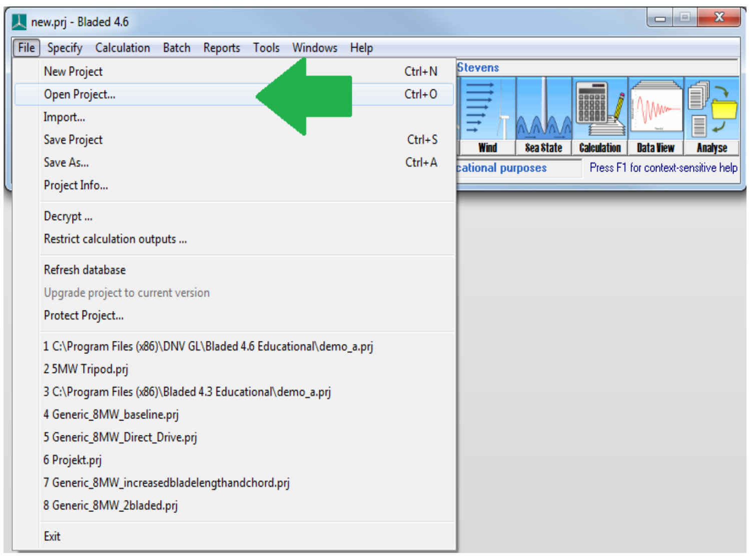
Cardiff University Engineering / DNV GL

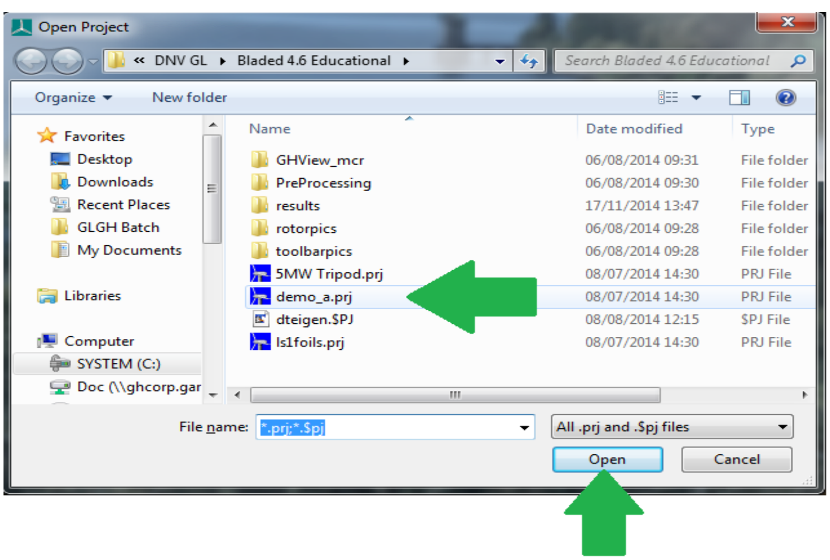
Bladed Educational Workshop Exercises

Day1

For these exercises we will work with the Demo Turbine included with Bladed Educational.

Open the demo turbine as shown below:





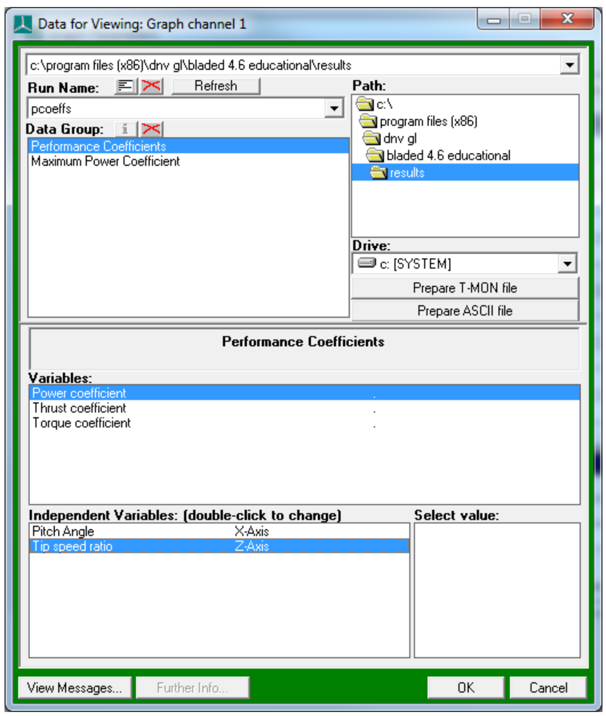
Part 1 Steady state calculations

1. Performance coefficients calculation (10mins)

The Performance Coefficients calculation generates dimensionless power, torque and thrust coefficients for the rotor as a function of tip speed ratio assuming uniform steady wind. This calculation is often used to select the 'fine pitch angle' (angle at which the blades are set on the pitch bearing).

