

# Introduction to Bladed Wind Turbine Design Software

**Cardiff University / DNV GL**  
**November 2016**



# BLADED

Wind turbine design

Bladed version 4.6.  
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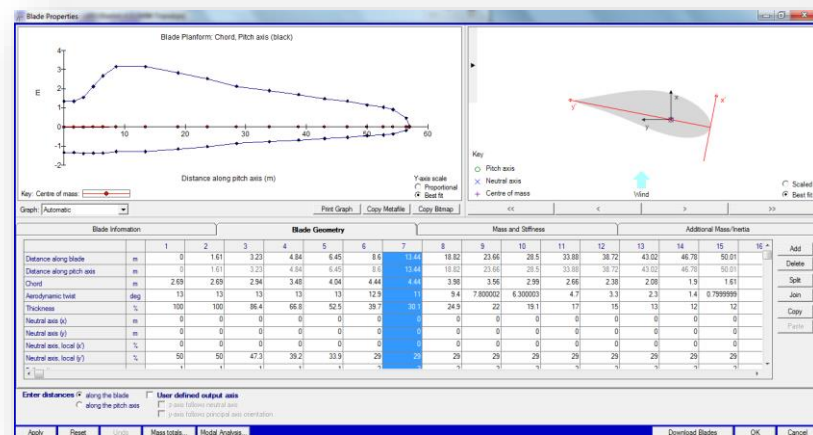
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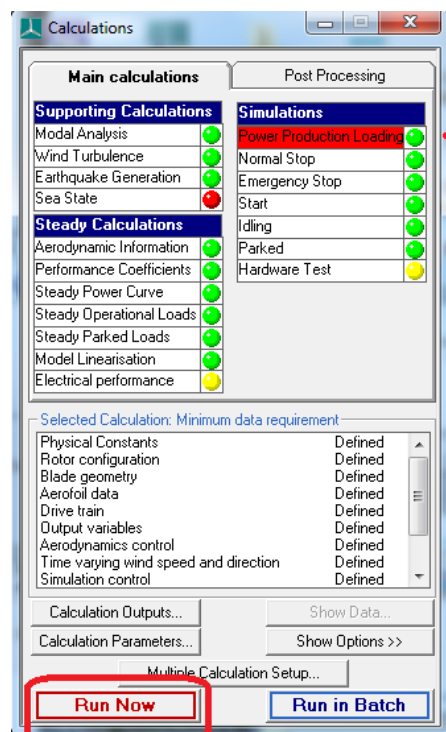
# Bladed: Wind turbine design software

- Bladed is the industry standard integrated software package for the design of onshore and offshore wind turbines.
- Based on self-consistent and rigorous multibody formulation of structural dynamics
- Maintained and developed by engineers with over 3 decades experience in the wind industry
- 500 licenses worldwide, 300 organisations
- Full technical support and training courses

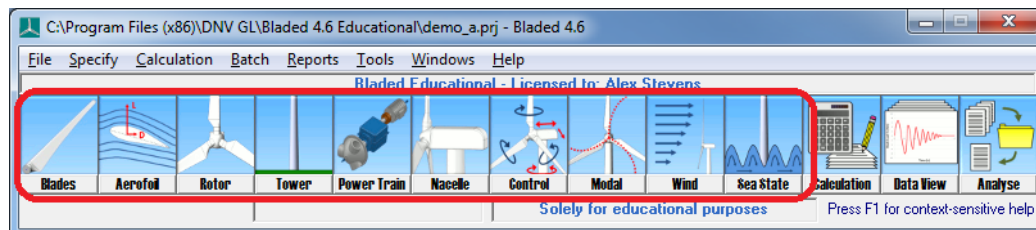


# Bladed: A Virtual Wind Turbine

## 1) INPUT

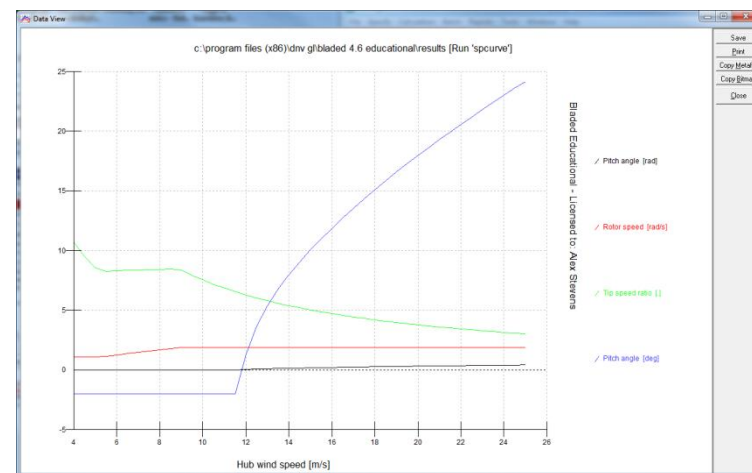


- Turbine definition
- Environmental Conditions (Wind + Wave)



