

# **QBlade Short Manual**

## v0.8

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### Contents

Introduction	2
Changes in v.08	2
Data Structure	3
General User Interface	4
Airfoil Design	6
Direct Airfoil Analysis	7
Polar 360° Extrapolation	8
Blade Design	9
Rotor / Turbine Blade Element Momentum (BEM) Simulation	10
Multi Parameter Simulation	11
QFEM - Structural Blade Design / Modal Analysis / Static Loading	12
Turbulent Windfield Generator	14
FAST Unsteady Aeroelastic Simulation	15
References	18

#### Introduction

This short manual is not intended to give an overview of the applied simulation methods and their theory. This document is rather meant as a brief guide to enable the users to work with the new version of QBlade and give a short overview of the overall functionality and the new features of v.08. A more detailed document, an update to the QBlade Guidelines v.06 [1] will be made available later this year.

With the new version QBlade has been fully integrated the aeroelastic simulator FAST [2] from NREL. To be able to setup a FAST simulation inside QBlade a generator for turbulent windfields and module to generate a simplified structural model and perform a modal analysis have been integrated in QBlade. The new FAST module can be used to setup, run and post process FAST simulations. An overview of the coupling can be seen in figure 1.



figure 1: Overview of the FAST coupling within QBlade

#### Changes in v.08

The following new modules and functionality has been added to QBlade v.08:

- Windfield Generator: Correlated time series generated with Veers Sandia method
- QFEM Module: Structural blade design, modal analysis, static deflection & stresses
- FAST Module: Unsteady aerodynamics & structural dynamics integrated
- Improved import/export functionality for airfoils, polars, blade geometry, windfields in various NREL, XFLR and QBlade formats
- GUI improvements, refactoring of existing modules & integration of completely new database and object structure is resulting in a version that is much more stable and better suited for the easy integration of new modules

#### **Data Structure**

One important aspect is to understand how the data is structured within QBlade and how the data objects are related to each other. figure 2 shows the different modules and the related data objects and the types of analysis that can be performed. The arrows between the objects indicate the dependencies among them. For example a blade depends on 360° polars which depend on polars which depend on airfoils. If one of these objects is deleted from the database, all associated objects are deleted as well. If an airfoil is deleted all polars, the associated 360° polars, blades, structures and even simulation results are also deleted from the database. It can also be seen that, to create a FAST aeroelastic simulation a blade with a defined structure and a windfield needs to be present in the database.

MODULES	OBJECTS	ANALYSIS TYPE
Airfoil Design	Airfoil	
XFOIL Analysis	Polar	Viscous - Inviscid 2D Panel Method
<b>360</b> <sup>•</sup> Polar Extrapolation	360 Polar	Flat Plate Extrapolation
Blade Design	Blade	Steady BEM Simulation
Turbine Design & Simulation	−−−→Turbine	Steady BEM Simulation
Structural Blade Design	Structure	Euler Beam Modal Analysis
Static Blade Loading		Euler Beam Static Deflection
NREL FAST Simulation	FAST	Unsteady BEM & Structural Dynamics
Windfield Generator	Windfield	Veers Sandia Method Correlated Time Series

figure 2: QBlades object structure, modules and analysis types

QBlade v.08 can open old QBlade project files (\*.wpa), however due to the new object structure and database QBlade v.08 projects are not compatible with older QBlade versions.

#### **General User Interface**



figure 3: Qblades Graphical User Interface (GUI), startup screen

figure 3 shows the Graphical User Interface of QBlade. It consists of five different components:

- **Menu**: QBlade projects can be loaded from the File menu, the specific menus of the different modules each contain functionality to import / export or modify the related data objects
- Main Toolbar: From the main toolbar the different modules can be accessed, each module has a symbolic representation. If the mouse hovers over a symbol a tooltip with some explanation is displayed. From here it is also possible to start a new, open or save a project
- Module Toolbar: In the module toolbar the different objects (such as airfoils, blades etc.) that can be manipulated in the module are displayed in comboboxes. In case the object inside a combobox is changed, the related comboboxes are updated to only show associated objects (in case a DU-21 airfoil is selected in the airfoil combobox only the associated polars would be displayed inside the polar combobox)
- **Dock Window**: The dock window contains all functionality of a module. Simulations can be defined or blades can be designed. In case an object is displayed in a graph the curve properties (color, style width) can also be changed from the dock window
- **Module View**: There are two different module views. A 2D window that displays graphs and an OpenGL window that can render blade geometry, windfields, etc.



figure 4 shows a typical QBlade graph with a plot inside (in this case a 360° polar).

figure 4: A QBlade graph with a 360° polar curve object inside

A graph can be manipulated by clicking with the mouse and dragging the curve inside the graph window or by zooming in and out with the mouse wheel. Zooming while pressing **x** or **y** on the keyboard only zooms the respective axis. A **right click** on a graph activates the context menu (figure 5, left). In the graph context menu the graph type can be changed, the plotted curves can be exported and, depending on the module, other specific options are available. A **double-click** on a graph activates the graph settings (figure 5, right). Inside the graph settings the variables for the x- and y-axis can be selected. The general appearance of the graphs can also be changed here.

	🕞 Graph Settings	? ×
Current Rotor       ▶         Current Graph       ▶         Show all Rotor Curves       ▶         Hide all Rotor Curves       ▶         Isolate Blade Curve       ▶         Compare isolated Blade Curve       ▶         ✓ Set as Rotor Graph       ▶         Set as Blade Graph       ▶         Save View to Image File       Ctrl+1	Variables     Scales     Axis and Grids     Fonts and BackGround       YAxis     Vs.     XAxis       Power Coefficient Cp     Power Coefficient Cp     Thrust Coefficient Ct       Moment Coefficient Cm     Kp     Tip Speed Ratio       1 / Tip Speed Ratio     1 / Tip Speed Ratio	
	Restore Apply OK Cancel	

figure 5: The graph context (left) and settings menu (right)

### Airfoil Design

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figure 6: The Airfoil Design module

In the Airfoil Design module airfoils can be designed via splines, a NACA airfoil generator or imported from a point distribution. These functions are accessed from the **Foil** menu. This module is implemented from the XFLR5 software [3].

NACA generator:	Foil -> NACA Foils
Circular airfoil:	Foil -> Generate a Circular Foil
Import airfoil:	Foil -> Import Foil
Store Spline Airfoil:	Splines -> Store Splines as Foil

#### **Direct Airfoil Analysis**



figure 7: The Direct (XFOIL) Analysis module

In the Direct Analysis module polars can be created using the XFOIL algorithms. To define a polar select the airfoil in the airfoil combobox inside the modules toolbar and click on **Define XFOIL Polar** inside the right dock window. When a polar has been defined the lift and drag coefficients can be computed by pressing the **Analyze** button in the dock window. Polars can be imported / exported from the **Polars** menu at the top. This module is also an implementation from the XFLR5 software.

#### Polar 360° Extrapolation



figure 8: the Polar 360° Extrapolation module

In the 360° Polar Extrapolation module the polars that have been previously created inside the Direct Analysis module can be extrapolated to 360° angle of attack. To extrapolate a polar, select the polar to extrapolate in the polar combobox inside the modules toolbar, select the method of extrapolation (Montgomerie [4] or Viterna [5]) from the dock window and click the **New** button. You can tune the polar shape using the A+, B+, A- and B- sliders and the CD90 (drag at 90° AoA) or AR (Aspect Ratio) number edits. To save a 360° polar click the **Save** button. 360 Polars can be imported / exported from the **360 Polar** menu.

