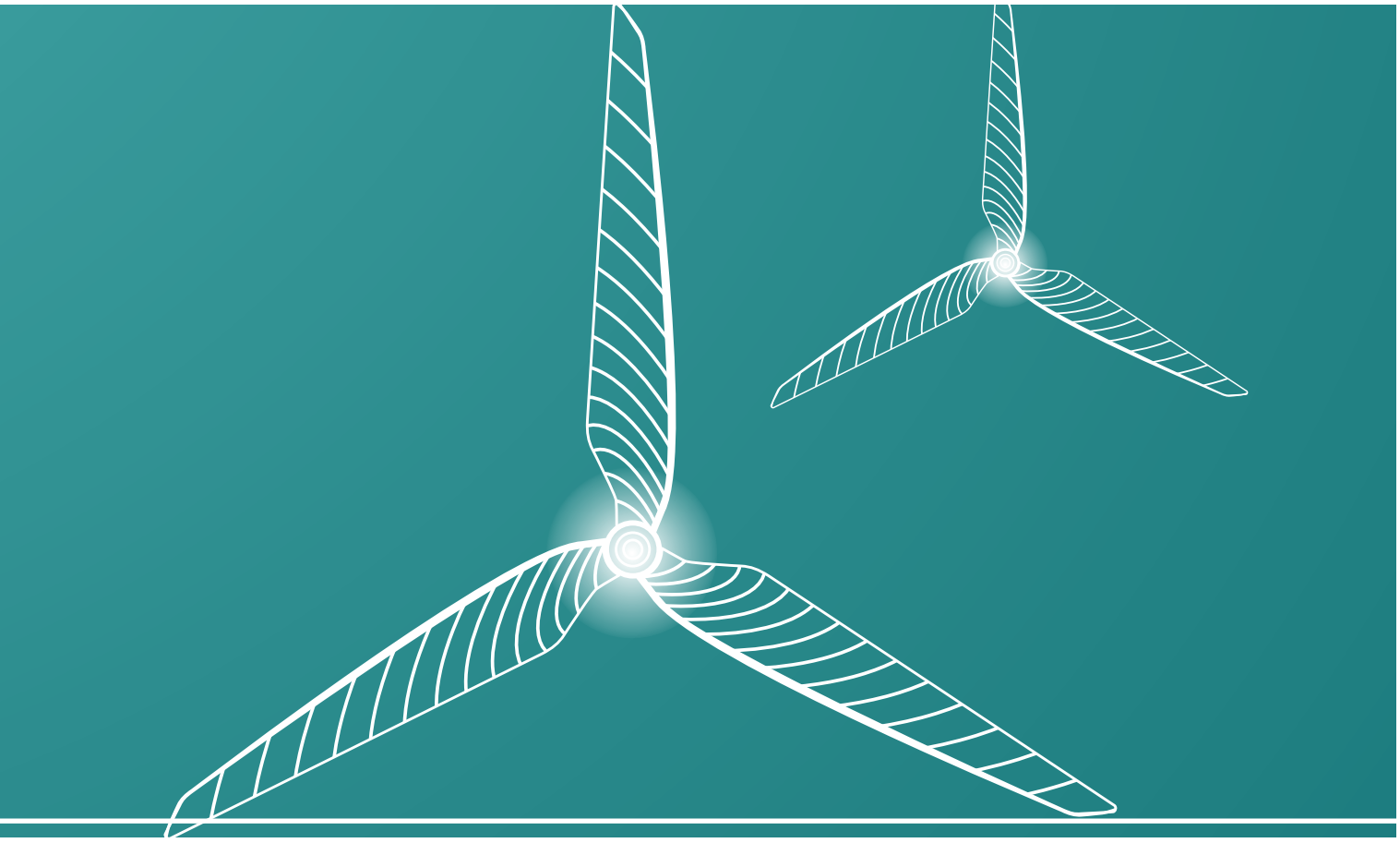
DNV·GL

TUTORIAL

WINDFARMER

Other Modules

Version: 5.3
Date: April 2014
DNV GL - Energy



SAFER, SMARTER, GREENER

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None of the data contained in this tutorial have references to existing or planned wind farms

1. INTRODUCTION

The aim of this tutorial is to help the user gain familiarity with the features provided by the modules of WindFarmer which are not covered elsewhere. The modules that are presented in this tutorial are:

- MCP+ Module
- Turbulence Intensity Module
- Electrical Module
- Shadow Flicker Module
- Financial Module

Most of this tutorial can be followed by a user with the demonstration version of WindFarmer. Users with a licensed version of the software should note that in order to function these modules also require the Base Module.

These tutorials are a supplement to the User Manual and the Theory Manual of WindFarmer. The user should refer to these for more information.

The exercises use sample files provided in a folder called 'Demodata', which can be found in Libraries\Documents\WindFarmer. Users of Windows XP can find this folder inside the WindFarmer installation directory, which is usually C:\Program Files\WindFarmer.

Throughout the tutorials, we recommend you save your work from time to time. However, note that Workbooks cannot be saved from the WindFarmer demonstration version.

2. MCP+ MODULE

The MCP+ Module contains the tools needed to take raw time series of wind speed and direction data through data assembly, cleaning, calibration and correlation to produce the wind regime at your site in the form of a wind speed and direction frequency distribution. See Section 4 of the User Manual for more details.

