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DEEPLINES WIND

FEATURES FOR WINDTURBINES DESCRIPTION FROM VERSION 5.6

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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.



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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.

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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:

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Lorb per Lorb per Poster motion types Poster motion types Decymony model of spec Decymony model of specific of speci	S <u>W E</u> N
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Vivida internet fluids Extra properties Relat properties Security properties Secu	
	
Ballad properties Brocknee properties Model Party Market Cock,d Party Market Cock,d </td <td></td>	
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(a) → (b) A traincole at (a) → Brake, OC 4,11 (b) → Brake, OC 4,12 (c) → Brake, OC 4,13 (c) → Brake, OC 4,14 (c) → Brake, OC 4,14 (c) → Hab, OC 4,14 (c) → Hab	
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e- M Default	
Eatigue	
- Zone Studies	
EOP Studies	
mu aj namice pressures	
Get check trutture	

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

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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:

E	dit displaceme	ent DOF_blocked					×
Obje	ect:	DOF_blocked		\sim			OK
Nam	ne DOF_bloc	ked		Color	•		Save
							Cancel
	Name	Object	Location	Туре			
1	Disp_0	Nacelle_SinBla	COG	Dis/Connection	Object	HAWT \sim	
2	Disp_1	Shaft_SinBla	End_1	Dis/Connection	Location	HUB_ref_point \sim	
3	Disp_2	Shaft_SinBla	End_2	Dis/Connection	Туре	Incremental V	
4	Disp_3	Shaft_SinBla	LSS_Bearing_1	Dis/Connection			
5	Disp_4	Shaft_SinBla	LSS_Bearing_2	Dis/Connection		reate new displacement	
					Rem	nove selected displacement	
Prop	erties of selecte	d sub-displacement					

Figure 3-2 : Shaft nodes and Nacelle reference node

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3.2 SUB-TAB: "BLADES"

3.2.1 Public Blades

		HAWT			~					OK
me:		HAW/T				He	eading / Ox: 📊	dea.		Save
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urbine	Blade T	ower Nacelle	Hub Power	Train Control	Aerodynamic					
	crypted mode									
	oryprod mode									
O B	ly mechanism d mass :	: Traction Bending Torsion	0			Chord			Pre-bend	
Numb	er of sections	: 17	•				()			
	Length (m) Chord (m)	Structural	Aerodyna	Profile	IP preben	OP preben	Dry weigh	El flap (N. ^	
	2.73300	3.54200	-13.30800	-13.30800	Cylinder1 🚬	0.00000	0.00000	7.65600	1.91000e+	
1	2.73300	3.85400	-13.30800	-13.30800	Cylinder1	0.00000	0.00000	6.08000	1.12300e+	
1	and the later of the later	4.16700	-13.30800	-13.30800	Cylinder2	0.00000	0.00000	4.13700	5.81500e+	
1 2 3	2.73300	1 (1000 (1012) SUST	-13.30800	-13.30800	DU21_A 💌	0.00000	0.00000	4.30000	4.65500e+	
1 2 3 4	2.73300 4.10000	4.55700				0.00000	0.00000	3.57900	2.54200e+	
1 2 3 4 5	2.73300 4.10000 4.10000	4.55700 4.65200	-11.48000	-11.48000	0035_A	2002 2000 2000 2000				
1 2 3 4 5 6	2.73300 4.10000 4.10000 4.10000	4.55700 4.65200 4.45800	-11.48000 -10.16200	-11.48000 -10.16200	DU35_A	0.00000	0.00000	3.44000	2.02200e+	
1 2 3 4 5 6 7	2.73300 4.10000 4.10000 4.10000 4.10000	4.55700 4.65200 4.45800 4.24900	-11.48000 -10.16200 -9.01100	-11.48000 -10.16200 -9.01100	DU35_A DU35_A DU30_A	0.00000	0.00000	3.44000 3.26700	2.02200e+ 1.54900e+	
1 2 3 4 5 6 7 8	2.73300 4.10000 4.10000 4.10000 4.10000 4.10000	4.55700 4.65200 4.45800 4.24900 4.00700	-11.48000 -10.16200 -9.01100 -7.79500	-11.48000 -10.16200 -9.01100 -7.79500	DU35_A • DU35_A • DU30_A • DU25_A •	0.00000 0.00000 0.00000	0.00000 0.00000 0.00000	3.44000 3.26700 2.99700	2.02200e+ 1.54900e+ 1.05100e+	

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.

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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.

