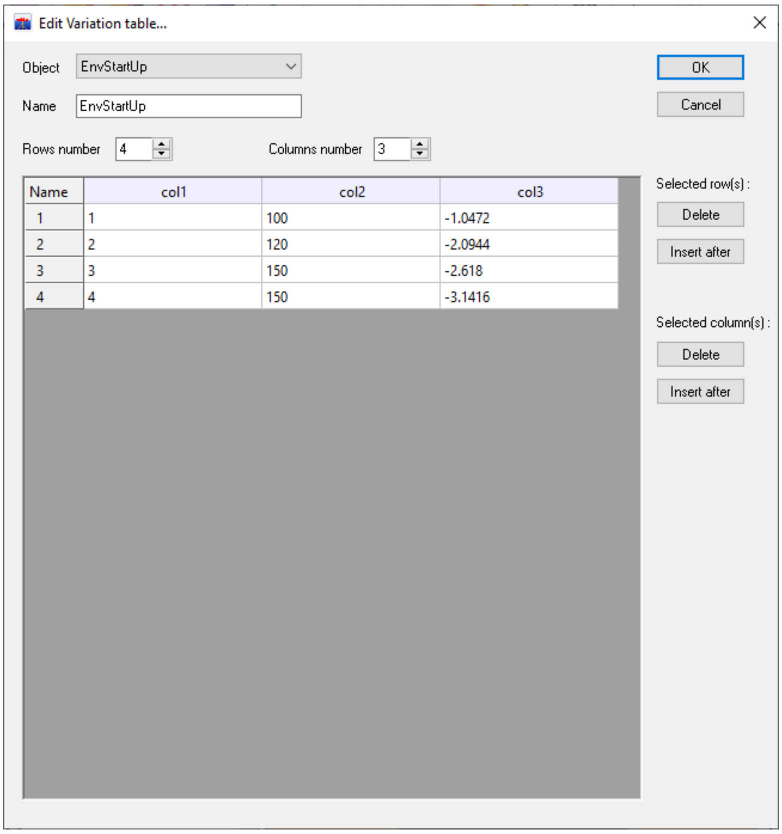


Figure 4-5 : Env. Table associated with the StartUp

In this example, that means:

- in analysis 1, the transient time is 100s to reach 10rpm;
- in analysis 2, the transient time is 120s to reach 20rpm;
- in analysis 3, the transient time is 150s to reach 25rpm;
- in analysis 4, the transient time is 150s to reach 30rpm.

4.3 TURBINE START-UP

4.3.1 Individual loading

A turbine Start-up is a sub-displacement of a displacement loading.

The definition is done with the following steps:

- First, define a displacement with a type "control":