Double-click on 'Performance Coefficients' in the 'Calculations' window. Enter min. and max. tip speed ratios of 2 and 20 respectively, ratio step of 0.1, min and max pitch angles of -2 and +2 degrees, pitch angle step of 1 degree, and rotor speed of 18rpm.

Run the calculation. Then open Data View.
Define Channel 1 to show a 3D plot of Power Coefficient against Tip Speed Ratio and Pitch Angle. Thrust and Torque Coefficients can be viewed in a similar way.



Find the Tip Speed Ratio and Pitch Angle that produces the maximum Power Coefficient.

To do this, view 2D graphs of : 'Maximum Power Coefficient (interpolated)' and 'Tip Speed Ratio at Maximum Power Coefficient (interpolated)'

The 'Tabulate' and 'Stats' buttons at the bottom of the Data View window are useful here.

Cpmax = _______________ Optimum Tip Speed Ratio = _______________

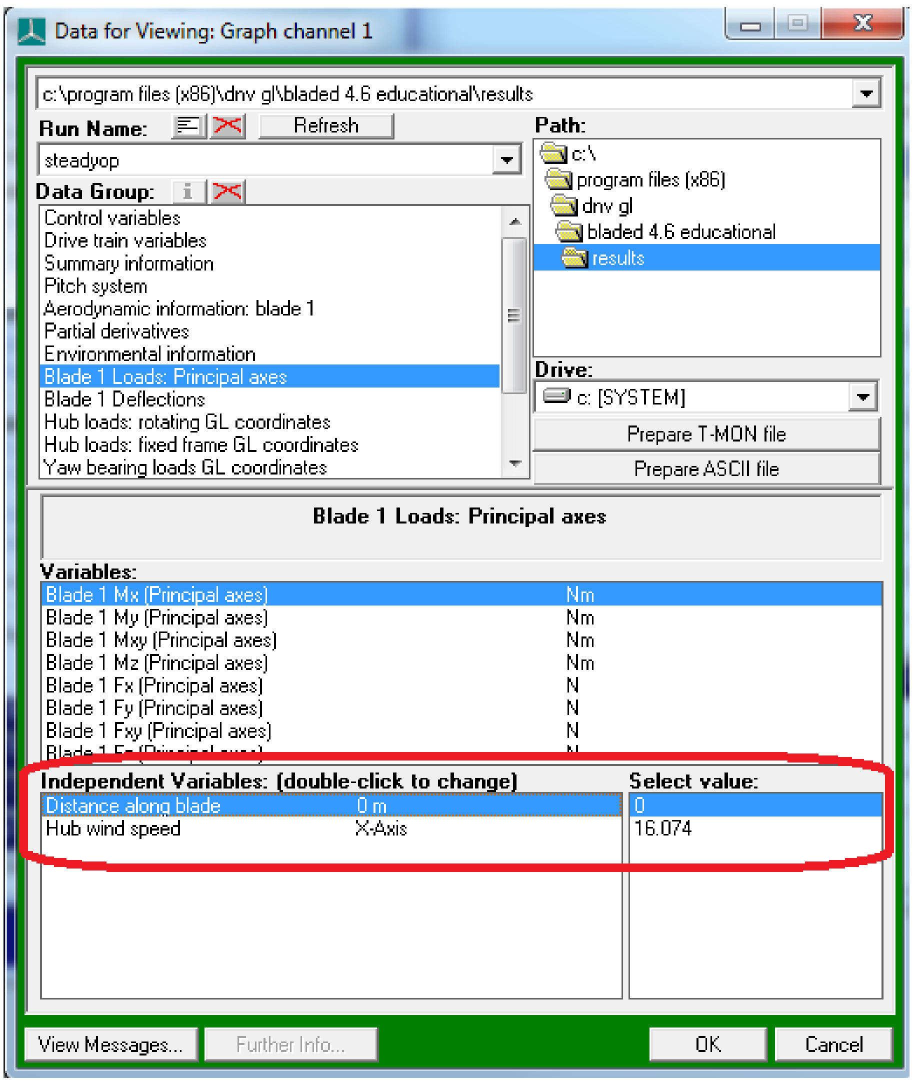
2. Steady operational loads calculation (10mins)