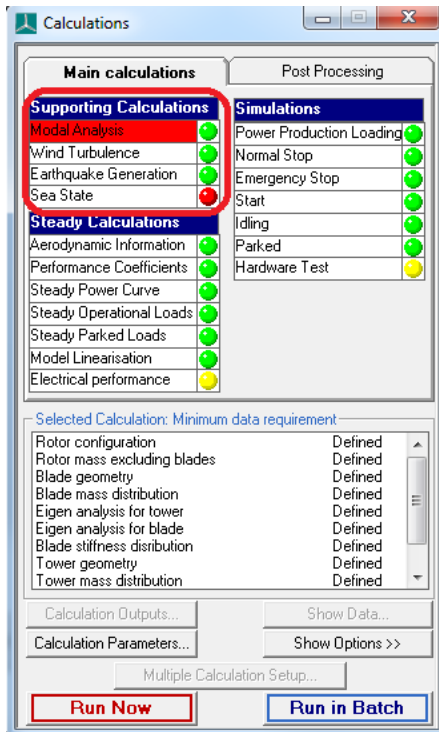
## 2) Choose a Calculation type and RUN

## 3) OUTPUT: loads and performance data and graphs



# Four main categories of calculations

## ■ 1) Preliminary Calculations



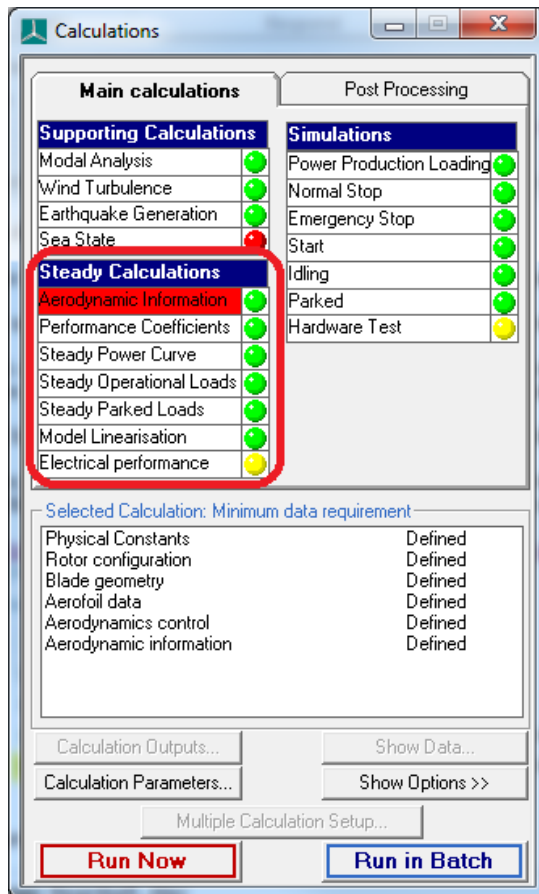
e.g. Modal Analysis, Turbulent wind file generation

These are stand-alone calculations that often need to be performed before full simulations.

For example 'Wind Turbulence' generates input turbulent wind conditions for time-domain simulations.

# Four main categories of calculations

## ■ 2) 'Steady' Calculations



These calculations generate a wide range of turbine outputs under 'steady state' conditions.

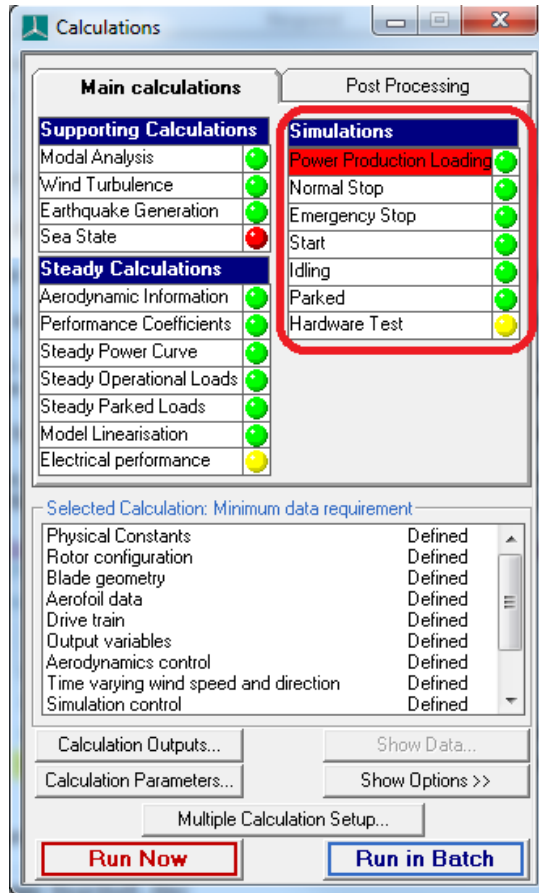
They are NOT time-domain dynamic calculations

They are quick to run but the price of speed is that they include many approximations.

Think of them as providing good 'snap shot' approximations of turbine conditions.

## Four main categories of calculations

### ■ 3) 'Simulations'



These are time-domain simulations.

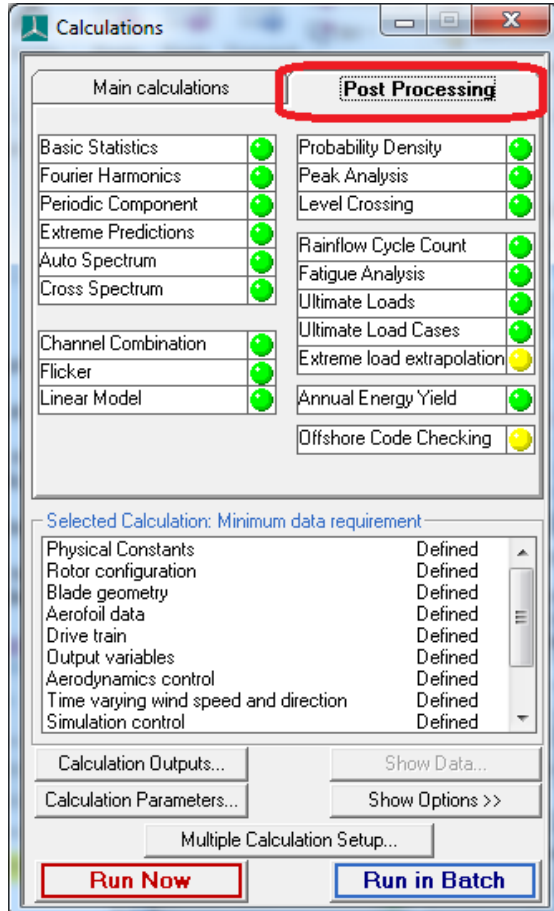
They are slow to run and provide very detailed, dynamic time series output.

Choice of wind input: constant, transient or turbulent.

Turbulent simulations require a pre-calculated turbulence file.

## Four main categories of calculations

### ■ 4) Post Processing Calculations



The input for these calculations is the output from simulations that have already been run.

They allow simulation output data to be analysed in a wide variety of ways.



## **Examples of Bladed input screens**

# Drivetrain and hub definitions

**Power Train**

Transmission Mounting Electrical Losses Network

☐ Not Defined  
☐ Locked speed drive train Fixed rotor speed 0 rpm  
☒ Dynamic drive train model

Gearbox ratio 86.39  
 Generator rotation Same as rotor

Generator inertia 600 kgm<sup>2</sup>  
 HSS inertia 0 kgm<sup>2</sup> (including brake)  
 Gearbox inertia 0 kgm<sup>2</sup>  
 Brake position HSS Define Brake ...