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	Edit segm	ent types						×			
	Туре:	HAWT_Blade_sec ~			New			OK			
	Name:	HAWT_Blade_sec_1	Color:	-	Copy as			Cancel			
					Delete						
	Mechanica	I properties AeroHydrodynar	mic properties Ther	rmal properties	Damping	Finite element model	Section deta	ils			
		Lineic mass	780.428	kg/m							
		Axial stiffness	1.067e+10	N							
	Bendi	ng stiffness in local axis X	1.955e+10	N.m ²							
	Bendi	ng stiffness in local axis Y	1.91e+10	N.m ²							
		Torsion stiffness	5.359e+09	N.m²/rad							
	She	ear stiffness in local axis X	0	N							
	She	ear stiffness in local axis Y	U	N							
		Shear center X Shear center Y	0	mm							
		Polar inertia X	1071	kam							
		Polar inertia Y	1063	kg.m							
		Polar inertia Z	2134	kg.m							
		Center of mass X	0	mm							
		Center of mass Y	0	mm							
		Mass axis orientation	0	deg.							
		Internal cross section	0	mm²							
		End cap effect area	62602.7	mm ²							
		Buoyancy area	62602.7	mm²							
		Submerged weight 🗌	0	N/m							
	Co	ntact equivalent diameter	3542	mm							

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.

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	Aero cer Aero cer Profile na	ter X me	0 Cylinder1	mm mm				

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:

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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.

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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.

Fichier Edition Format Affichage ?
Include Leuton Fonder Andruge . Image: Line Leuton Fonder Andruge . Image: Line Leuton Fonder Andruge . Image: Line Leuton Fonder Andruge . MIKENjAYBgkqhkiG9w0BAQcwCwYJYIZIAWUDBAIBBIIBgJ4MNVC1sczpeXX815LjkI5hs1rN yEgR4MwmCJV9+CMGr4RezMwykLz7iuvwiRehtgfp/ndx+JNnp0K3tbvX7456UJUvf/wRN7cs XsfczU08sQa/AB17HoyqcD/9dBn0c/Jb1/0v+p+wdDqK4WzK8JwG6tP6Ethb15mvNwVNYr7+ lY6nhoUnsA+syuIM8H1eZBaCJQs/L/2E1DDJmhvU5kI5fXwP32Do2TBGVaBfCqrDo9jbr/zT xvPjQdToHiqQtheJrcmicX//CdUbpjULb/+HMP4d5hCgzpDr5ydIX9II9NSwUkk0MVvwBFqT zzxPjqdToHiqQtheJrcmicX//CdUbpjULb/+HMP4d5hCg2pDr5ydIX9II9NSWUkk0MVvwBFqT zzrqTq6Bubb/8kJcjLtmtpAmccXsGnSaFAFT16E3JfGy1jzDv/U3DxwjQ27kwNUw6hnF29hG Lnk4zWZn+yaQCJWqzRwE73e27Pc2fE/TPKCGv0K70+0prAtV0mRT8AYJYIZIAWUDBAEuBAwr rFf/jhiQwH7JF0oEgq17ca49p4ynJdM4zkdY/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.

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

<pre>he: HAWT_1 Heading / 0x o deg Carce Ad of tence point 0 0 10 Free Connection bine Bade Tower Nacelle Hub Power Train Control Aerodynamic Bencypted mode ScUER_PATHY filename Lod Damping Coefficient 0.0024 By mechanism: Traction Bending 0 Torsion 0 Pre-bend </pre>	ect	HAWT_1			~			OK
Attach point Connection Id of errors point 0 0 10 Free Edit connection blae Blade Tower Nacelle Hub Power Train Control Aerodynamic Control SUIF_PATH/Viename3x Image: Control in the second	me:	HAWT_1				Heading / Ox: 0	deg.	Save
di di cence point 0 0 10 Free Cetticonnection Encrypted mode SULE PATHVienemeste Damping Coefficient 00024 Bending 0 Torsion 0 Pre-bend		X(m) Y(m	n) Z(m)	State \ Linked t	o Attach point	Connection		Cancel
tine Blade Tower Nacelle Hub Power Train Control Aerodynamic	ord, of erence point	0 0	10	Free	~	~	 Edit connection 	
Encrypted mode SCUR_PATHVilename.tx	urbine Blade	Tower Nacelle	e Hub Po	wer Train Contro	Aerodynamic			
Damping Coefficient type: Beta Bayleigh: Coefficient Damping Coefficient Damping Damp	7 Encrypted mod	e SCUR PA	TH\filename to	1				
Damping Coefficient type : Beta Bending Demonstration Bending Demonstration Pre-bend Pre-bend	1 - 10, jpto 0 1100							
Rayleigh: Coefficient By mechanism: Traction Bending D Torsion Ø Pre-bend	Damping Coefficient type :	🖲 Beta						
By mechanism: Traction Bending 0 Torsion Ø	Rayleigh:	Coefficient	0.0024			Chord	>	
Bending 0 Torsion 0 Pre-bend) By mechanis	m: Traction	0	7				
Torsion 0 Pre-bend		Bending	0					
Pre-bend		Torsion	0				1	
							Pre-bend	
					I			

Figure 3-9 : Blades definition panel – encrypted mode

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

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	DeeplinesGUI Blade file	e successfully loaded		

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.