The steady operational loads simulation calculates the wind turbine loads as a function of wind speed assuming uniform steady wind.

Enter the minimum and maximum wind speed required and wind speed step (typically 4m/s, 25m/s and 0.5m/s respectively). Select yes for “Calculate pitch and speed change”.

Run the steady state operational loads simulation and view the results.

Plot blade root loads, tower loads, deflections and hub loads against wind speed (to set blade root loads, select ‘distance along the blade = 0, Hub Wind speed = x axis’ as independent variables as shown below).



Thrust Force on the Rotor = Hub Fx. At what wind speed is the mean thrust force on the rotor greatest?

Which other load components share this characteristic?

3. Steady power curve calculation (10mins)

The steady power curve calculation generates the wind turbine power curve as a function of wind speed assuming uniform steady winds.

Run the steady power curve calculation using the following parameters: minimum wind speed 4m/s, maximum wind speed 25m/s, step size 0.1m/s. Select yes for "Calculate pitch and speed change".

Plot the following as a function of wind speed

- Rotor speed
- Pitch angle
- Shaft power and electrical power
- Tip speed ratio and power coefficient

Before looking at the graph predict what each curve will look like by sketching on a piece of paper.

How do you think the shape of the power curve might change if it was plotted as a function of the 10-minute average of a turbulent wind field?

Part 2 : Dynamic Simulations workshop

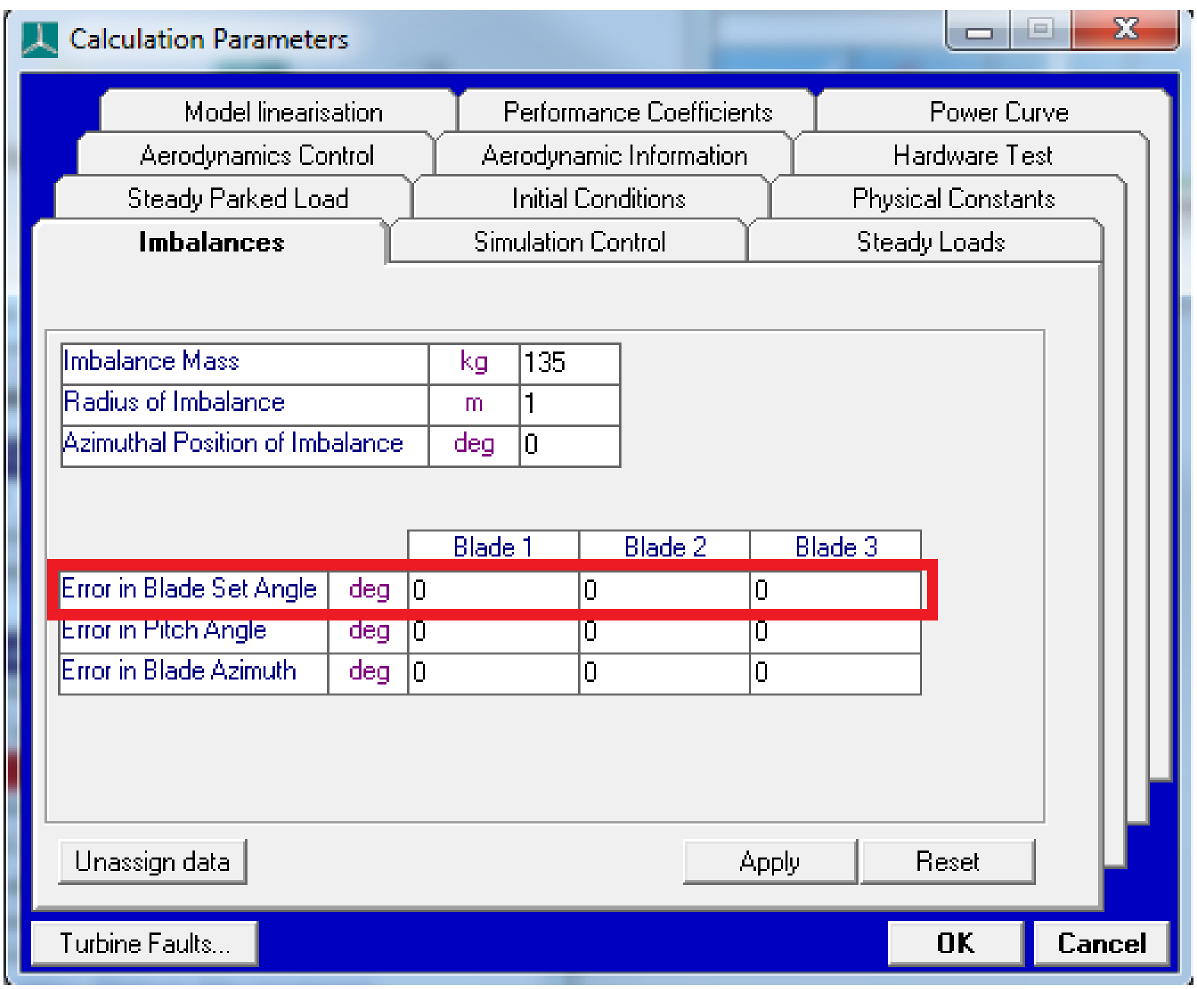
1. Power production simulations: steady wind and periodic loads (30mins)