2.1 Loading time series

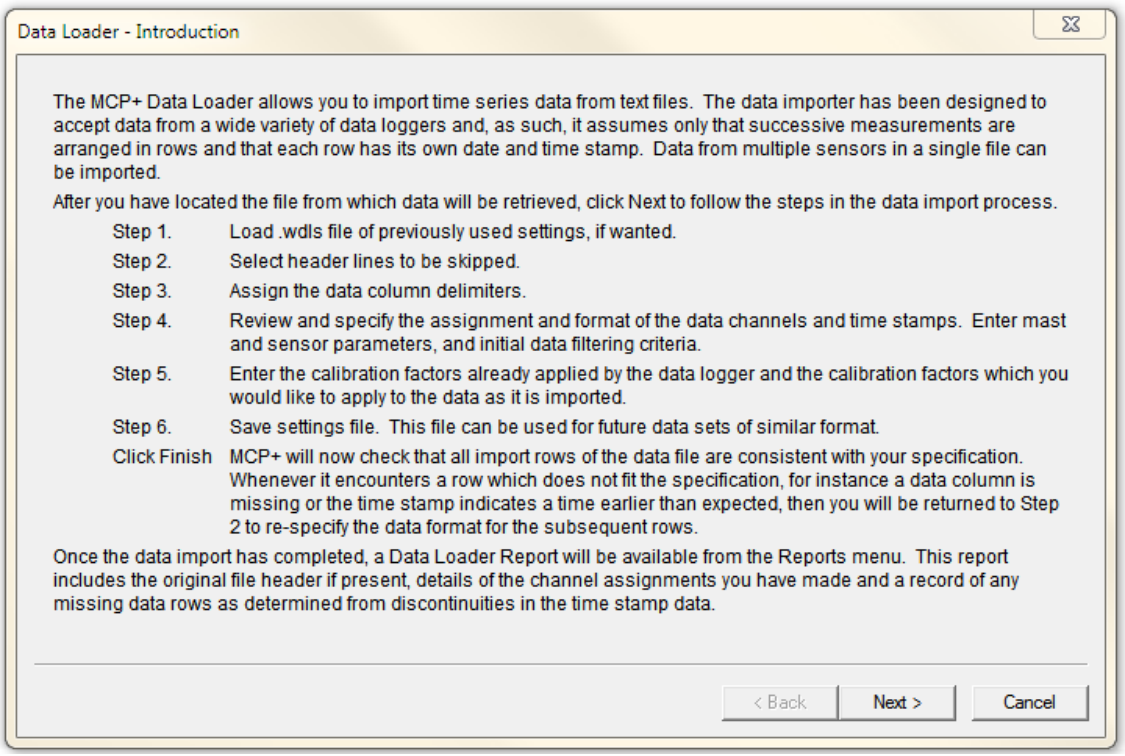
The following steps explain the process of loading raw time series meteorological data into WindFarmer. The MCP+ module acts as a database to store time series data from all of the masts on a project site and any long-term reference data sets considered as well.

Step 1. Click on the main toolbar or go to File > New Workbook to begin with a blank workbook. Cancel the Wizard window if it opens.

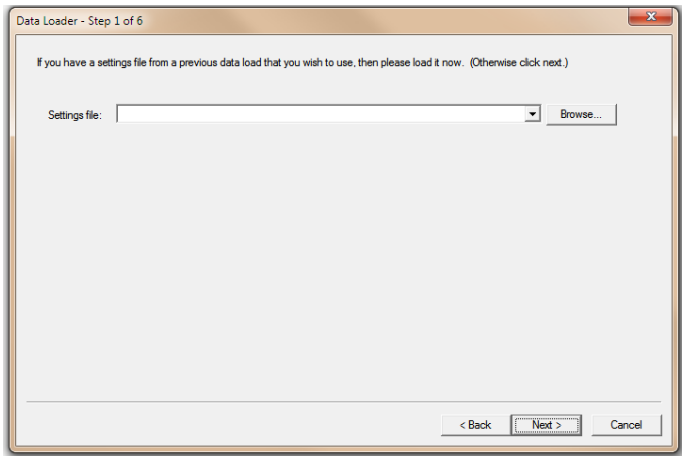
Step 2. Click or go to File > Load MCP+ data.

Navigate to the Demodata folder in the WindFarmer library and open the file "Reference.txt". The file "Reference.txt" contains raw data as recorded by a data logger on a met mast, and this data set will be the long-term reference data for this tutorial. This simple example file comprises four columns of data featuring date, time, wind speed and direction. MCP+ can handle many other types of data generated by standard data loggers.

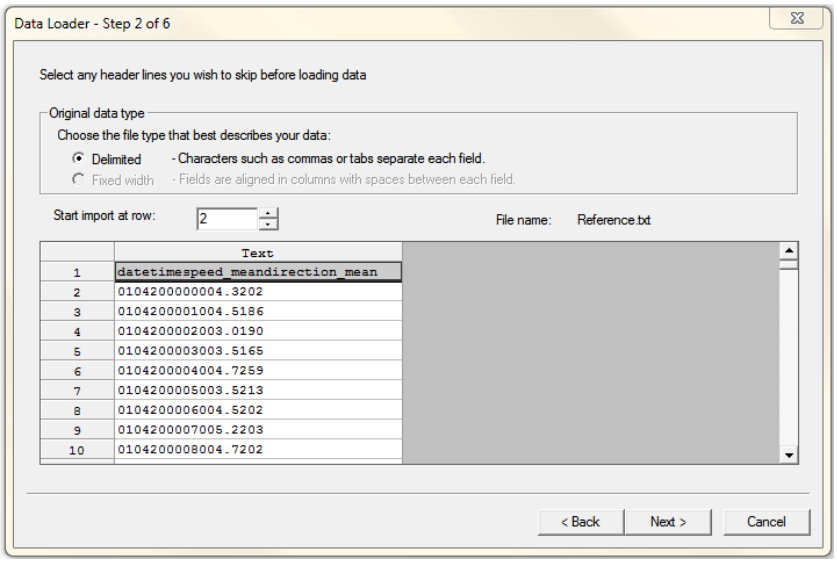
Click Open. The dialog box below will appear.



Step 3. Click Next. The window below will appear as step 1 of the process. Here the user can load in a *.wldst file, if one was previously created, that contains all the load settings based on the structure of the input file. In this example there is no previously created settings file, and the settings will be entered manually in the following steps.



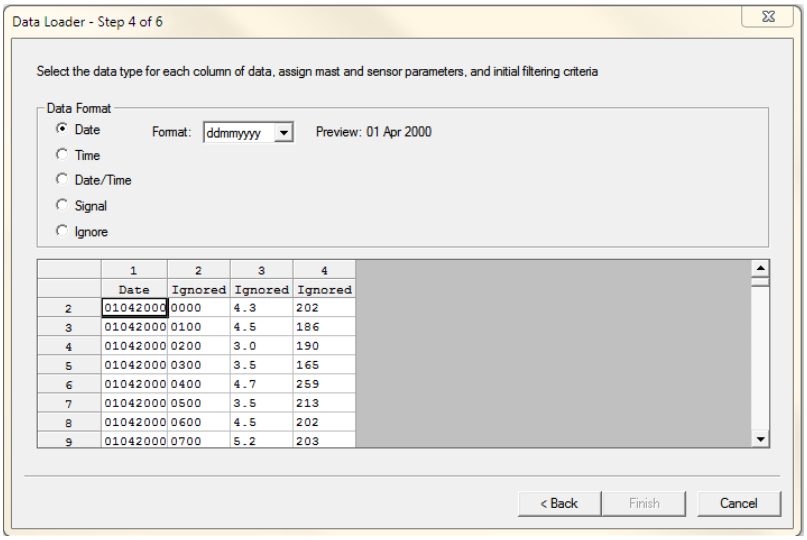
Step 4. Click Next, and Step 2 of the Data Loader will appear. Here the user sets the row at which to start the import. This is important if the data file contains header information in the first rows. In this case, “Reference.txt” has one row of header data, so set ‘start import at row’ to 2.