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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:

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			Featur	es for Wind tu	rbines		
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	Edit foil profile.						×
	Type: DI Name: DI Options	U35_A17 J35_A17	Vew Copy as Delete				OK Cancel
	🗹 Use stall e 🗹 Thickness	ffect	☑ Fully s □ Angle	eparated flow 30 lift curve slope 0	deg 1/rad		
	Reynold's num Number:	ber	1.000 Attack Angle (deg)	Lift coeff (-)	Drag coeff (-)	Moment coeff	
	Insert	Delete	-180.0000	0.0000	0.0407	0.0000	.,
	Revn	old's	-175.0000	0.2230	0.0507	0.0937	
	1 1.000		-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	
	Attack angle		-95.0000	0.0210	1.3692	0.3867	
	Number:	35	-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).

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3.4 TSUB-TAB: TOWER

The new panel looks like as follows:

)bject:	HAW1	_1						\sim							OK
ame:	HAWT	21		Í					He	ading / C	0×: 0	deg.			Save
	X (m)	Y (m) Z (r	n)	State \	Linked to		Attach poi	nt	Conn	ection				Cance
oord, of aference point	0	0	10		Free		×	1		~.			Edito	connection	
Turbine Blade	Tower	Nacelle	Hub	Powe	er Train	Control	Aerod	ynamic							
Tower length :	77.6			m		Color :									
Tower type	6		14277342					0.1		L.u.s.	24207				
	e	/ Conica	tower					Userd	Jenned from	Dottom t	otop				
Mechanical pr	roperties							Pipe	material na modulus :		210	1	SPa		
Beginr	ning of pip	e						Poiss	ion coefficie	nt :	0.3				
Ou	tside diam	eter :	6500			mm		Spec	ific gravity :		7.85				
Wa	all thickne	3S :	27			mm									
End of	f pipe														
Ou	tside diam	eter :	3870			_ mm									
w	all thickne		19												
	an tracerte.		15												
Partition :			15												
Rayleigh <mark>d</mark> ampii	ng <mark>co</mark> effici	ent : [0.0001				1	Number of F	Reynolds :	1	-				
Tower shadow Drag coefficien	t:		hel				[Drag coef	f.	<u>L</u>	toolaid]				
(used by aero s	olver only		u					Reynolds	Number	CD					
Line :			Default			\sim		0.000		0.000	(

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.