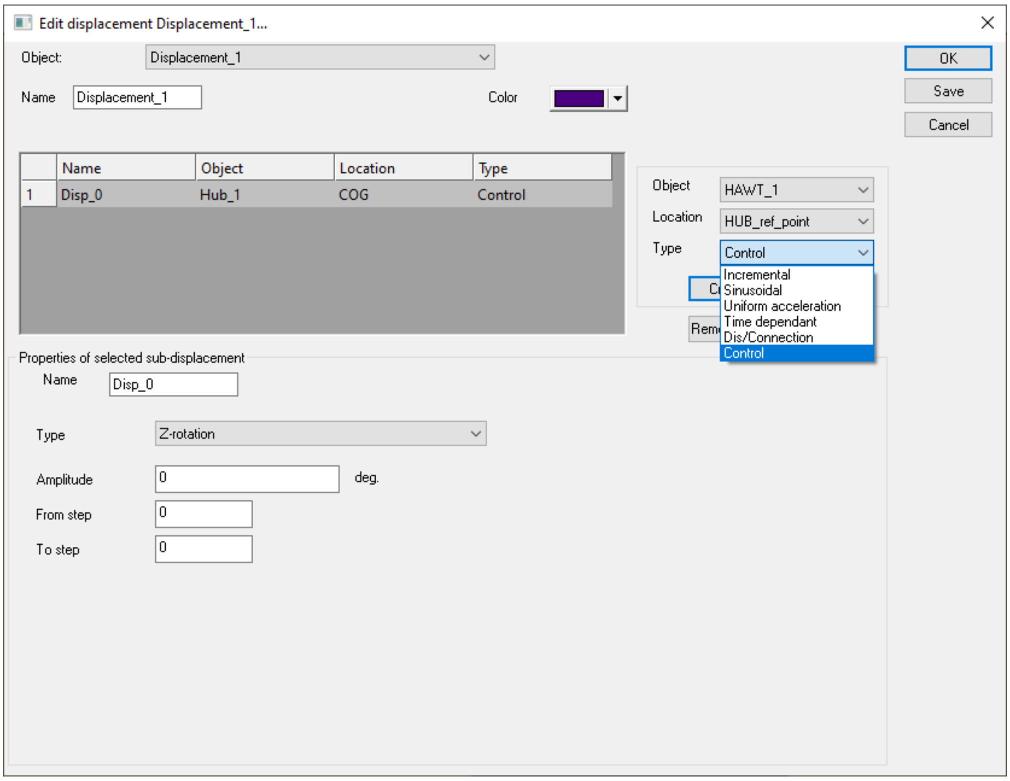


Figure 4-6 : Selection of a displacement loading type "Control"

- Then among the different option, select "turbine start-up":

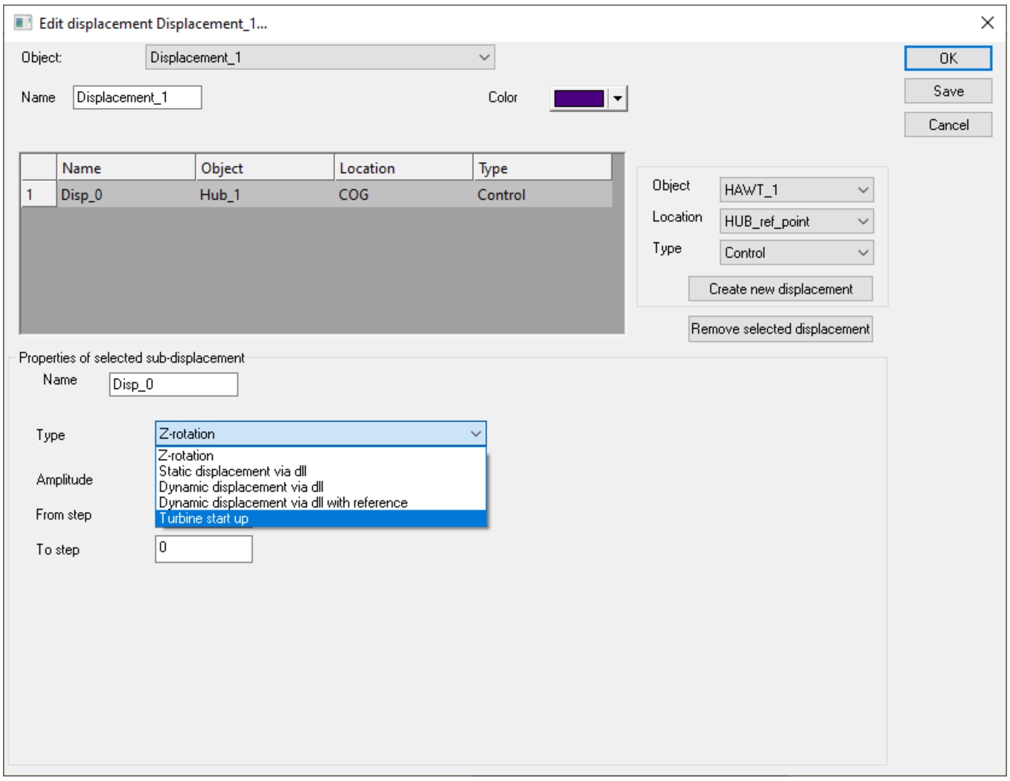


Figure 4-7 : Sub-loading "Start-up" selection

- A “turbine start-up” allows imposing a rotation speed to a turbine through a PID.