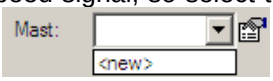
Step 5. Click Next. At Step 3 of the Data Loader, set the delimiter type. In this case the file has tab delimiters. Check the box labelled “Tab”.

Step 6. Click Next. At Step 4 of the Data Loader, associate a data format to each column of data. Click anywhere in column 1 to highlight the column. Since the first column contains the date information, select the radio button labelled “Date” as the data format. Check that the format specified matches the data set. The “Reference.txt” data set has data information in “ddmmyyyy” date format.

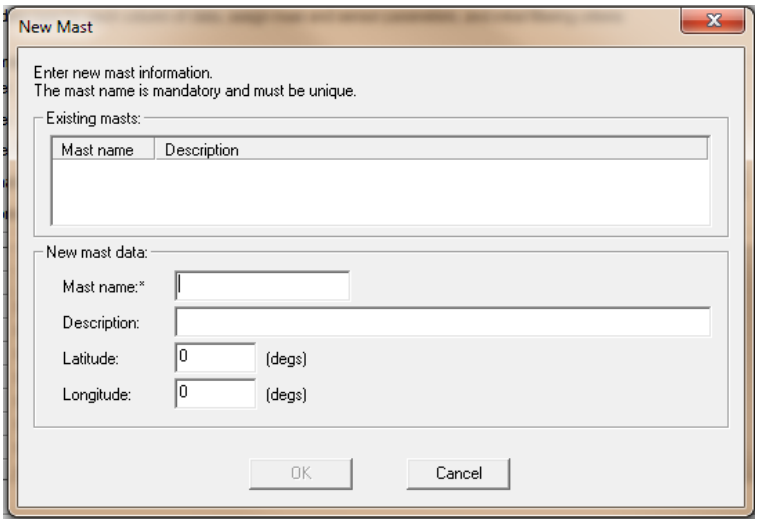
Note: Different models of data loggers produce raw data with different time stamps. MCP+ will accept the typical data settings of the most common data loggers used in the wind industry; just check that the date format is set appropriately at this step in the Data Loader.



Step 7. Select the second column of data. Select the radio button labelled “Time” to associate the time format. Ensure the format matches the data set, and in the “Timestep” box, enter the time step increment. In the “References.txt” file, the time format is “hhmm” and the time stamps have 60 minute increments.

Step 8. Select the third column of data. This is a wind speed signal, so select the “Signal” data type. Click the drop down box for the mast 

and select “<new>” to open the window below



Step 9. Enter “Ref_mast” as the mast name, “Reference mast” as the description, and the coordinates (56.0°N, -3.4°E) for the mast. Note that entering a description and geographic coordinates are optional. Click OK.

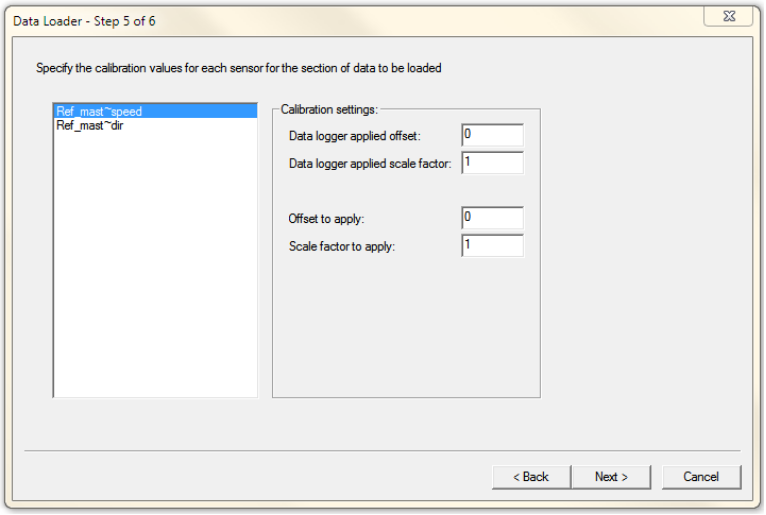
Step 10. Now, in the same way, create a new sensor from the Sensor drop down box. Anemometer, wind vane, pressure, temperature, battery voltage or any other sensor specified by the user can be analysed in MCP+. In this specific exercise enter “speed” as the sensor name, select “Anemometer” as signal type and set a height of 10 m. Note that WindFarmer has automatically chosen sensible minimum and maximum data values based on the sensor type, although these can be changed if necessary. Click OK.

Step 11. Specify the signal type in the last drop down box (options are mean, standard deviation, max, min or flag). In this data set, column 3 represents the mean value of wind speed.

Step 12. Click in column 4. Select the “Signal” radio button to register column 4 as another sensor. In this data set, we know that column 4 belongs to Ref_mast. Input a new sensor using the drop down box. In the New Sensor dialog box enter “dir” as sensor name (for wind direction) and select “Wind Vane” as signal type. Set a height of 10 m. Click OK.