DI DI	RINCIPIA		Deep	Lines Wind			
			Features for	or Wind turbines			and the second second
Principia D	Document No.	DSL.21	4.013		Rev.	02	Date : 12-02-21
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	Edit horizonta	I axis wind tu	urbine HAWT_1				
	Object:	HAWT_1		~			OK
	Name:	HAWT 1			Heading / Ox:	lo li	deg. Save
		[<u>[[[[]]]]</u>]					Cancel
	Coord. of	X (m) Y	Y(m) Z(m) State\Linke	d to Attach point	Connect	tion	
	reference point	0	0 10 Free	×			 Edit connection
	Turbine Blade	Tower Nac	celle Hub Power Train Con	trol Aerodynamic			
	Tower length :	60	m Col	or :			
	Towertype						
	570	000	nical tower	User defin	ed from bottom to to	00	
				C ober delin		op	
				0,000,000		op	
	Add		Remove Edit segment typ	es Create segment type	1	op	_
	Add		Remove Edit segment typ	Des Create segment type]	ор 	- 1
	Add Number of sec	tions : 3	Remove Edit segment typ	Des Create segment type]	op	
	Add Number of sec Sections : 3	tions : 3	Edit segment typ	bes Create segment type]		
	Add Number of sec Sections : 3	tions : 3	Edit segment typ	Des Create segment type	Segment prope	-rty P	ronetty type
	Add Number of sec Sections : 3	tions : 3 S Length (m) 20.000	Edit segment typ	Create segment type Number of elements 2	Segment prope	erty Pr	roperty type pered seam
	Add Number of sec Sections : 3 Name 1 seg_1_1 2 Sectio 2	tions : 3 S Length (m) 20.000	Edit segment typ Edit segment typ Sections length : 60.000 m Target element length (m)	Create segment type Number of elements 2 2	Segment prope Tower_1_Tower. Tower 1 Tower	erty Pı ▼ Ta ▼ FI	roperty type spered segm exible pipe
	Add Number of sec Sections : 3 Name 1 seg_1_1 2 Sectio 2 Sectio 2	tions : 3 S Length (m) 20.000 20.000	Edit segment typ Edit segment typ Sections length : 60.000 m Target element length (m) - -	Create segment type Number of elements 2 2 2 2 2	Segment prope Tower_1_Tower. Tower_1_Tower.	erty Pr ▼ Ta ▼ Fi.	roperty type upered segm exible pipe gid pipe
	Add Number of sec Sections : 3 Name 1 seg_1_1 2 Sectio 2	tions : 3 S Length (m) 20.000 20.000 20.000	Remove Edit segment typ Sections length : 60.000 m Target element length (m) - - -	Number of elements 2 2 2 2	Segment prope Tower_1_Tower. Tower_1_Tower. Tower_1_Tower.	erty P ▼ Ta ▼ Fl. ▼ Ri	roperty type ipered segm exible pipe gid pipe
	Add Number of sec Sections : 3 Name 1 seg_1_1 2 Sectio 2	tions : 3 S Length (m) 20.000 20.000 20.000	Edit segment typ Image: Edit segment typ Image: Sections length : 60.000 m Target element length (m) - - - - -	Number of elements 2 2 2 2	Segment prope Tower_1_Tower. Tower_1_Tower. Tower_1_Tower.	erty Pı ▼ Ta ▼ Fl. ▼ Ri	roperty type ipered segm exible pipe igid pipe
	Add Number of sec Sections : 3 Name 1 seg_1_1 2 Sectio 2 Sectio 2	tions : 3 S Length (m) 20.000 20.000 20.000	Remove Edit segment typ Sections length : 60.000 m Target element length (m) - -	Number of elements 2 2 2	Segment prope Tower_1_Tower. Tower_1_Tower. Tower_1_Tower.	erty Pı ▼ Ta ▼ Fl. ▼ Ri	roperty type spered segm exible pipe gid pipe
	Add Number of sec Sections : 3 Name 1 seg_1_1 2 Sectio 2	tions : 3 S Length (m) 20.000 20.000	Remove Edit segment typ Sections length : 60.000 m Target element length (m) - -	Create segment type Number of elements 2 2 2 2 2 2	Segment prope Tower_1_Tower. Tower_1_Tower. Tower_1_Tower.	erty Pı ▼ Ta ▼ Fl ▼ Ri	roperty type spered segm exible pipe gid pipe
	Add Number of sec Sections : 3 Name 1 seg_1_1 2 Sectio 2	tions : 3 S Length (m) 20.000 20.000	Remove Edit segment typ Edit segment typ Sections length : 60.000 m Target element length (m) - -	Vumber of elements 2 2 2 2 Warning : this ddrag coefficients	Segment prope Tower_1_Tower. Tower_1_Tower. Tower_1_Tower.	erty P ▼ Ta ▼ Fl. ▼ Ri arsedes th I drag in tl	roperty type upered segm exible pipe igid pipe e nomal he
	Add Number of sec Sections : 3 Name 1 seg_1_1 2 Sectio 2 Sectio 2 Rayleigh damp	tions : 3 S Length (m) 20.000 20.000 20.000	Edit segment typ Edit segment typ Sections length : 60.000 m Target element length (m) - - - 0.0001	Vumber of elements 2 2 2 2 Warning : this di drag coefficients Aerodynamic co	Segment prope Tower_1_Tower. Tower_1_Tower. Tower_1_Tower. Tower_1_Tower.	erty Pr ▼ Ta ▼ Fl. ▼ Ri ersedes th I drag in ti of segmen	roperty type spered segm exible pipe gid pipe le nomal he t types
	Add Number of sec Sections : 3 Name 1 seg_1_1 2 Sectio 2 Sectio 2 Rayleigh damp	tions : 3 S Length (m) 20.000 20.000 20.000 20.000	Remove Edit segment typ Image: Edit segment typ Sections length : 60.000 m Target element length (m) - - - - - - - - - - - - - - - -	Create segment type Number of elements 2 2 2 Warning : this di drag coefficients Aerodynamic co Number of Reyr	Segment prope Tower_1_Tower. Tower_1_Tower. Tower_1_Tower. Tower_1_Tower.	erty Pr V Ta V Fr Ri ersedes th I drag in ti of segmen \$	roperty type pered segm exible pipe igid pipe de nomal he he nt types
	Add Number of sec Sections : 3 Name 1 seg_1,1 2 Sectio 2 Sectio 2 Rayleigh damp Tower shadow Drag coefficier	tions : 3 S Length (m) 20.000 20.000 20.000 20.000	Remove Edit segment typ Cections length : 60.000 m Target element length (m) - - - 0.0001	Create segment type Number of elements 2 2 2 2 2 Warning : this d drag coefficients Aerodynamic co Number of Reyn Drag coeff.	Segment prope Tower_1_Tower. Tower_1_Tower. Tower_1_Tower. Tower_1_Tower.	erty Pr Ta Fl. Ri ersedes th I drag in th of segment \$	roperty type ipered segm exible pipe igid pipe ie nomal he ti types
	Add Number of sec Sections : 3 Name 1 seg_1_1 2 Sectio 2 Sectio 2 Sectio 2 Rayleigh damp Tower shadow Drag coefficier (used by aero s	tions : 3 <u>S</u> <u>Length (m)</u> 20.000 20.000 20.000 20.000 ing coefficient nt : solver only)	Remove Edit segment type Image: Sections length : 60.000 m Target element length (m) - - - - - - 0.0001	Number of elements 2 3 3 4 4 4 5 4 4 5 5 5 4 4 5 5 5 6 7<	Segment prope Tower_1_Tower. Tower_1_Tower. Tower_1_Tower. Tower_1_Tower.	erty Pr Ta Fl Ri ersedes th I drag in ti of segmen	roperty type spered segm exible pipe gid pipe the normal he nt types
	Add Number of sec Sections : 3 Name 1 seg_1_1 2 Sectio 2 Sectio 2 Sectio 2 Rayleigh damp Tower shadow Drag coefficier (used by aero s Line :	tions : 3 S Length (m) 20,000 20,000 20,000 20,000 20,000 20,000	Remove Edit segment type Image: Edit segment type Sections length : 60.000 m Target element length (m) - - - - - - - - 0.0001 Default	Vumber of elements 2 2 2 2 2 Varning : this di drag coefficients Aerodynamic co Number of Reyn Drag coeff. Reynolds Nut 0.000	Segment prope Tower_1_Tower. Tower_1_Tower. Tower_1_Tower. Tower_1_Tower. Tower_1_Tower.	erty Pr ▼ Ta ▼ Fl. ▼ Ri arsedes th I drag in ti of segmen \$	roperty type upered segm exible pipe igid pipe he nomal he t types