☐ Slipping clutch  
 Friction 0 Additional stiction 0 Nm

☒ Low speed shaft torsional flexibility  
 LSS stiffness 7.5E+08 Nm/rad  
 LSS damping 0 Nms/rad

☐ High speed shaft torsional flexibility  
 HSS stiffness 0 Nm/rad  
 HSS damping 0 Nms/rad

☐ Low speed shaft bending  
 LSS length 0 m  
 Bending point 0 %  
 Bending stiffness 0 Nm/rad  
 Damping 0 Nms/rad

Uncoupled shaft torsional modes:  
 Frequency: 2.222 Hz (13.959 rad/s), damping: 0.0

Encrypt transmission ... Decrypt transmission ...

Apply Reset OK Cancel

**Turbine configuration**

Turbine and Rotor Hub

Blade: 57 m

Nominal rotor diameter	118	m
Rotor diameter (coned)	118	m
Number of blades	3	
Tower height (Ht)	78	m
Hub vertical offset (h)	2	m
Total hub height (Ht+h)	80	m
Blade set angle	-3	deg
Cone angle (C)	0	deg
Tilt angle (T)	4	deg
Overhang (O)	6	m
Lateral Offset (L)	0	m

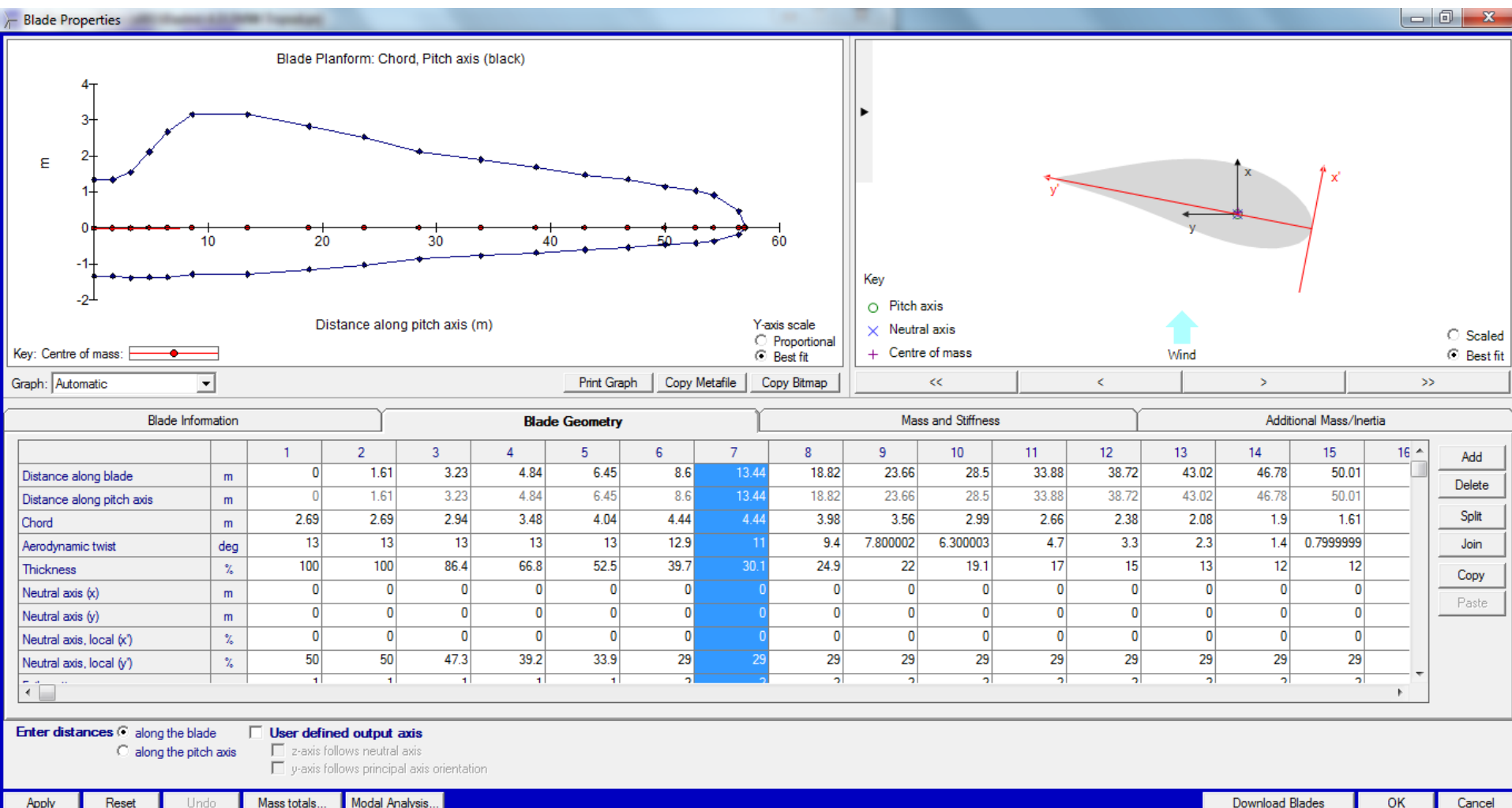
Rotational sense Clockwise  
 Rotor position Upwind  
 Speed Type Variable  
 Control surfaces Pitch  
 Transmission Gearbox

View turbine graphic ...

Encrypt rotor and hub ...  
 Decrypt rotor and hub ...

Apply Reset Mass totals... OK Cancel

# Blade definition



# Tower module

**Tower**

**Tower properties**

☒ Geometry **Tower type:** Material Density (kg/m³) Young's mod (N/m²) Add Delete

☒ Mass ☒ Tubular axisymmetric

☒ Stiffness ☐ Multi-member

☐ Shear flexibility

☐ Torsional degree of freedom ☐ Use geometric stiffening

**Environment**

☐ Land Aerodynamic drag coefficient 0.6

☒ Sea Hydrodynamic drag coefficient 1 Define for each station

Hydrodynamic inertia coefficient 2 Define for each station

Mean water depth (m) 10

Depth of first tower station (m) 15

**Tower Structure**

Add Station Delete Station Copy Paste Undo

Tower Station Number	1	2	3	4	5
Height above surface m	-15	-5	0	5	1
Outside diameter m	3.5	3.36	3.35	3.26	3.1923
Mass per unit length kg/m	2935.71	2668.2	2574.9	2430.1	2214.0
Bending Stiffness Nm²	2.46E+11	2.09E+11	1.945E+11	1.75E+11	1.43E+11
Shear Stiffness N					
Torsional stiffness Nm²					
Polar mom. of inertia kgm					
Wall thickness mm					
Material	-	-	-	-	-
Hydro drag coeff.	-	-	-	-	-
Hydro inertia coeff.	-	-	-	-	-

Point masses (0 defined)

Vibration damper (off) ...