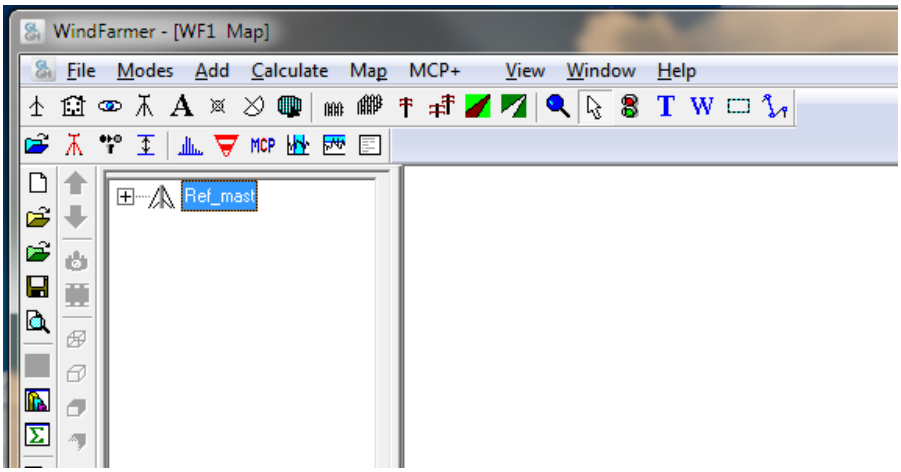
Note: MCP+ can handle as many columns as the raw data contains. If the data set contained additional columns, the process for loading in these data would be the same as described here in Steps 8 – 12.

Step 13. Once all of the columns of the file are defined, click Next. Step 5 of the Data Loader will appear as shown below. Sometimes the scale factor and the offset applied at the logger for the conversion of the frequency signals to wind data do not reflect the values that should have been applied (i.e. calibration factors, consensus calibrations, technical specifications, etc.). Sometimes the requirement may simply be to convert a wind speed signal from one unit to another. Whatever the reason, Step 5 allows the user to change the calibration upon loading. Sensor calibrations can also be edited after the data have been loaded. In this case, no adjustments are going to be applied to the calibrations at this stage.



Step 14. Click Next. In step 6 of the Data Loader, the user is prompted to save the settings given in the previous steps (i.e. delimitation, data format associated to each column, calibrations, etc.). Click Browse and enter a name for the settings file, then click Save. If you need to reload the data set, these settings could be loaded in Step 1 of the Data Loader, allowing you to skip steps 2 to 4 in the loading process. This can be very handy when dealing with complex raw data files containing many columns of data.

Step 15. Click Finish to finish the data loading. A dialog box will show the progress of the data loading. If inconsistencies are found within the data set, MCP+ will display a warning message specifying the column in which the inconsistency occurs. Typical inconsistencies are duplicate time stamps, time stamps out of order, variation of the total number of columns within the file, etc. After the loading finishes without problems, the mast “Ref_mast” appears on the top left corner of the MCP+ window, as shown below.



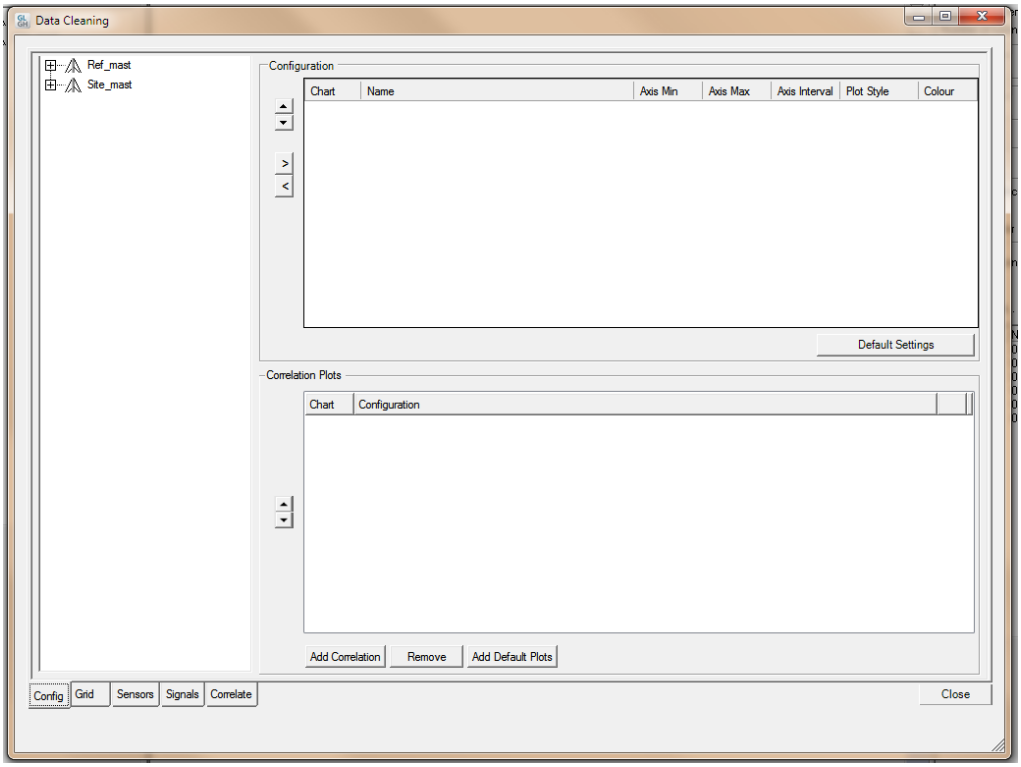
Step 16. Repeat the loading process just described for the site mast file “Site.txt”. Again click or go to File > Load MCP+ data. The file “Site.txt” is also located in the same demo data directory. This file has the following columns: Date, Time, Wind Speed Mean, Wind Speed Standard Deviation, Wind Direction Mean, and Temperature Mean. Call the mast “Site_mast” in the Data Loader, and its location as (55.8°N, -3.0°E). Enter appropriate names for the anemometer, wind vane, and temperature sensors such as “speed,” “direction,” and “temp.” The wind speed measurements are at a 50 m height, and the wind vane measurements are at a 47 m height.

Once the loading process is finished the mast “Site_mast” should appear right below “Ref_mast”.