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:

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	DeepLines 5.6.0 - 01 OC4 test.dsk *			



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.
- Tower shadow:

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

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		Fea	tures for W	ind turbines			
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Edit horiz	ontal axis wind turb	ine HAWT_2					,
Object:	HAWT_2			~			ОК
Name:	HAWT_2				Heading /	Ox: 0 de	g. Save
Coord. of reference po	X(m) Y(m	n) Z(m) S	tate \ Linked to	Attach point	Con	nection	Cancel
Turbine Bl Tower len Tower to Number o	ade Tower Nacell gth : 0.2 pe O Conic idd Re f sections : 1	e Hub Power m kal tower move Edit	Train Control A Color:	erodynamic User define Create segment type	ed from bottom	to top	
Sections	1 Sec	tions length : 0.200 Farget element len	m Igth (m) Nun 1	nber of elements	Segment pr Tower_2_To	roperty Pro wer 💌 Tape	perty type ared segm
Rayleigh	lamping coefficient : idow	0.0001	1	Warning : this dr drag coefficients Aerodynamic coe Number of Reyn- Drag coeff.	ag coefficient s entered as No efficients section olds : 1	supersedes the ormal drag in the ons of segment t	normal ypes
Drag coe (used by	aero solver only)			Reynolds Nur	nber CD	-	-

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

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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.

land the second s	HAWT_1			~			OK
lame:	1 1				Heading /	Ox: n dea.	Save
	10m1_1				-	0 00	Cancel
ioord. of 🚽	(m) Y (m)	Z (m) 9	State \ Linked to	Atta	ach point Con	nection	
eference point		10	Free	~	~	 Edit connect 	stion
Turbine Blade To	wer Nacelle	Hub Power	Train Control	Solver			
Drawing Fairlead/	Hang-Off points	Physical Prop	erties				
Diawing Taileau/	nang-on points	r njelodi r rop					
					Number of angles :	1	
					Drag coefficient mu	Itiplied by area (m²)	
					Angle (deg.)	Cd x A	
					0.000	0.000	
Nacelle N	lass	0.000	t	1			
	IXX	0.000	kg.m²	1			
Nacelle Ir	IYY	0.000	kg.m ²	1			
	IZZ	0.000	kg.m²]			
				Π			
			area (m ⁴)				
Vertical d	aq coefficient	multiplied by	area (m)	1			

Figure 3-18 : Nacelle new panel

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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:



Figure 3-19 : Example of HAWT.JSON file

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• HAWT_1_Blade.JSON gathers the blade mechanical and aerodynamic data:





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- 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

С

- 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 postprocessed on the blades except on the blades root node.

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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 EnvironmentalSet to define different analyses with different options for the same HAWT object.

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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.

Control mode		×
Control mode		ОК
Generator	Edit	Cancel
Pitch	Edit	
Yaw	Edit	
Brake	Edit	
Cut-in wind speed :	3 m/s	
Cut-out wind speed :	25 m/s	
Time step for controler :	2e-2 s	

Figure 3-22 : New Control mode panel

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

🔳 Edit horizontal a	axis wind turbine HAWT_1	×
Object:	HAWT_1 ~	OK
Name:	HAWT_1 Heading / 0x: 0 deg.	Save
<u> </u>	X (m) Y (m) Z (m) State \ Linked to Attach point Connection	Cancel
Loora, or reference point	0 0 10 Free ~ Connectio	n
Turbine Blade	Tower Nacelle Hub Power Train Control Aerodynamic	
No Cor	ntrol	
◯ Control	A	
Dil opti	tion	
Mode	\sim	



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

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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.