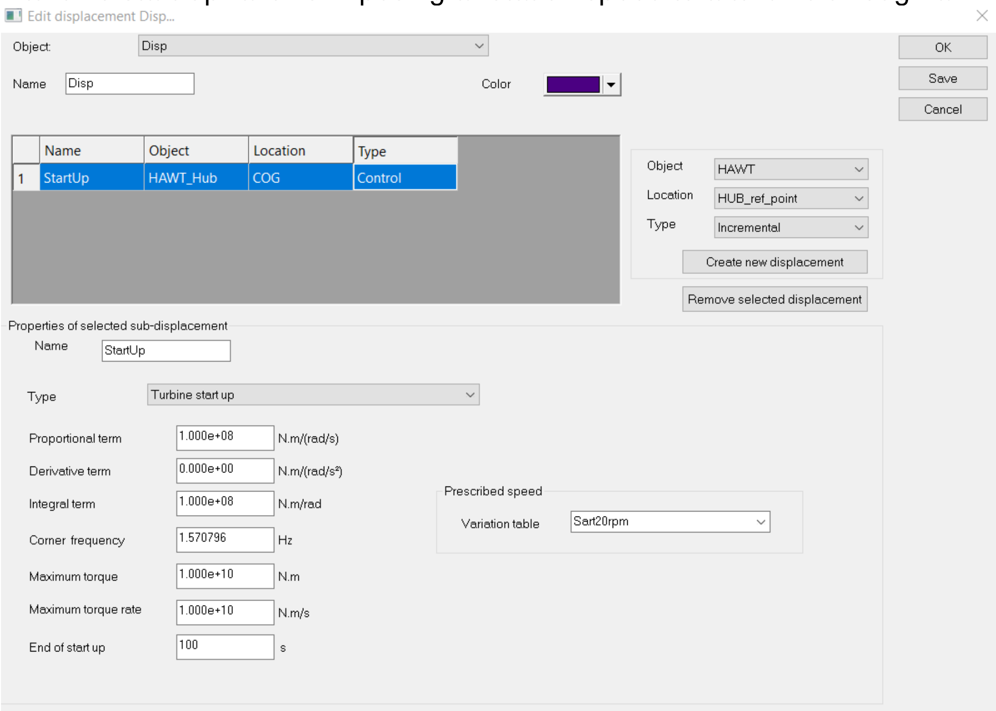


Figure 4-8 : Example of turbine “Start-up” definition

Default parameters are proposed for this PID which may be modified if needed.

Otherwise, two specific parameters are to be adjusted with your case:

- “End of start-up” (in seconds): this defines the last time when the “start-up” control is applied. That means that above this time, the turbine is either set free or, for a turbine in production mode, the handover is done with the control DLL;
- Variation table: for the variation table two situations may be distinguished:
  - For a loading to be included in a single analysis, the variation table can defined a scenario of rotation speed varying in time. This may be useful to check the turbine performance;
  - For a loading to be implemented in an EnvironmentSet, the variation table must only defined a target speed and a transition time window as shown on Figure 4-8.

4.3.2 Start-Up in a EnvironmentSet

Finally, to define a turbine start-up in an EnvironmentSet, it shall be done that way:

1) Define a Start-up sub-displacement (Figure 4-8);
2) Define an Environmental table (if needed) as shown on Figure 4-5;
3) Define an EnviromentSet to apply the Environmental table on the previous Start-up in an EnviromentSet (see Figure 4-2).

4.4 FF-WIND DEFINITION

4.4.1 Individual FF-wind

The definition of a FF-type wind has been improved to include in the GUI two options that, in the previous version, required a direct modification of the LOG file.

Two specific parameters have been added in the definition panel (Figure 4-9):

- "Ramp time duration": this parameter defines the duration of the transition phase to ramp up the specified wind speed (see keyword *RAMPTIWIND, parameter RAW);
- "Beginning of turbulent wind": this parameter also defines a transition phase during which a constant wind speed is used before switching to the turbulent wind. The constant wind speed is directly read from the *.SUM file associated with the FF-Wind, its heading is the heading of the definition panel. (see *RAMPTIWIND, parameter RCST).