#### **Blade Design**

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2	1,36	3,54	13,08	Circular Foil1	Circular Foil1 360 P				\		
3	4,1	3,85	13,08	Circular Foil1	Circular Foil1 360 P			L	4		
4	6,83	4,167	13,08	Circular Foil2	Circular Foil2 360 P						
5	10.25	4.55	13.08	DU99W405LM	DU99W405LM 360 P			h			
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8	22.55	4,249	9.011	DU97W300LM	DU97W300LM 360 P	=					
9	26.65	4 007	7 795	DU91W2250LM	DU91W2250LM 360				1-1		
10	30.75	3 748	6 544	DU01W2250LM	DU91W2250LM 360						
11	24.95	2 502	5 261	DU02W210LM	DU02W210LM260 D						
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15	51,25	2,518	1,526	NACA64618	NACA64618 360 Polar						
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figure 9: The Blade Design module

Inside the Blade Design module blades can be designed from airfoils and 360° polars. A blade can only be created if at least one 360° polar is present in the database. To start a blade design click the **New** button. Existing blades can be edited via the **Edit** button. The import / export functions for an .stl geometry file a blade table or a WT\_Perf or AeroDyn blade file can be found inside the **Blade/Rotor** menu.



#### Rotor / Turbine Blade Element Momentum (BEM) Simulation

figure 10: The Rotor BEM Simulation module

The Rotor / Turbine Simulation modules perform a Blade Element Momentum Method simulation of a rotor or a turbine. A rotor simulation only contains dimensionless variables such as tip speed ratio or power coefficient. After a turbine object is defined from a rotor within the turbine simulation module a non-dimensionless simulation can be performed (power, windspeed, etc). A simulation is defined from the **Define Simulation** button in the dock window. A range of tip speed ratios or windspeeds has to be defined before the simulation is started with **Start Simulation**. Simulation results can be exported by right clicking on a graph and selecting: **current graph -> export graph**, which exports all curves that are plotted inside the graph as a .txt or .csv file.



#### **Multi Parameter Simulation**

figure 11: The Multi Parameter Simulation module

A multi parameter simulation is a simulation over a range of wind speeds, rotational speeds and pitch angles. Before a simulation is defined the range for each parameter should be set, parameters can also be selected as fixed for a simulation. The simulation is defined and started using the dock buttons. Each graph in this module can plot curves over one main variable and one free parameter. The main variable and free parameter can be set in the graphs context menu (right click). The fixed parameter of each graph has the value that is selected in the according combobox from the toolbar (windspeed, rotational speed, pitch angle). An export is possible from the graphs context menu.

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	Shell Thickness(%)	Spar Thickness(%)	Spar Position	Spar Angle	-
1	0,02	0,08	0,25	0	
2	0,02	0,08	0,25	0	
3	0,02	0,08	0,25	0	
4	0,02	0,08	0,25	0	
5	0,02	0,08	0,25	0	
6	0,02	0,08	0,25	0	
7	0,02	0,08	0,25	0	
8	0,02	0,08	0,25	0	
9	0,02	0,08	0,25	0	
10	0,02	0,08	0,25	0	
	0,02	0,08	0,25	0	
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11 12	0,02	0,08	0,25	0	
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#### **QFEM - Structural Blade Design / Modal Analysis / Static Loading**

figure 12: The QFEM – Structural Blade Design / Modal Analysis / Static Loading Module

In the structural blade design module [6] a simple structural model for the blade can be defined inside the **Structural Blade Design / Modal Analysis** tab. The model is defined and simulated using isotropic material properties only, but can be a good first approximation. After a structural model has been defined and the **Save** button is clicked the sectional blade properties are automatically computed and a modal analysis is being performed. The resulting mode shapes and frequencies can be visualized and changed from the dock

window. The structural properties can be plotted in graphs, by changing to **Graph View** in the toolbar. After a structural model has been defined a static loading simulation can be set up from the **Static Loading / Deflection** tab. It is possible to import loading data from a previously simulated turbine (that uses the same rotor). After Save is clicked the static deflection and blade surface stresses (von Mises) are computed and displayed in the **3D View**. Results of the loading simulation can be plotted in **Graph View**.