Default Option: No specific data exchange

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

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Control dll option	1						;
DLL file	\00-CONTROL\Dis	con.dll					OK
DLL procedure n	ame DISCON						Cancel
Input files for dll :				•	· Add	Remove	
Data exchange og Reference frar Mean win Nacelle Rotor Data exchan Constant val Load/relo Variable	ptions me d ge option ue exchange ad Data exchange batch file Object Position	None Unit(Factor/SI)	Channel id (Write to file	None rame) Posi	tion(Ref.Frame)	Add line Remove line

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

Example of DATA Exchange:

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

PRIN	NCIPIA		[Featu	DeepLines W	/ind			
V Drincipio Door	um aust Nia		10				Dete : 1	0.00.01
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(Control dll optio	n						
	DLL 6la	100.00						01
	DELTIC		ATTICE (Discontial					UK
	DLL procedure r	name DISCON						Cancel
	Input files for dll	:					Add Remove	
	- Data exchange o	options						
	Reference fra	ime						
	🔿 Mean wi	nd						
	Nacelle							
	Onotor							
	🗹 Data excha	nge option						
	Constant va	ilue exchange	D1		\sim	Write to file D2_wri	ite	/
	✓ Load/reload Data exchange batch file C:\\DLW_Test\Turbine_GUI_2020_11_25\One_Aero_d2_Batch.tv				tch.txt			
	Variable	Object	Position	Unit(Factor/SI)	Channel id	Object(Ref.Frame)	Position(Ref.Frame)	Add line
	POSITIONX	Hub_4	Blade hang-of	1	100	Default	Default	Bemove line
	REACTION_	M Blade_41	0.000000	2	101	Default	Default	Tremove mile
	VELOCITY_R	Y Nacelle_4	Center of grav	3	102	Hub_4	Blade hang-off 0	

Figure 3-25 : New Control DLL option panel

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• 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:

💼 Edit Va	riation table		×					
Object [Name [Object D1 ~							
Rows num	Rows number 4 2							
Name	x	у	Selected row(s):					
1	210	-9	Delete					
2	211	5	Insert after					
3	212	12.2						
4	213	13.3						
			Selected column(s) :					
			Delete					
			Insert after					

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.

Edit Variation table >								
Object	D2_write ~		ОК					
Name [Name D2_write Cancel							
Rows nun	Rows number 3 🗘 Columns number 2 🐳							
Name	x	у	Selected row(s):					
1	2	2	Delete					
2	10	12	Insert after					
3	210	213						

Figure 3-27 : Writing of exchanged data

PRINCIPIA	DeepLines Wind				
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• 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.

🛛 Data exchange o	ption						
Constant value e	xchange	D1		\sim	Write to file D2_write	ite 🗸 🗸 🗸	
Load/reload Data exchange batch file C:\\DL\W_Test\Turbine_GUI_2020_11_25\One_Aero_d2_Batch.txt							
Variable	Object	Position	Unit(Factor/SI)	Channel id	Object(Ref.Frame)	Position(Ref.Frame)	Add line
POSITIONX	Hub_4	Blade hang-of	1	100	Default	Default	Bemove lin
REACTION_M	Blade_41	0.000000	2	101	Default	Default	Tremove in
VELOCITY_RY	Nacelle_4	Center of grav	3	102	Hub_4	Blade hang-off 0	

Figure 3-28 : Exchanged data definition

PRINCIPIA	DeepLines Wind				
	Features for Wind turbines			And	
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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.

- Generate XML file	for aerodynamic option		OK
🔄 Prandtl's co	prrection for tip losses	Save as	Cancel
🔄 Prandtl's co	prrection for hub losses		
Tower sha	dow model (effects of the tower on the wind)		
🗌 Dynamic st	all model		
Model for d	lynamic inflow		
	for skewed wake (yawed rotor)		
Snel's corre	ection for three dimensional and rotation effects		
XML file for aerody	namic option		
Aero models XML	\Examples\07_Windturbine\01_0C4\aeroBEM_V	14.xml 🛄	
XML file for blades	profiles (previous versions)		

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.