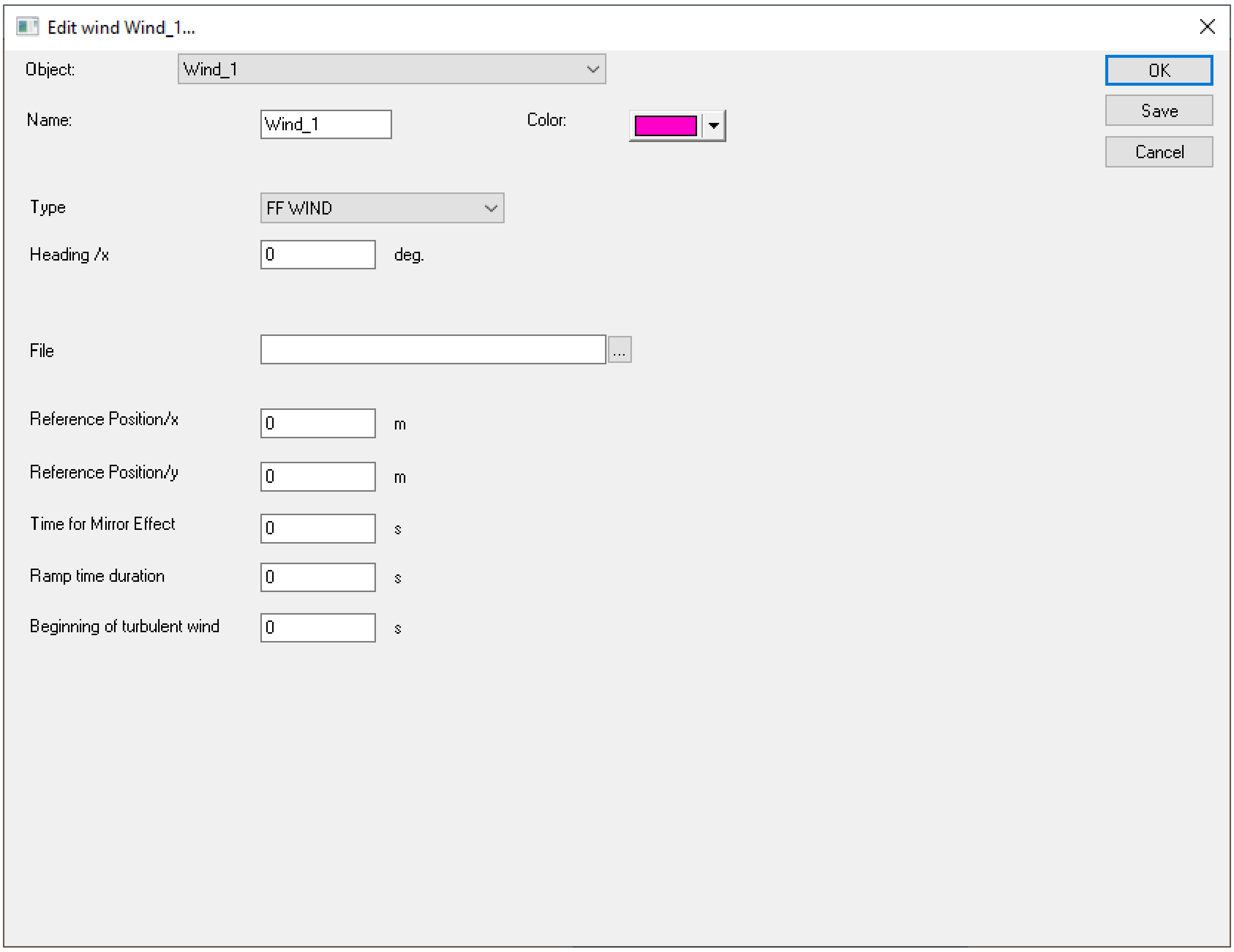


Figure 4-9 : FF-WIND new definition panel

4.4.2 FF-Winds in an EnvironmentSet

The two parameters mentioned at section 4.4.1 can also be defined within an EnvironmentSet (Figure 4-10):

- The “ramp time duration” is called “duration”
- The “beginning of the turbulent wind” is called “Beg. Time”.