2.2 Checking and cleaning the data

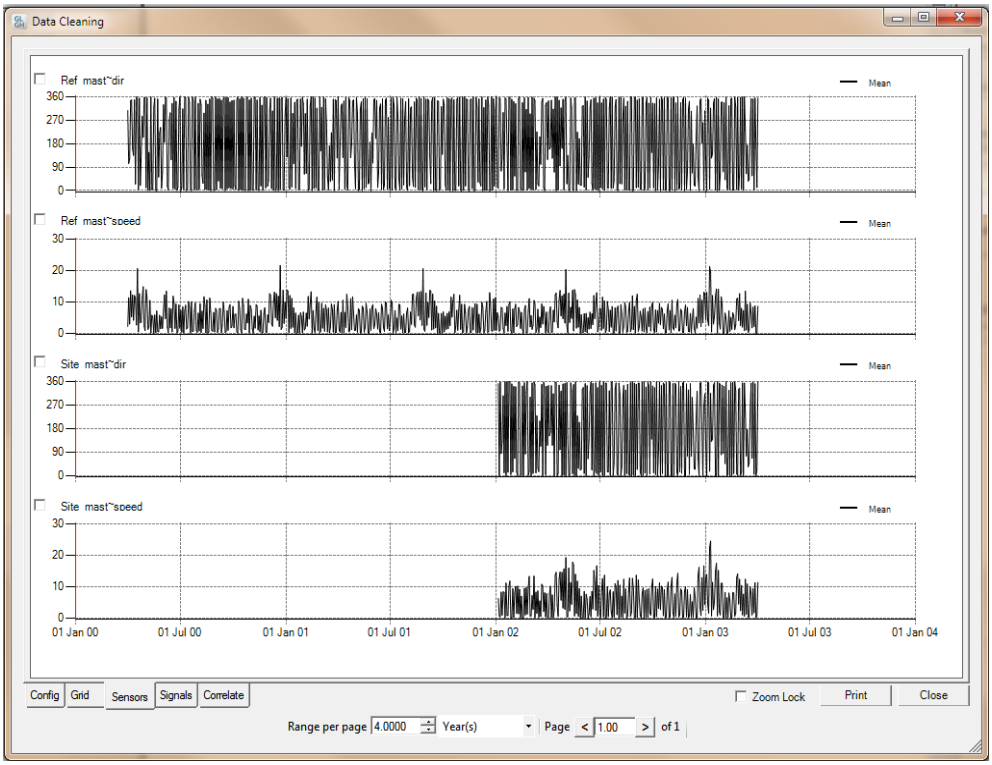
Once raw time series data are loaded into WindFarmer, the MCP+ module provides the user with tools to review each data set for quality assurance. Time series and correlation plots help identify erroneous data from, for example, failing or malfunctioning sensors, logger issues, and icing events, and these data can be easily removed within the MCP+ module. The steps below describe the tools available for reviewing and removing data and changing sensor calibrations.

Step 17. Click  in the MCP+ toolbar or go to MCP+ > Exclude Data > Data Cleaning… and the following Data Cleaning window will appear.



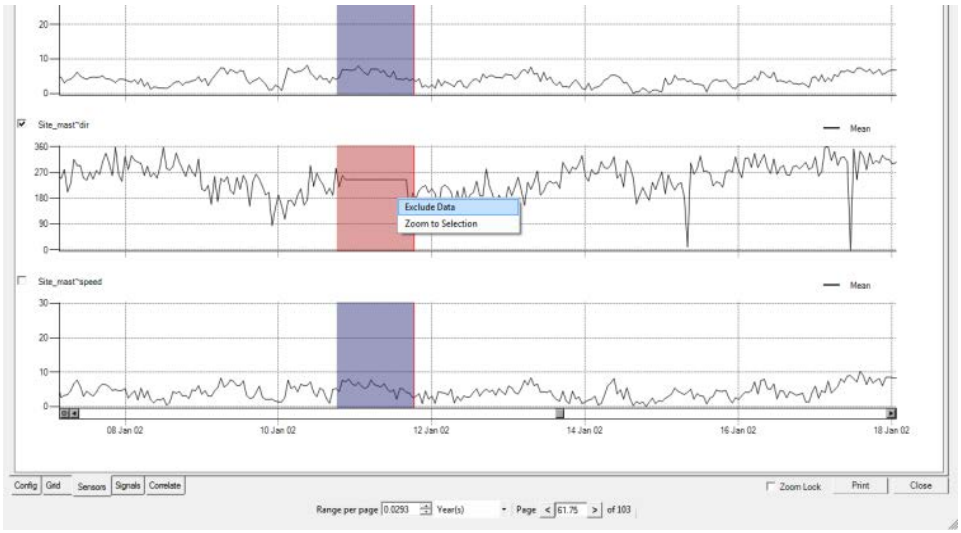
Step 18. Use the '+' symbols next to the mast and sensor names to expand the tree structure and reveal the sensor signals. Left click on the sensor signal to be plotted. To select more than one signal, hold the 'Ctrl' key while left clicking each sensor. Click the '>' button to move the mean wind speed and direction signals for Ref_mast and Site_mast into the Configuration window.

Step 19. At left hand bottom of the window, select the Sensors tab to view the time series plots. A graphing window similar to the following will appear.



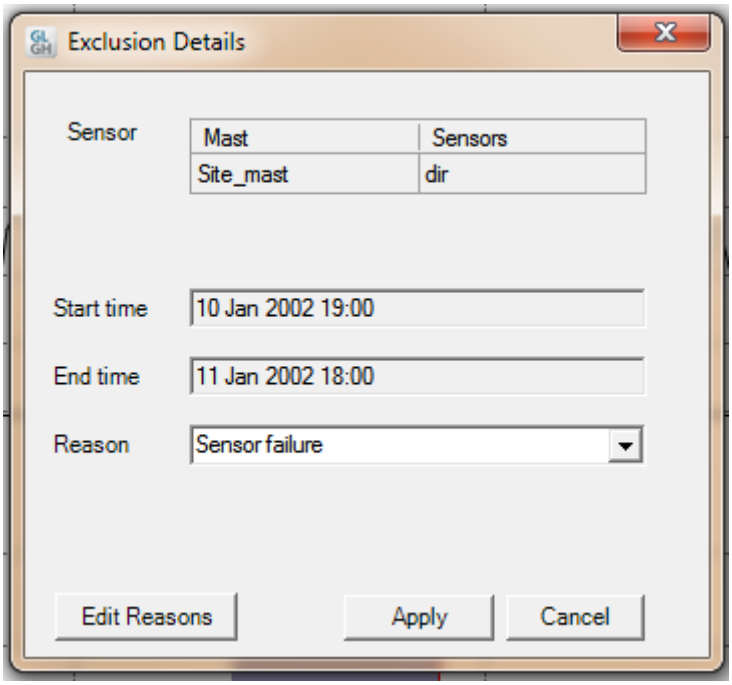
Step 20. When in the plotting window, use the scroll wheel on the mouse to zoom in and out of the data. Alternatively, select a period of data, right-click, and select Zoom to Selection. Scroll to different periods of data by using the keyboard arrow keys or by the scroll bars at the bottom of the Data Cleaning window. To return to the fully zoomed-out view, click the button at the left of the scroll bar.