The power production simulation calculates the loads and deflections of the operating wind turbine *as a function of time*. Different models of the wind can be used: steady, turbulent or a deterministic transient.

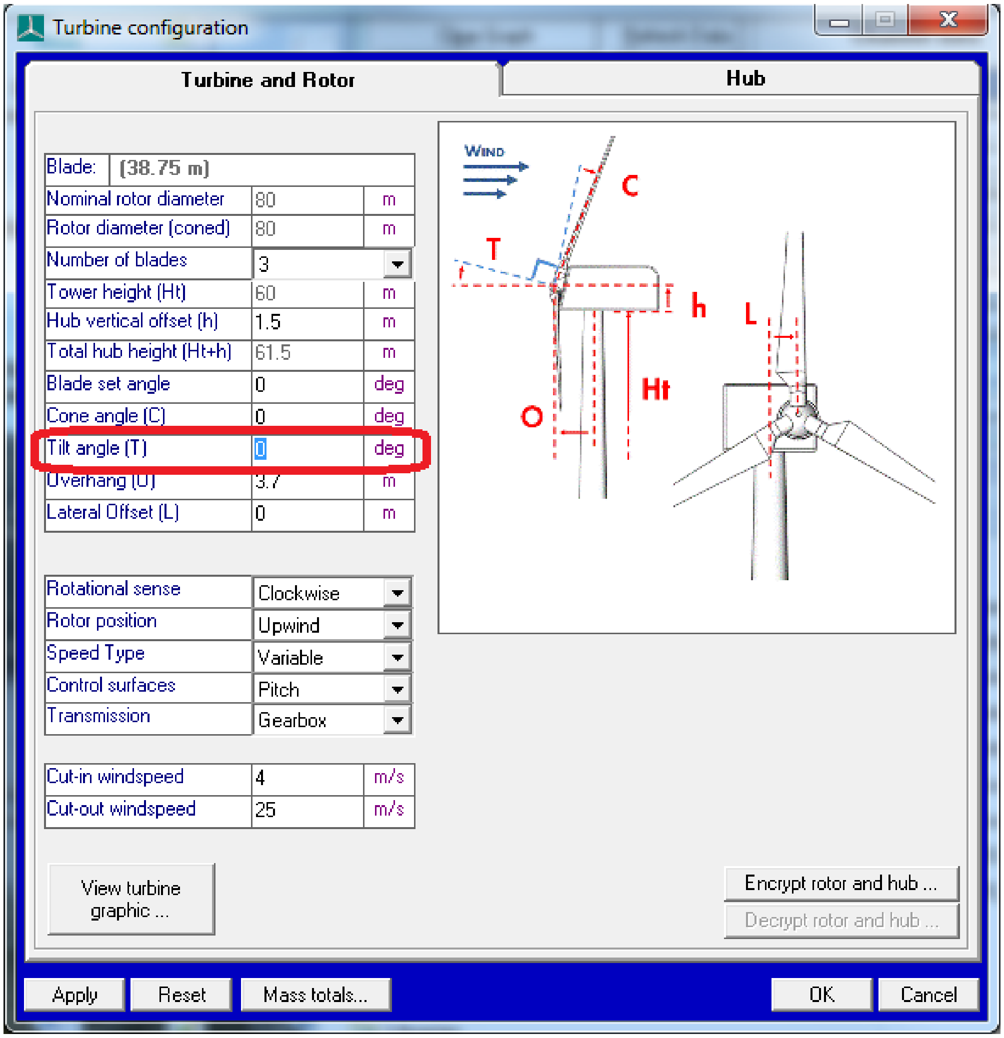
Use a steady wind of 12m/s and examine how rotor imbalances, wind shear, upflow and tower shadow individually produce periodic loads on the turbine. Run a total of 6 Power Production simulations, with different effects activated.