**Foundations and Ground / Sea-bed Properties**

☐ Translational motion ☐ Rotation about horizontal axis

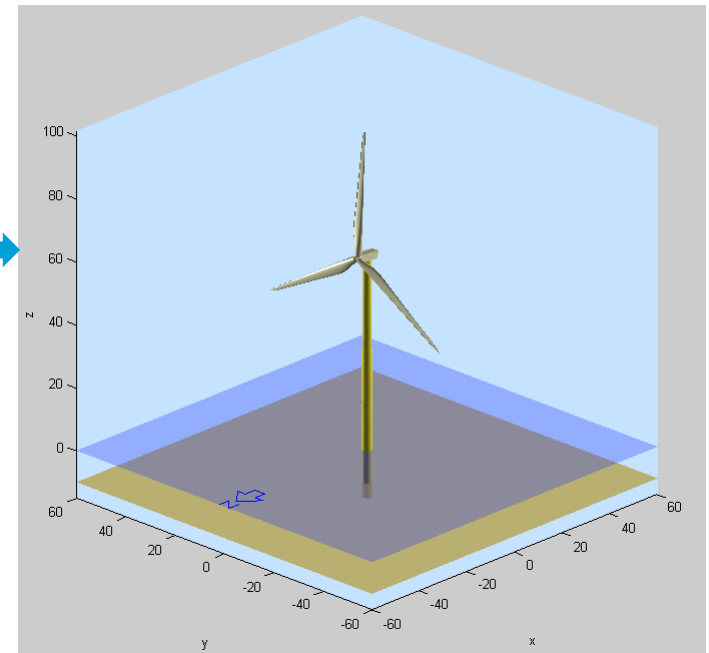
Translational stiffness N/m	0	Rotational stiffness Nm/rad	0
Foundation Mass kg	24000	Inertia of Foundation kgm²	380000

**Graph**

Show: Automatic Copy Metafile Copy Bitmap Print Save

Apply Reset Mass totals... Modal Analysis... Encrypt... Decrypt... OK Cancel

**Tower Geometry**



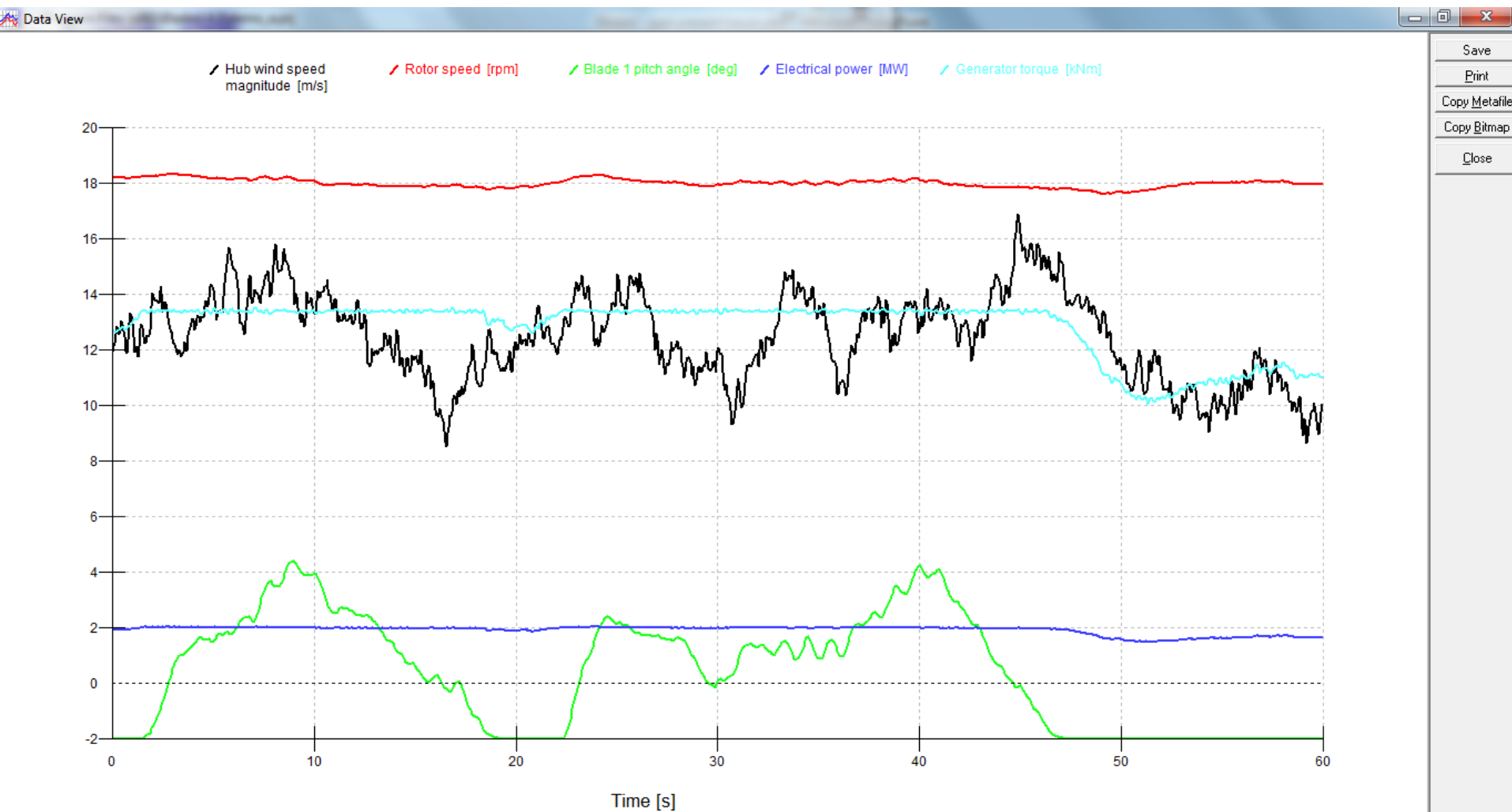
# Batch Capability

- The full version of Bladed includes a Batch function that allows large numbers of simulations to be run, using multiple cores
- This feature is disabled for Bladed Educational