Step 21. To remove defective data from the analysis, use the left mouse button to select and drag the mouse across a period of data on the Sensors tab plots. The selected section of data will be highlighted purple. Release the mouse button, and left click the checkbox on the left margin corresponding to the signal whose data should be removed. This will highlight the selection to be excluded in red, as shown below. Right click within the red highlighted area, and select Exclude Data.



Step 22. The following Exclusion Details box will appear. It presents the time range for the exclusion and offers a drop down menu of choices to assign an explanation for why the data is being excluded. Use the Edit Reasons button to add a custom

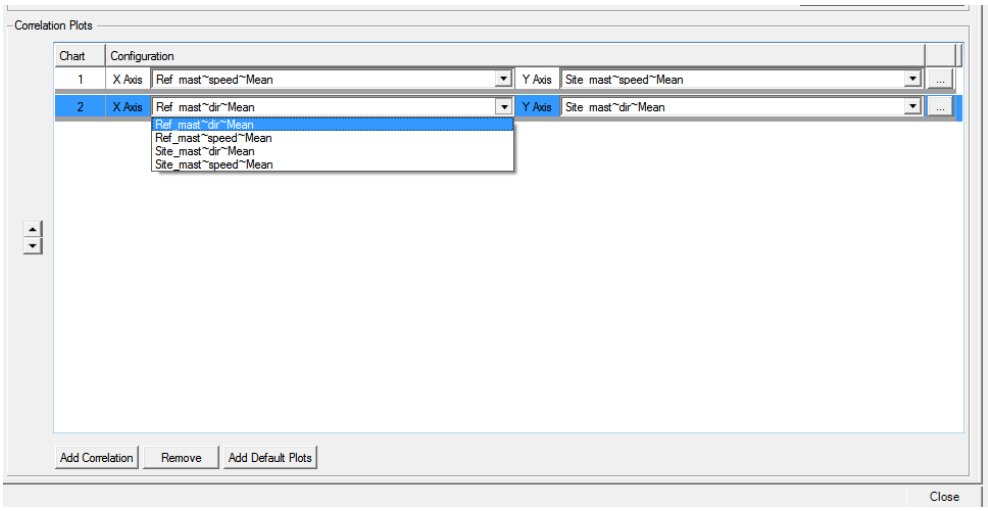
reason to the list. Once the reason has been selected, select the Apply button to exclude the data selection from the data set.



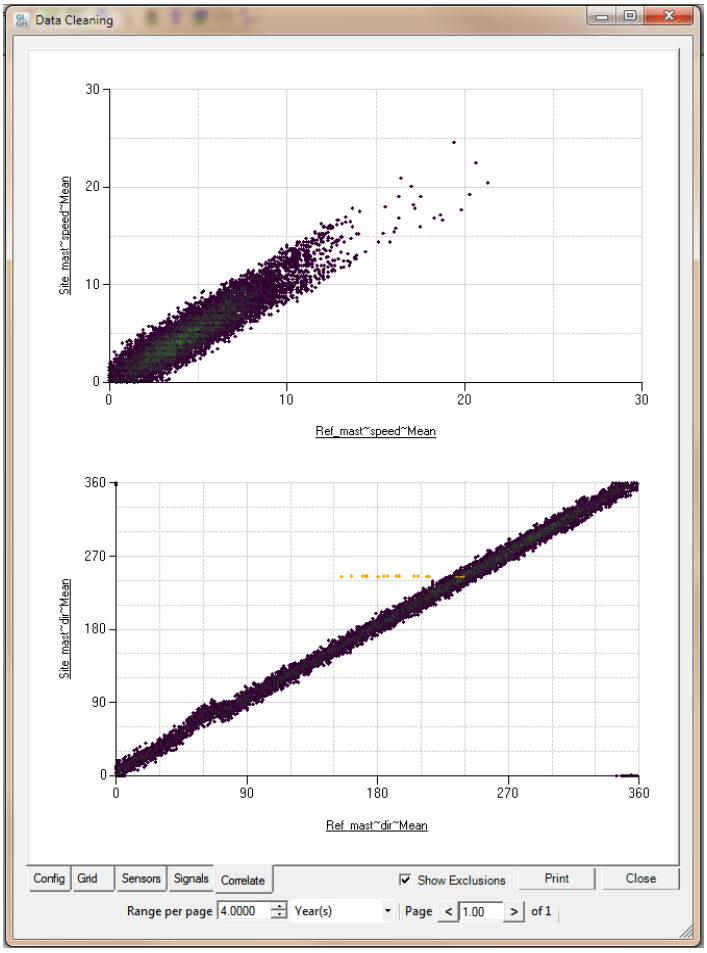
Step 23. Select the Grid tab at the bottom left hand corner of the window. This tab displays the sensor signal data in a spreadsheet. Data can be excluded in this view, following the same steps just described. This time you select the signal to be excluded by clicking on the column header. Data that have been excluded appear as light blue text.

Step 24. Go to the Signals tab. Here signals of the same type are plotted together for easy visual inspection of the data. Again, use the same techniques described in Step 20 above to zoom in and out of the data and scroll to different sections of data. Note that data cannot be excluded from the Signals tab; return to the Sensors or Grid tabs to exclude any additional data.

Step 25. Return to the Config tab. Click the Add Correlation button at the bottom of the window. Use the drop downs for the X and Y Axes to select two sensors to compare. In this case, select the Ref_mast and Site_mast wind speeds. Click the Add Correlation button again and then select the Ref_mast and Site_mast wind directions, as shown below.