Simulations:
Open the Demo turbine.

From the Calculation Window, click on 'Calculation Parameters' – 'Imbalances' tab.
Set all of the 'Error in Blade Set Angle' values to zero (as shown below). This will remove any periodic loading contribution from blade set angle errors:



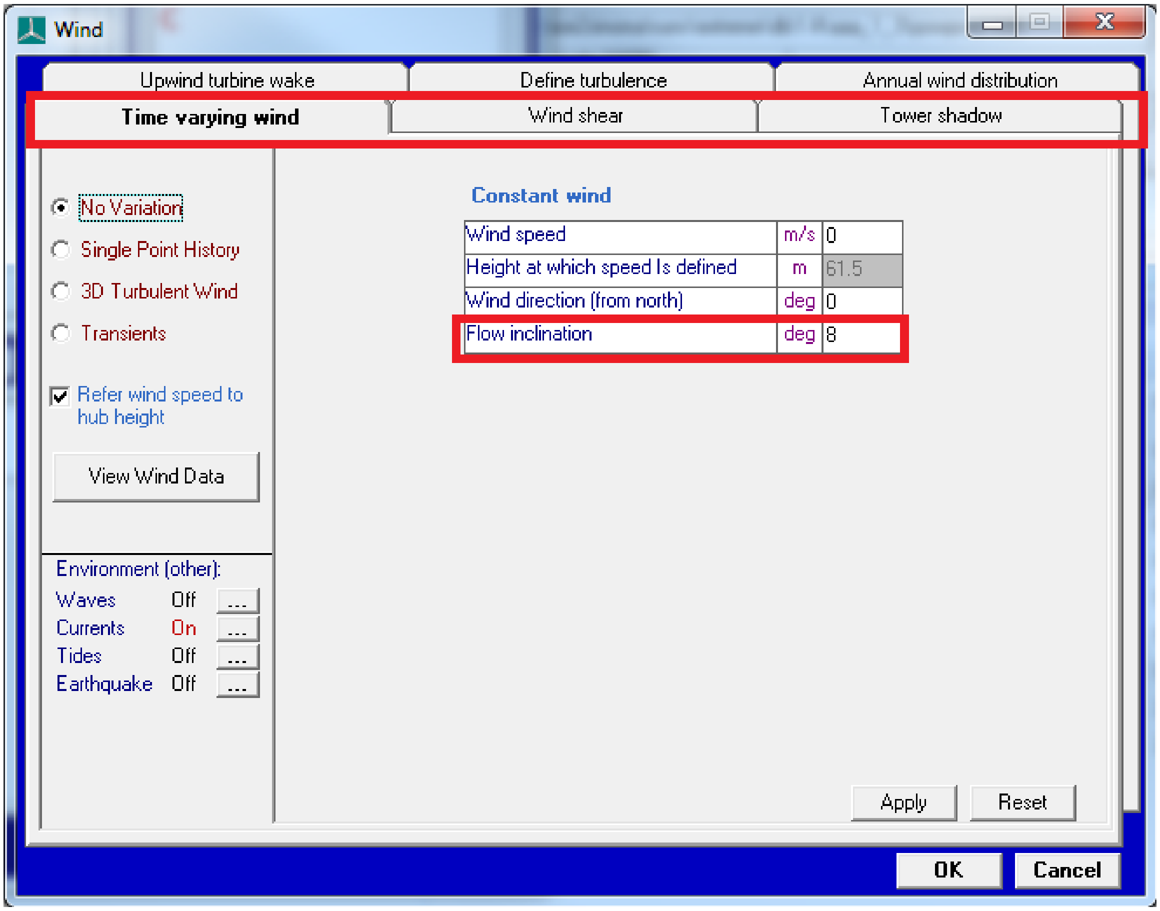
Also set the Tilt Angle to 0deg in the Rotor screen as shown below. This will remove any periodic loading contribution arising from the shaft tilt angle :