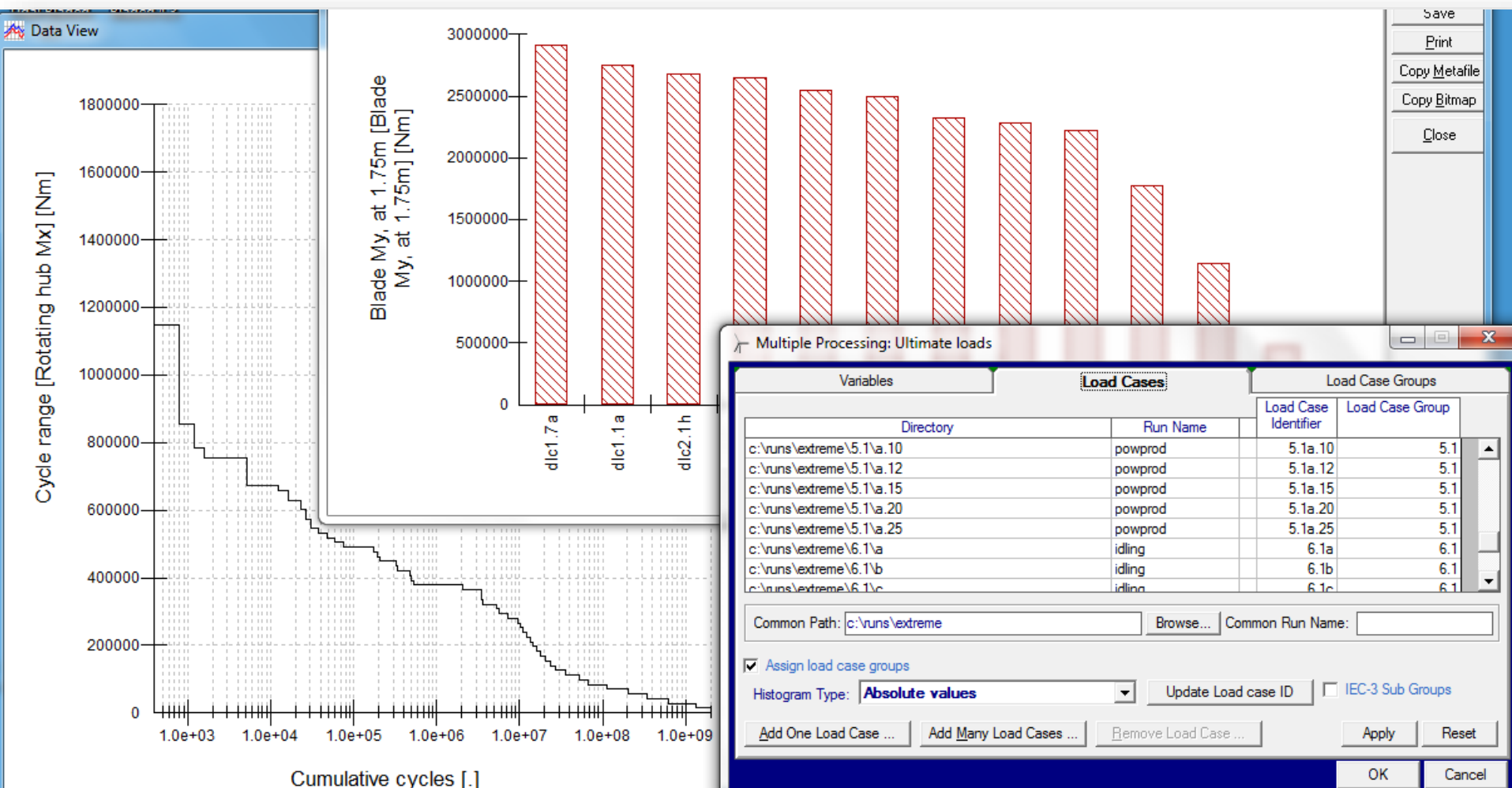
The screenshot shows a software interface for managing simulation batches. At the top, there's a title bar 'T:\AS\Batch\4.5 Comparison' and a toolbar with icons for file operations, execution, and settings. A 'Batch Progress' bar is visible on the right. Below the toolbar, there are tabs for 'Job Lists' and 'Batch Runners (1)'. Under 'Job Lists', there are buttons for 'New List' and 'Jobs From Runs'. A table lists two job lists: '4.5 List' and '4.4 List', both with 589 jobs and a 'Completed' status. Below this, a 'Jobs:' section contains a detailed table of individual jobs. The table has columns for Order, Name, Enabled, Status, Output folder, Progress, Version, Run With, Runner, and Info. The first 10 jobs are listed, all with a 'Success' status and a progress bar. At the bottom, it says '589 jobs (0 selected)' and 'Connected to Manager at GHBMOBILE29 This host is a runner for this batch folder'.