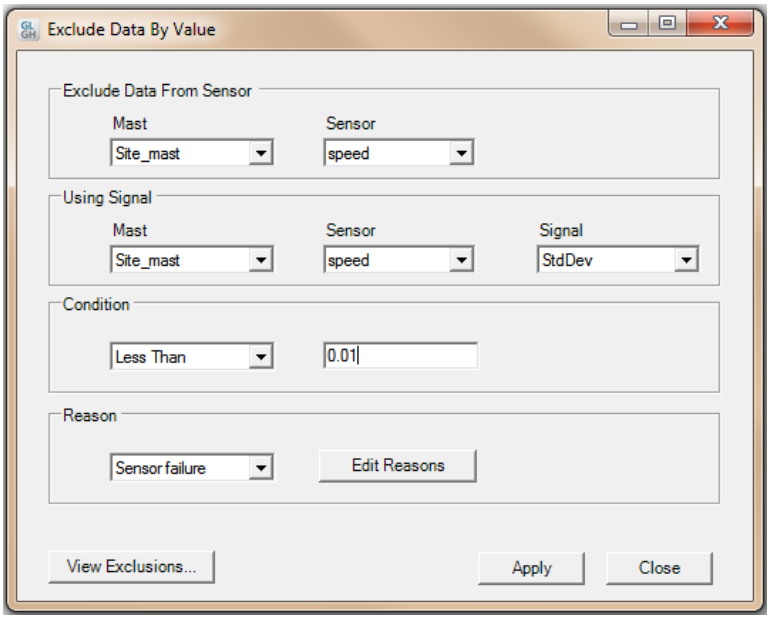


Step 26. Go to the Correlate tab to see the correlation plots. Data that are poorly correlated may indicate erroneous data at one or both sensors. The zoom level in the correlation plot corresponds to the zoom level in the Sensors and Signals plots. It may be useful to begin at the most zoomed-out level to view the correlation of the full period of concurrent data. Then zoom in to the time series on a weekly or monthly level and step through the data, using the Page arrows at the bottom of the screen, to identify periods where the correlation changes. If the Show Exclusions checkbox at the bottom of the window is checked, any data that have been excluded are displayed in orange, as shown below in the bottom plot.



Step 27. Close the Data Cleaning window. This saves all data exclusions made.

Step 28. Data cleaning can also be applied based on the values of certain signals. Click  or go to MCP+ > Exclude Data > By Value… to apply a filter to a certain sensor signal output. Set the filters to exclude wind speed data from Site_mast when the wind speed standard deviation is less than 0.01 and label the exclusions as “Sensor failure”, as shown below. Click Apply to exclude the data identified by that filter.



Step 29. Click the View Exclusions… button to view all exclusions that have been applied to the data, both from this and the Data Cleaning window. We have been quite careless in the way that we have excluded data during this tutorial, so you should now delete all the exclusion records you have created. This will return the data to the state in which it was loaded. Press Ctrl-A to select all exclusion records and click the Delete button to remove all exclusions. Close the Exclusions List and Exclude Data By Value windows.

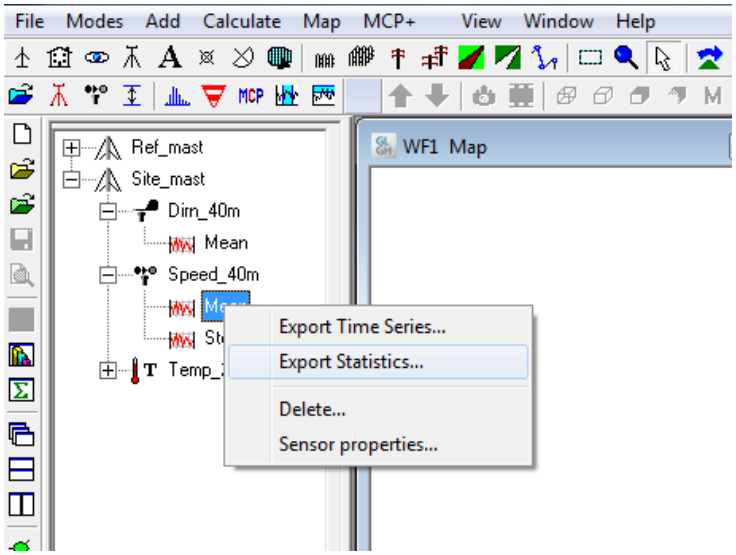
Step 30. To change any of the calibrations applied to the sensors in the loaded data sets, open the Calibrations window by right clicking the mast or sensor name in the MCP+ window, or alternatively, go to MCP+ > Edit > Calibrations in the top toolbar. Once in the Calibrations window, right click the row of the sensor to be edited, and select one of the options listed: Edit Calibration, Split Calibration, or Merge Calibration.

Step 31. Go to the MCP+ > Edit > Mast, Sensors, and Calibrations options in the top toolbar to review the settings applied to the loaded data sets. The same dialog boxes can be accessed by clicking  ,  and  on the MCP+ toolbar, respectively.

2.3 Exporting data and frequency distributions

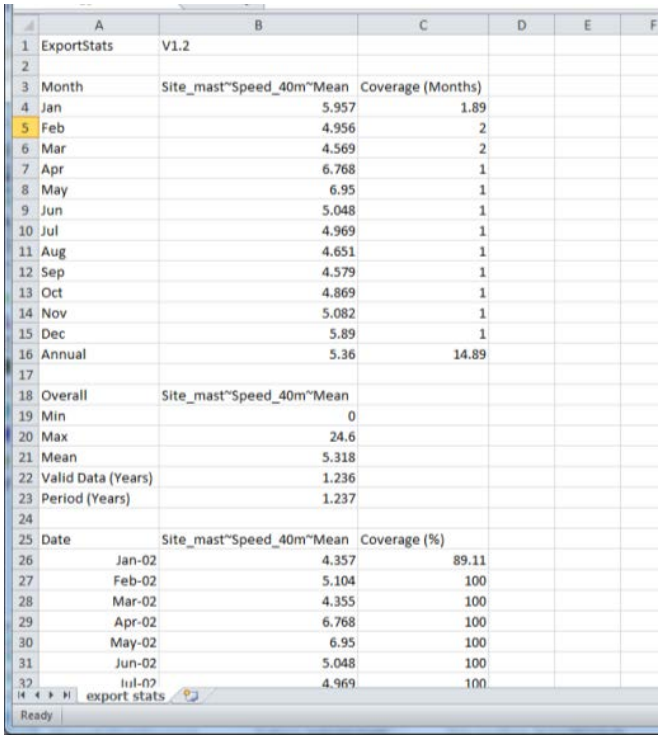
Once you have cleaned and calibrated your data, you may want to export statistics about it, or create a wind rose or frequency distribution.