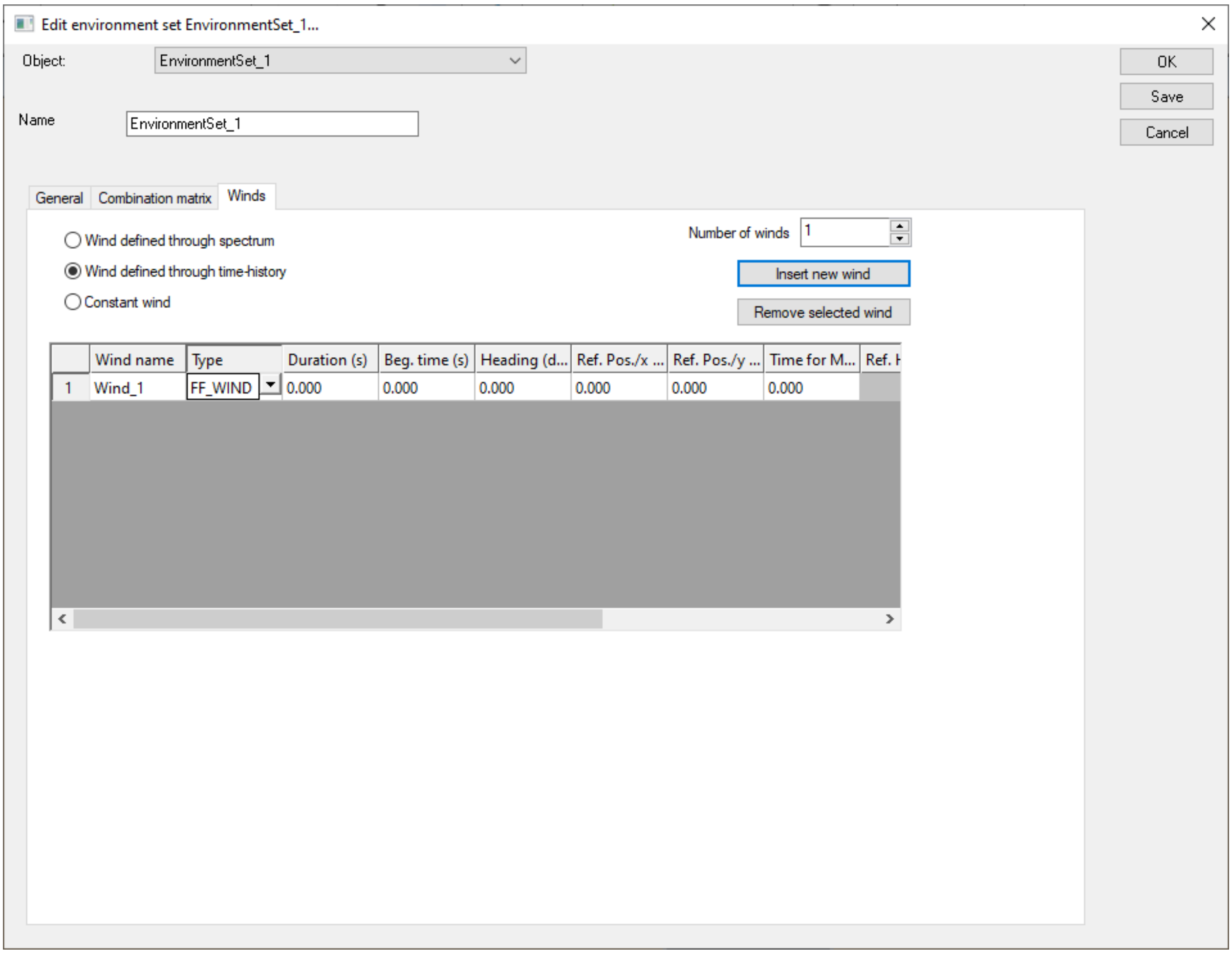


Figure 4-10 : FF-WIND definition in an EnvironmentSet