Flapwise Mode 2 Eigenfrequency: 4.56502 Hz

#### figure 13: Visualization of the 2nd flapwise mode shape and Eigenfrequency



X Axis Tip Defl.0.00512723 [m]

Z Axis Tip Defl. 0.0781274 [m]

figure 14: Visualization of a static blade deflection test, von Mises stress distribution and tip deflection

#### **Turbulent Windfield Generator**



figure 15: The Turbulent Windfield Generator module

Inside the Turbulent Windfield Generator [7] module a correlated, turbulent windfield can be created using the Sandia Method [8]. The windfield objects generated here can later be used within a FAST simulation. The different timesteps can be visualized using the slider inside the toolbar. It is important to note that creating windfields is computationally very expensive, increasing the number of points or timesteps results in much larger computational times.



#### FAST Unsteady Aeroelastic Simulation

figure 16: The FAST Unsteady Aeroelastic Simulation module

From inside the FAST module a whole aeroelastic FAST simulation can be set up, run and post processed from QBlades internal database. To setup a FAST simulation a rotor, a windfield (with a suitable diameter) and a blade structure are needed in the database. A FAST simulation can be defined by pressing the **New** button.

rameters	Outpu	ut Sections	Output Parameter	rs			
AST Simulat	ion Para	ameters			Aerodynamic Parame	eters	
Name of Sim	ulation:	FAST Simul	ation		Aero Time step [s]:	0.01	
Windfield:		New Windf	field	•	StallMod:	STEADY	•
Total run tim	e [s]:	10			UseCm:	NO_CM	•
AST Time st	ep [s]:	0.01			InfModel:	EQUIL	•
Rotor:		NREL 5MW	Reference	•	IndModel:	SWIRL	•
Number of B	ades:		0 2 0	3	TLModel:	PRANDTL	•
lotor Speed	[rpm]:	12			HLModel:	PRANDTL	•
Nacelle Yaw	[deg]:	0			Blade Structure		
Invironment					Blade Structure:	IREL 5MW Reference Structural Model	•
Gravity [m/s	^2]:	9.81				FlapDOF 1	
AirDens [k/m	^3]:	1.225				FlapDOF 2	
KinVisc [m^2	/s]:	1.4661e-05				EdgeDOF	

figure 17: Parameter tab of FAST Simulation dialog

To setup a simulation a windfield, rotor and blade structure need to be selected and simulation parameters for FAST and AeroDyn [9] and environmental parameters need to be specified in the **Parameters** tab (figure 17). The degrees of freedom of the structural model (FlapDOF 1&2, EdgeDOF) can be enabled or disabled for the simulation.

arameters	Outpu	ut Sections	Output Parameters			
hoose blad lease notic ection as ca	le sections e that FAS alculation r	where you w T uses anoth node there is	vant to put virtual strain er represantation of the one node less.	n gages or produ e blade than QBl	ce AeroDyn out ade. Because F/	put. AST uses the midpoint of a blade
Strain	AeroDyn					
Gage	Output					
(max. 5)	(ariy)					
	set all					
<b>V</b>	<b>V</b>	1 - 2.18m	- Circular Foil 1 360 Pola	r		
	<b>V</b>	2 - 4.23m	- Circular Foil 1 360 Pola	r		
	<b>V</b>	3 - 6.96m	- Circular Foil 1 360 Pola	r		
<b>V</b>	<b>V</b>	4 - 10.04m	- Circular Foil2 360 Pola	ar		
<b>V</b>	<b>V</b>	5 - 13.80m	- DU99W405LM 360 Pc	blar		
<b>V</b>	<b>V</b>	6 - 17.90m	- DU99W350LM 360 Po	lar		
<b>V</b>	<b>V</b>	7 - 22.00m	- DU99W350LM 360 Pd	olar		
	<b>V</b>	8 - 26.10m	- DU97W300LM 360 Pd	olar		
	<b>V</b>	9 - 30.20m	- DU91W2250LM 360 P	Polar		
	<b>V</b>	10 - 34.30n	n - DU91W2250LM 360	Polar		
	<b>V</b>	11 - 38.40n	n - DU93W210LM 360 P	olar		
	<b>V</b>	12 - 42.50n	n - DU93W210LM 360 P	olar		
	<b>V</b>	13 - 46.60m	n - NACA64618 360 Pola	ar		
	<b>V</b>	14 - 50.70m	n - NACA64618 360 Pola	ar		
	<b>V</b>	15 - 54.46m	n - NACA64618 360 Pola	ar		
	<b>V</b>	16 - 57.53n	- NACA64618 360 Pola	ar		
	<b>V</b>	17 - 60.27m	n - NACA64618 360 Pola	ar		
	V	18 - 62.32n	n - NACA64618 360 Pola	ar		