Order	Name	Enabled	Status	Output folder	Progress	Version	Run With	Runner	Info
1	powprod	<input checked="" type="checkbox"/>	Success	t:\AS\Bladed4.5\runs\extreme\DLC1.1\aa	<div></div>	4.5.0.51	4.5.0.51	GHBMOBILE29	!
2	powprod	<input checked="" type="checkbox"/>	Success	t:\AS\Bladed4.5\runs\extreme\DLC1.1\ab	<div></div>	4.5.0.48	4.5.0.51	GHBMOBILE29	!
3	powprod	<input checked="" type="checkbox"/>	Success	t:\AS\Bladed4.5\runs\extreme\DLC1.1\ac	<div></div>	4.5.0.48	4.5.0.51	GHBMOBILE29	!
4	powprod	<input checked="" type="checkbox"/>	Success	t:\AS\Bladed4.5\runs\extreme\DLC1.1\ba	<div></div>	4.5.0.48	4.5.0.51	GHBMOBILE29	!
5	powprod	<input checked="" type="checkbox"/>	Success	t:\AS\Bladed4.5\runs\extreme\DLC1.1\bb	<div></div>	4.5.0.48	4.5.0.51	GHBMOBILE29	!
6	powprod	<input checked="" type="checkbox"/>	Success	t:\AS\Bladed4.5\runs\extreme\DLC1.1\bc	<div></div>	4.5.0.48	4.5.0.51	GHBMOBILE29	!
7	powprod	<input checked="" type="checkbox"/>	Success	t:\AS\Bladed4.5\runs\extreme\DLC1.1\ca	<div></div>	4.5.0.48	4.5.0.51	GHBMOBILE29	!
8	powprod	<input checked="" type="checkbox"/>	Success	t:\AS\Bladed4.5\runs\extreme\DLC1.1\cb	<div></div>	4.5.0.48	4.5.0.51	GHBMOBILE29	!
9	powprod	<input checked="" type="checkbox"/>	Success	t:\AS\Bladed4.5\runs\extreme\DLC1.1\cc	<div></div>	4.5.0.48	4.5.0.51	GHBMOBILE29	!
10	powprod	<input checked="" type="checkbox"/>	Success	t:\AS\Bladed4.5\runs\extreme\DLC1.1\da	<div></div>	4.5.0.48	4.5.0.51	GHBMOBILE29	!

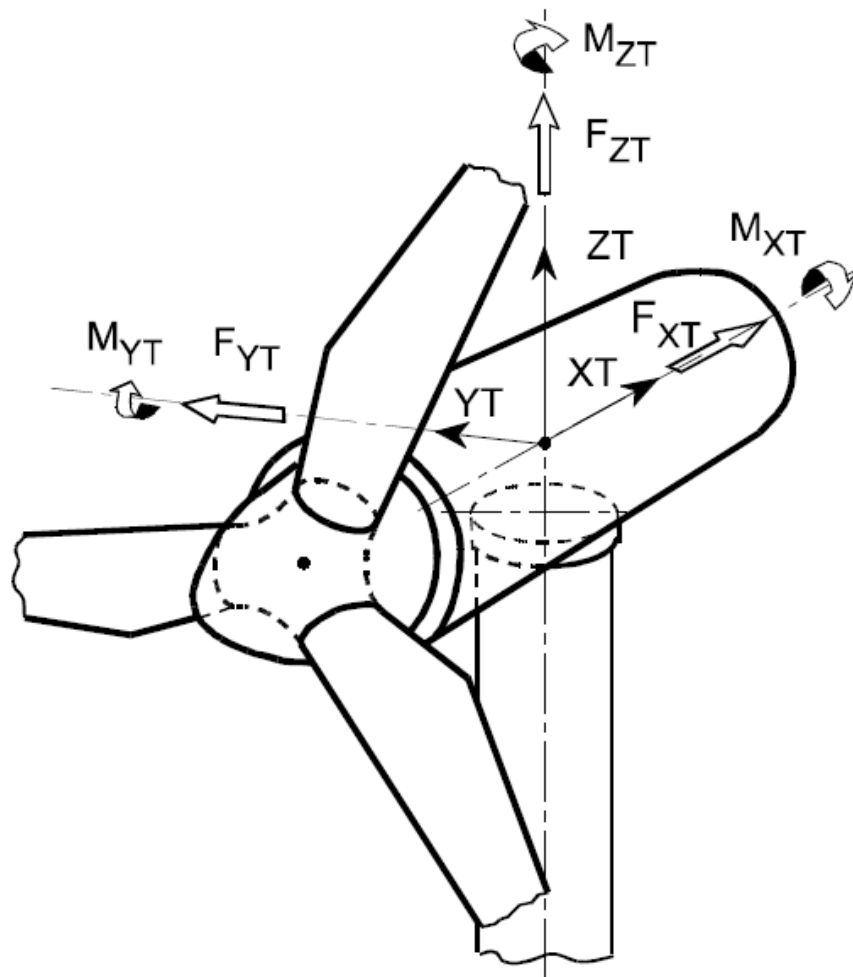
# Example graphical output of time-domain simulation



# Post processing output examples



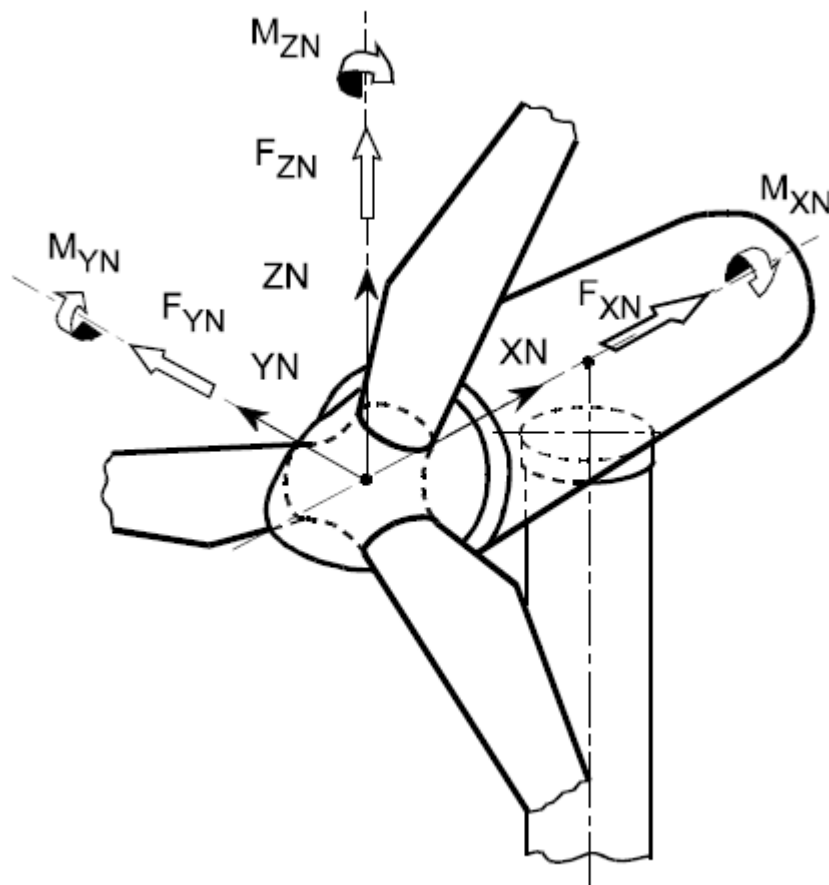
## Coordinate Systems in Bladed (1)