Now set up and run the 6 power production simulations as shown in the table below:

	Calculation Parameters			
Simulation name (save it as this)	Rotor Imbalance	Flow Inclination (upflow)	Wind Shear	Tower Shadow
powprod_none	0	0	0	0
powprod_imbalance	135kgm	0	0	0
powprod_upflow	0	8°	0	0
powprod_wshear	0	0	0.2	0
powprod_tshadow	0	0	0	Potential Flow model: Tower diameter correction factor = 1
powprod_all	135kgm	8°	0.2	Potential Flow model: Tower diameter correction factor = 1

Imbalance mass can be changes in the Imbalances tab. Flow Inclination, Wind Shear and Tower Shadow are all controlled from the Wind Module:



Analysis:

1. Blade Root 1 My

Out of the four parameters that were changed, predict which one will :

- cause large a large drop on blade root My when the blade is pointing vertically downwards?
- cause the largest variations in blade root My?

2. Hub Mx

Out of the four parameters that were changed, predict which one will cause the largest variations in hub Mx?

Use the Data View module to look at the effect on **hub Mx**. Explain the effect that changing each parameter has.

EXTENSION : Notice that even the *powerprod_none* simulation shows a very small periodic My variation. What do you think could be the cause of this? How could we test this?

2. Turbulent wind files (10mins)

In order to perform a simulation with turbulent wind, a turbulent wind field file must first be generated and stored. The turbulence field is defined on a rectangular grid made up of points which contain time histories of wind speed variations which covers the turbine. The wind file has spectral and coherence characteristics according to the turbulence model which is selected.

a) Double click on the 'Wind' icon. Go to the 'Define Turbulence' tab.
b) Set the dimensions of the wind file grid, ensuring that they are big enough to fully cover the turbine, with points spaced 5m apart. Create a 60s turbulent wind file with 12m/s hub height average wind speed. Set 'Frequency along X' > 10Hz. Use the improved von Karman spectral model with 3 components, and adjust the roughness length to achieve a longitudinal turbulence intensity of 17%.
c) Click 'Generate Turbulence Now and save your wind file.

3. Power production simulations: turbulent wind (10mins)

a) Run a power production simulation using the turbulent wind file created previously. In the Calculation window, make sure that the 'Power Production' calculation is selected. In the Wind module select '3D turbulent wind' and enter the windfile path in the 'Turbulent wind file name' field.

b) In 'Calculation Parameters' (bottom of the Calculation window), set 'Time to start writing output' as 5s, and 'Simulation end time' to 55s. Save the Run Name as '*powprod_turb*'.
(Run with imbalance, windshear, towershadow and upflow all enabled)

c) View the results for different load components (blade root Mx, My) and from summary information (hub wind speed, electrical power, rotor speed, pitch angle). It's also interesting to look at the individual blade root Mx & My values, and see how they correspond with the overall hub Mx & My values.

4. Auto Spectrum Calculations (10mins)

The auto spectrum calculation plots the frequency distribution of already completed simulations.

a) Run a single-channel auto-spectrum on Blade root My, for all the simulations completed in section 2. Start by comparing *powprod_all* with *powprod_turb*.
Select 256 points, 50% overlap, Hanning and 'remove trends'. You will also need to select logarithmic y-axis. Compare the results for the different simulations, identifying 1P, 3P etc...

b) Repeat for tower My and Mx.