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	Aero	o solver option			×
		Generate XML file for aerodynamic option			ОК
		Prandtl's correction for tip losses	Save as	5	Cancel
		Prandtl's correction for hub losses			
		Tower shadow model (effects of the tower on the wind)			
		Dynamic stall model			
		Model for dynamic inflow			
		Correction for skewed wake (yawed rotor)			
		Snel's correction for three dimensional and rotation effects			
)	XML file for aerodynamic option Aero models XML \$CUR_PATHL\aero_IFP\aeroBEM_Automatic.xml			
	>	XML tile for blades profiles (previous versions) Blade XML \$CUR_PATH\aero_IFP\airfoil_OneRotor_V14.xml			

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

Edit horizontal	axis wind turbine HAWT_1			
Object:	HAWT_1	~		OK
Name:	HAWT_1		Heading / Ox: 0 deg.	Save
Coord. of	X (m) Y (m) Z (m)	State \ Linked to Attach poir	t Connection	Edit connection
ererence point		rice v	· · ·	Ear connection
Turbine Blade	Tower Nacelle Hub Po	wer Train Control Aerodynamic		
◉ No Ae	rodynamic loads on blades			
○ Aerody	ynamic loads on blades (aero s	olver)		
Onti	on	~		
opu	VII I			

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

Figure 3-31 : Default aero solver option

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TWO TURBINES AND MORE 3.9

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.

~

Aero solver option	×
Generate XML file for aerodynamic option	OK
Prandtl's correction for tip losses Save as	Cancel
Prandtl's correction for hub losses	
Tower shadow model (effects of the tower on the wind)	
Dynamic stall model	
Model for dynamic inflow	
Correction for skewed wake (yawed rotor)	
Snel's correction for three dimensional and rotation effects	
XML file for aerodynamic option	
Aero models XML\00-AERO\aeroBEM_noTS.xml	
XML file for blades profiles (previous versions)	
Blade XML\00-AER0\airfoil_IEATASK37_2rotors.xml	

Figure 3-33 : Aerodynamic option for two turbines

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

Object:	HAWT_2	~
Name:	HAWT_2	Heading / Ox: 0 deg.
Coord of	X (m) Y (m) Z (m) State \Linked to	Attach point Connection
reference point	0 110 119 Anchored ~	✓ Clamp ✓ Edit connection
Turbine Blade	Tower Nacelle Hub Power Train Control Aerody	ynamic
◯ No Ae	erodynamic loads on blades ynamic loads on blades (aero solver)	
Opt	ion AeroSolverOpt_1 ~	

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.

Aero solver option	×
Generate XML file for aerodynamic option	OK
Prandtl's correction for tip losses	Cancel
Prandtl's correction for hub losses	
☑ Tower shadow model (effects of the tower on the wind)	
🗹 Dynamic stall model	
Model for dynamic inflow	
Correction for skewed wake (yawed rotor)	
Snel's correction for three dimensional and rotation effects	
XML file for aerodynamic option	
Aero models XML\00-AER0\aero_opt.xml	
XML file for blades profiles (previous versions)	
Blade XML	

Figure 3-35 : Updated aerodynamic option for two turbines

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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.

me General Combination matrix Turbine Environment components Bisecondary Swells Becondary Swells <th>OK</th> <th>\sim</th> <th></th> <th>t DLC1</th>	OK	\sim		t DLC1
eneral Combination matrix Turbines eneral Combination matrix Turbines	Sav			
eneral Combination matrix Turbines Environment components Bain Swells Baccondary Swells Clocal seas Offsets Currents Prescribed motions Number of quasi-static motions Image: static motions Turbine options Image: static loadings Number of dynamic loadings	Can]		DLC1
eneral Combination matrix Turbines Environment components Main Swells Secondary Swells Local seas Winds Currents Prescribed motions Number of quasi-static motions 1 Prescribed loadings Number of quasi-static loadings Number of quasi-static loadings 1 Number of quasi-static loadings 1 <	ound			
Environment components Main Swells Secondary Swells Local seas Winds Currents				neral Combination matrix Turbines
Main Swells Secondary Swells Coral seas Winds Currents Prescribed motions Number of quasi-static motions Number of quasi-static notions Number of quasi-static loadings Number of dynamic loadings Number of dynamic loadings		Floater motion		Environment components
Secondary Swells □ Local seas □ Winds □ Currents Prescribed motions □ Number of quasi-static motions □ Number of quasi-static motions □ Number of quasi-static loadings □ Number of dynamic loadings □ Number of dynamic loadings				Main Swells
□ cocal seas □ Winds □ currents Prescribed motions □ Number of quasi-static motions □ Number of quasi-static loadings □ Number of dynamic loadings □ Number of dynamic loadings		Number of Floaters		Secondary Swells
Winds □ Currents Prescribed motions □ Number of quasi-static motions □ Number of quasi-static loadings □ Number of quasi-static loadings Turbine of dynamic loadings □ Number of dynamic loadings		Offsets		Local seas
□ Currents Prescribed motions □ Number of quasi-static motions 1 Turbine options □ Turbines Prescribed loadings □ Number of quasi-static loadings 1 ↓		Low Frequency imposed motion		Winds
Prescribed motions Number of quasi-static motions 1 Number of dynamic motions 1 <td></td> <td>Floater motion</td> <td></td> <td>Currents</td>		Floater motion		Currents
Number of quasi-static motions Number of dynamic motions Image: static loadings Number of quasi-static loadings Image: static lo		Turbine options		Prescribed motions
Number of dynamic motions		Turbinge	1	Number of quasi-static motions
Prescribed loadings			1	Number of dynamic motions
Number of quasi-static loadings 1 + Number of dynamic loadings 1 +				Prescribed loadings
Number of dynamic loadings			1	Number of quasi-static loadings
			1	Number of dynamic loadings