**Tower Loads**  
**(‘Global’ coordinate system)**

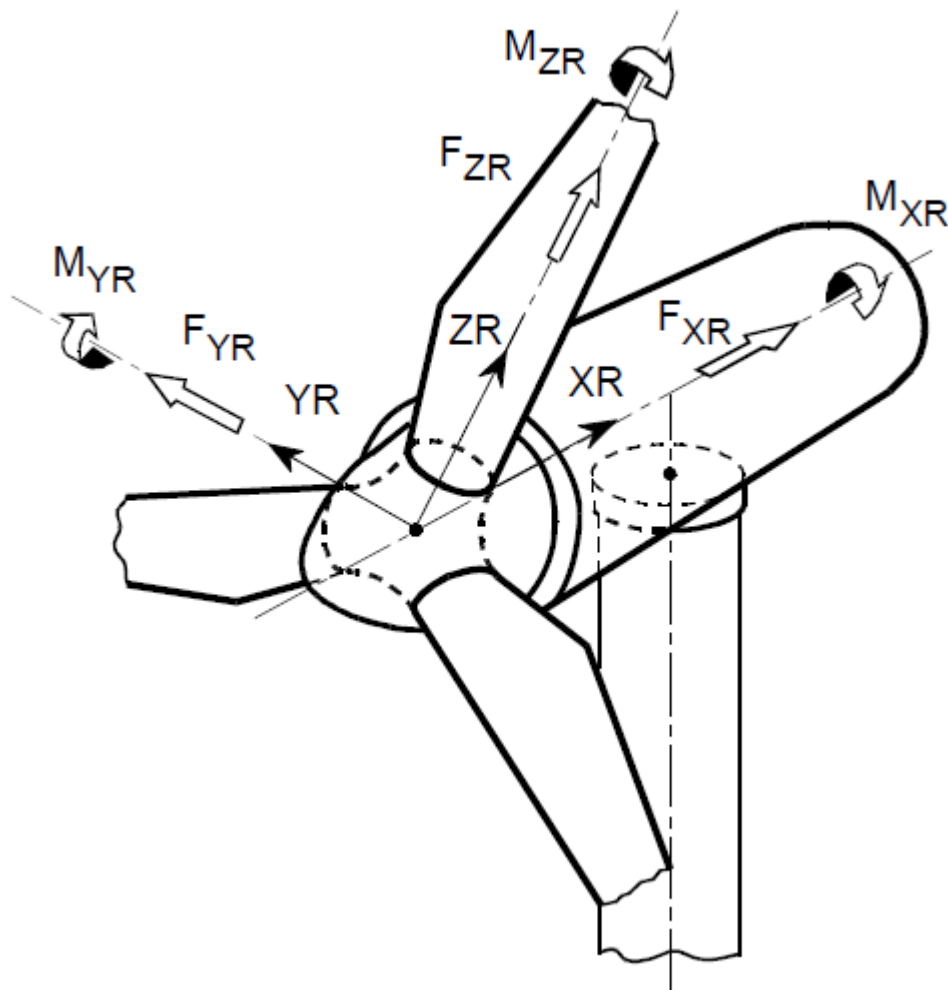


## Coordinate Systems in Bladed (2)



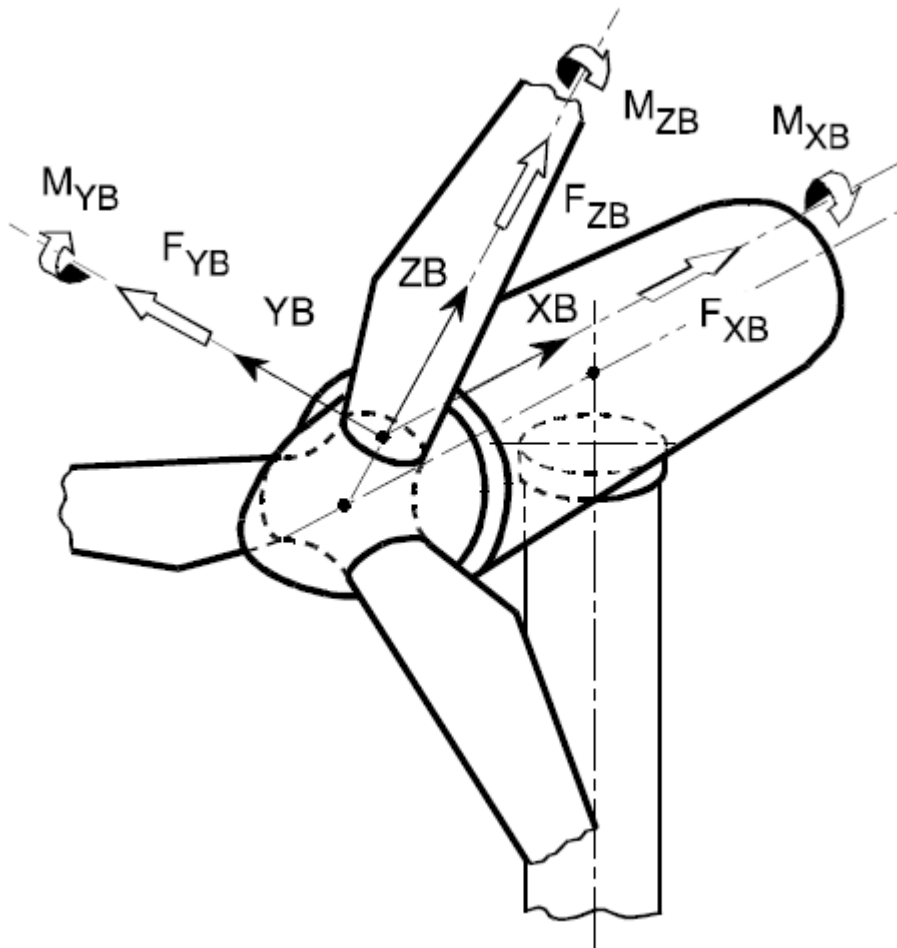
**Hub Loads**  
**(Stationary system)**

## Coordinate Systems in Bladed (3)



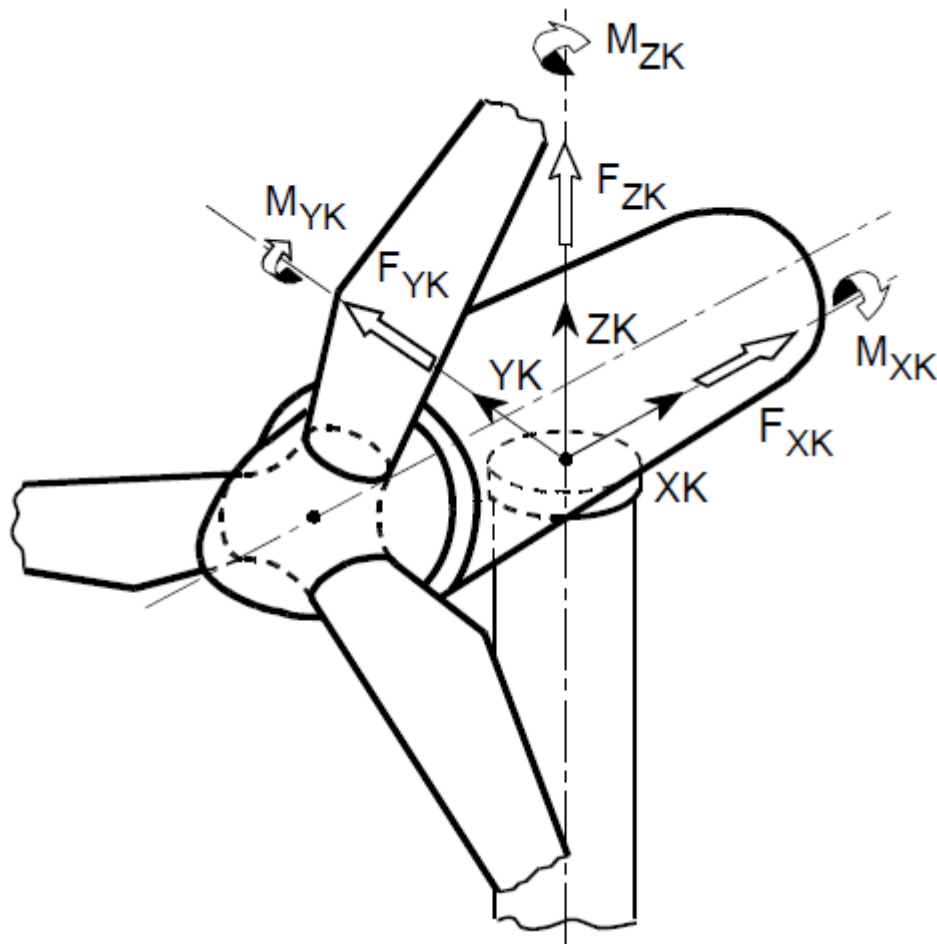
**Hub Loads**  
**(Rotating system)**

## Coordinate Systems in Bladed (4)



**Blade Root Loads**

## Coordinate Systems in Bladed (5)



**Yaw Bearing Loads**

# Coordinate Systems in Bladed (6) – Blade Loads



## Principal axes

Z axis parallel to deformed neutral axis. Y axis parallel to principal axis. Rotates about z axis with pitch.