figure 18: Output Sections tab of FAST Simulation dialog

In the second tab **Output Sections (**figure 18) of the FAST Simulation dialog virtual strain gages can be distributed and AeroDyn output can be enabled / disabled for every blade station.

	Output Sections	Output Parame	eters		
Choose which	parameters the FAST	Foutput should co	ontain.		
General					
TStart [s]:	0				
DecFact:	1				
Rotor Paran	neters				
TotV	VindV	WindVxi	WindVyi	WindVzi	HorWindV
Hor	Total hub-height w	ind speed magn	itude [m/s] wr	RotTorq	RotThrust
Ro	tCp	RotCq	RotCt	LSSTipPxa	LSSTipVxa
LSST	īpAxa				
Blade Param	neters				
Blade Param	neters lades: 📝 Blade 1	🔲 Blade 2 🔲 I	Blade 3		
Blade Param For which b	neters lades: 👿 Blade 1 Dxc	Blade 2	Blade 3	TipDxb	ТірDуb
Blade Param For which b Tip Tip	neters lades: V Blade 1 Dxc	Blade 2 III	Blade 3 TipDzc TipALzb	TipDxb TipRDxb	TipDyb TipRDyb
Blade Param For which b Tip Tip	Iades: V Blade 1 Dxc ALxb CIrnc S	Blade 2 II	Blade 3 TipDzc TipALzb Spn%1ALyb	TipDxb TipRDxb Spn%1ALzb	TipDyb TipRDyb PtchPMzc
Blade Param For which b Tip Tip Roo	neters Iades: ♥ Blade 1 Dxc C ALxb C Clrnc Si otFxc C	Blade 2 III	Blade 3 TipDzc TipALzb Spn%1ALyb RootFzc	TipDxb TipRDxb Spn%1ALzb RootFxb	TipDyb TipRDyb PtchPMzc RootFyb
Blade Param For which b Tip Tip/ Tip/ Roc Roc	neters Iades: ♥ Blade 1 Dxc	Blade 2 TipDyc TipALyb pn%1ALxb RootFyc RootMyc	Slade 3 TipDzc TipALzb Spn%1ALyb RootFzc RootMzc	TipDxb TipRDxb Spn%1ALzb RootFxb RootMxb	TipDyb TipRDyb PtdrPMzc RootFyb RootFyb

figure 19: Output Parameters tab of FAST Simulation dialog

In the third tab **Output Parameters** (figure 19) the desired FAST output parameters can be selected. Hovering the mouse over one of these parameters enables a tooltip with a short explanation. A more detailed explanation can be found inside the FAST User's Guide [10].

A simulation is started by pressing the **Start Simulation** button from the dock. When a simulation is finished the FAST results are automatically loaded inside QBlades database and can be investigated and compared in the graphs. There are two types of graphs, FAST graphs and Blade graphs. FAST graphs can plot the fast variables, or aerodyn variables (for one selected section). AeroDyn variables are plotted for the section that is selected inside the combobox the toolbar. Blade graphs can only plot AeroDyn results (all blade sections at once) for the timestep that is currently selected by the slider in the toolbar.

The FAST simulation files can be exported from the **FAST Simulation** menu and be used to setup more advanced FAST simulations outside QBlade.

#### References

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