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;

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

	Edit er	nvironment set DLCp	orod										×
C)bject:	DLCprod				\sim							OK
													Save
N	ame	DLCprod											Cancel
	General	Combination matrix	Winds Turbines										
				•									
		Number of turbines pro	operties: 2	•	_	Insert new turbine	prop	erties					
					Rer	nove selected turb	ines p	properties					
		Name	Hawt	Start Up		Start Up var tak	le	Control mode		Control options	Aerodynamic so	ol	
	1	TurbineProd	HAWT .	 StartUp 	•	EnvStartUp	-	Production	-	ControlDII_dis	AeroBEM_V14	•	
	2	TurbineParked	HAWT	 None 	•	Default	•	Default	•	ControlDII_par 💌	Default	-	

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:

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		Tables			

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.

🕻 Edit Va	riation table		· · · · · · · · · · · · · · · · · · ·
Object	Sart20rpm 🗸 🗸		OK
Name [Sart20rpm		Cancel
Rows num	ber 2 🔹 Columns nur	mber 2	
Name	x	у	Selected row(s):
1	0	0	Delete
2	100	-2.0944	Insert after
			Delete Insert after
			Graph

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 EnvironmentSet 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":

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	Edit displacement	Displacement_1						×	
	Object: D	isplacement_1		\checkmark				OK	
	Name Displacement_	1		Color	•			Save	
								Cancel	
	Name	Object Hub 1	Location COG	Type	Object	HAWT_1	~		
		1100_1		control	Locatio	n HUB_ref_poin	it 🗸		
					Туре	Control	~		
						Ci Sinusoidal Uniform accele	eration		
					F	Rem Time dependa Dis/Connectio	int in		
	Properties of selected su Name Disp_0	b-displacement				Control			
	lype	∠-rotation		~					
	Amplitude	0	deg.						
	From step	0							
	To step	0							

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

bloor	Displacement_1		\sim		OK
ame Displacem	ient_1		Color		Save Cance
Name Disp_0	Object Hub_1	Location COG	Type Control	Object HAWT_1 ~ Location HUB_ref_point ~	
operties of selecte Name Disp	d sub-displacement			Create new displacement Remove selected displacement	
Type Amplitude From step	Z-rotation Z-rotation Static displacement via Dynamic displacement Dynamic displacement Turbine start up	dll via dll via dll with reference	~		
To step	0				

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

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

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

E	dit displacement L	Jisp							~
Obje	ect: (Disp			\sim				OK
Nan	ne Disp				Color	•			Save
									Cancel
	Name	Object	Location	Туре			Object		
1	StartUp	HAWT_Hub	COG	Control			Location	HAWT V	
							Туре	Incremental ×	
								Create new displacement	
Properties of selected sub-displacement Name StartUp									
т	уре	Turbine start up			~				
F	roportional term	1.000e+08	N.m/(rad/s)						
C)erivative term	0.000e+00	N.m/(rad/s²)						
Ir	ntegral term	1.000e+08	N.m/rad		Prescribed speed	Cod20mm			
C	Corner frequency	1.570796	Hz		Variation table	Sanzoipin		~	
N	faximum torque	1.000e+10	N.m						
N	faximum torque rate	1.000e+10	N.m/s						
E	ind of start up	100	s						

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 EnvironmentSet to apply the Environmental table on the previous Start-up in an EnvironmentSet (see Figure 4-2).

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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).

Edit wind Wind_1		×
Object: Wind_1	~	OK
Name:	Wind_1 Color:	Save
		Cancel
Туре	FF WIND ~	
Heading /x	0 deg.	
File		
Reference Position/x	0 m	
Reference Position/y	0 m	
Time for Mirror Effect	0 s	
Ramp time duration	0 s	
Beginning of turbulent wind	0 \$	

Figure 4-9 : FF-WIND new definition panel

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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".

			F :									
Obier	ait en	Ivironment set	incomposite of 1	oet_1		~						04
obler	ы.		nioninencoer_1			•						AU Source
Name	,	Environn	nentSet_1									Canaal
												Cancer
Ge	neral	Combination n	natrix Winds									
	0							Number o	of winds 1	-		
	0								Remove selected	wind		
[Wind name	Туре	Duration (s)	Beg. time (s)	Heading (d	Ref. Pos./x	Ref. Pos./y	Time for M	Ref. I		
	1	Wind_1	FF_WIND	0.000	0.000	0.000	0.000	0.000	0.000			
1	<									>		

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