## Root axes

Z axis parallel to pitch axis. Y axis perpendicular to rotor axis when blade is at zero pitch. Does not rotate with twist or deflection, does rotate about z axis with pitch



## Aerodynamic axes

Origin at 25% chord. Z axis parallel to deformed neutral axis. Y axis parallel to chord. Rotates about z axis with pitch.

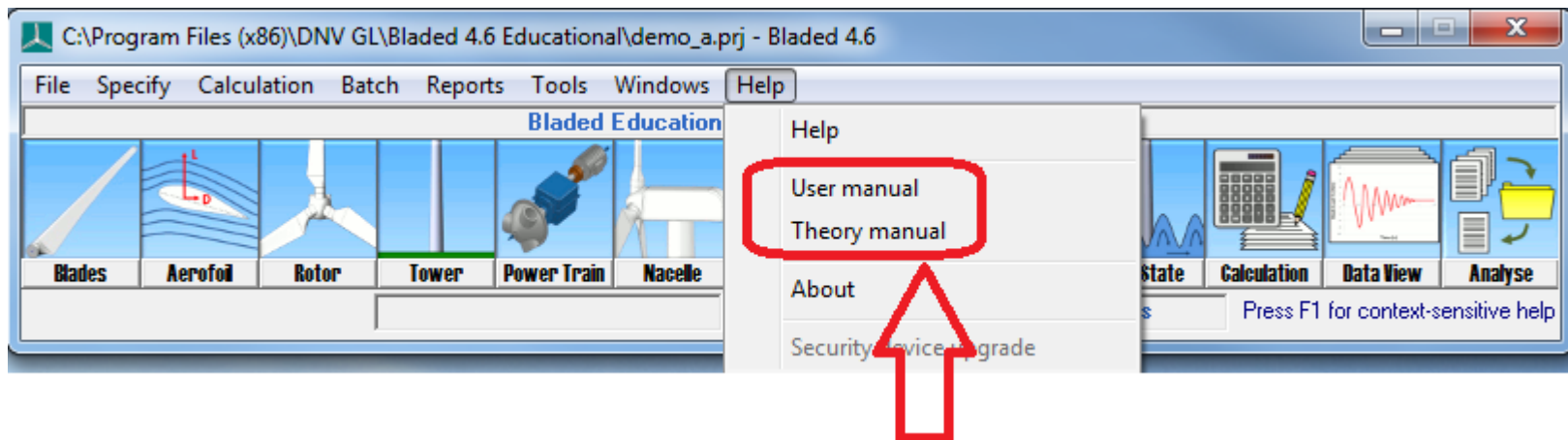
## Help and Support

- Bladed Educational Introductory Guide

- Google : 'Bladed Educational Youtube Videos'

[https://www.youtube.com/playlist?list=PLmQHHinSMOEopu\\_2I6KhQFflz4VkD7I](https://www.youtube.com/playlist?list=PLmQHHinSMOEopu_2I6KhQFflz4VkD7I)

- Bladed User Manual and Theory Manual



- Or simply press 'F1' for instant access to User Manual!



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