Step 32. Right click on the Site_mast > Speed > Mean signal in the MCP+ data tree, and select “Export Statistics…”



Step 33. Enter a filename and save the file. This creates a short text file which contains a summary of the data which has been measured at the site mast.

Step 34. Open the file you have just created in a text editor or Excel.

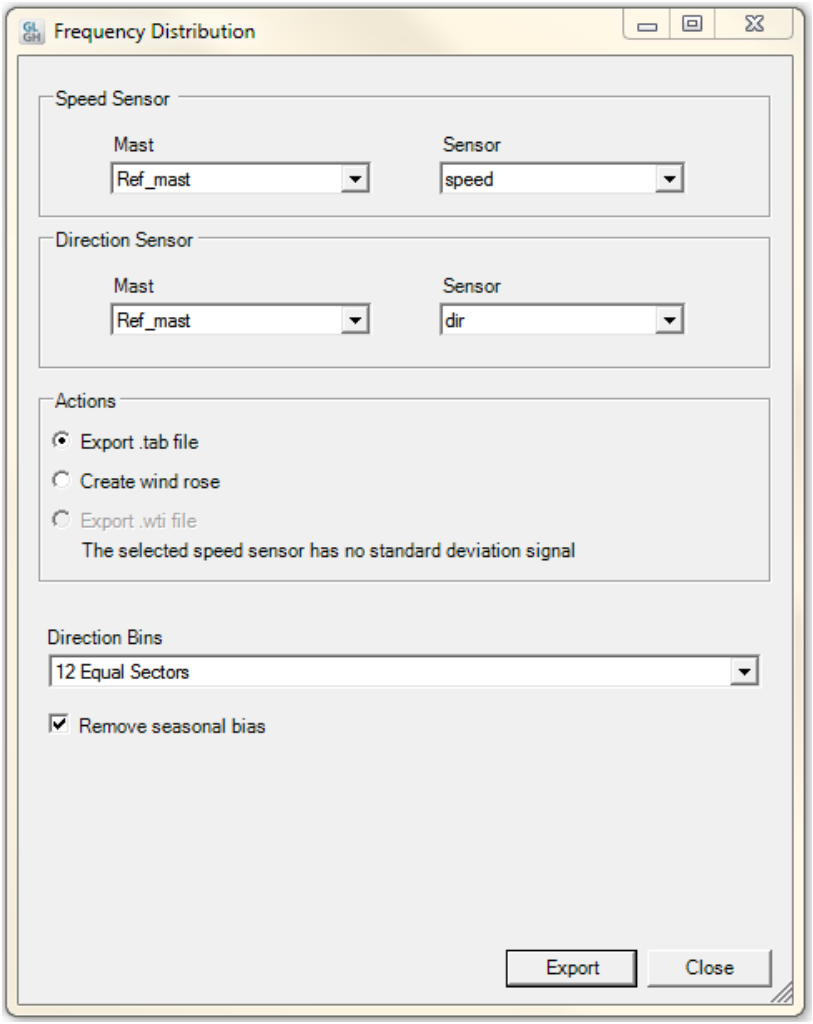


	A	B	C
1	ExportStats	V1.2	
2			
3	Month	Site_mast~Speed_40m~Mean	Coverage (Months)
4	Jan	5.957	1.89
5	Feb	4.956	2
6	Mar	4.569	2
7	Apr	6.768	1
8	May	6.95	1
9	Jun	5.048	1
10	Jul	4.969	1
11	Aug	4.651	1
12	Sep	4.579	1
13	Oct	4.869	1
14	Nov	5.082	1
15	Dec	5.89	1
16	Annual	5.36	14.89
17			
18	Overall	Site_mast~Speed_40m~Mean	
19	Min	0	
20	Max	24.6	
21	Mean	5.318	
22	Valid Data (Years)	1.236	
23	Period (Years)	1.237	
24			
25	Date	Site_mast~Speed_40m~Mean	Coverage (%)
26	Jan-02	4.357	89.11
27	Feb-02	5.104	100
28	Mar-02	4.355	100
29	Apr-02	6.768	100
30	May-02	6.95	100
31	Jun-02	5.048	100
32	Jul-02	4.969	100

export stats
Ready

The “ExportStats” file summarises measured data. It shows you both mean values and data coverage, and will help you to judge the quality of your wind measurement campaign.

Step 35. Click  or go to MCP+ > Frequency distribution to create a wind speed and direction frequency distribution. The dialog box below will appear.

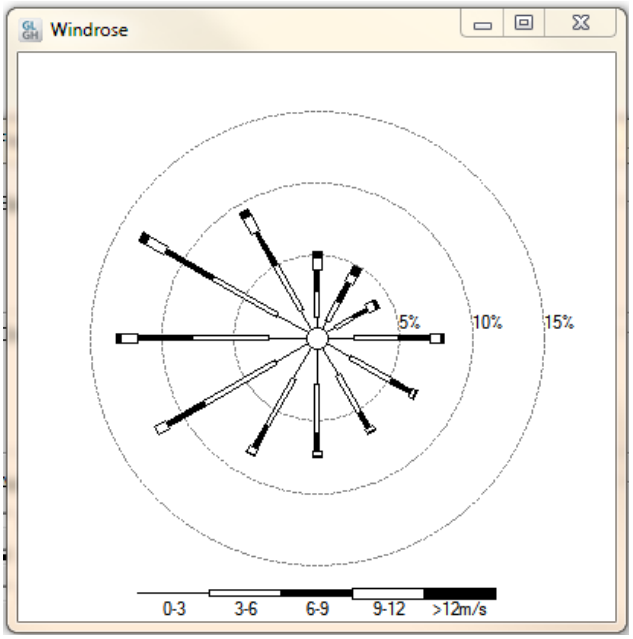


Step 36. Select Site_mast as the mast for wind speed and direction. In this case it is not necessary to specify the wind speed and direction sensors to use since there is only one of each type of signal loaded in Site_mast.

Note this window provides three export options: .TAB file, wind rose, or .WTI file.

Step 37. To export the wind speed and direction frequency distribution as a .TAB file that can be used in flow models to calculate the representative wind flow over the wind farm site, select the radio button labelled “Export .tab file” and choose the number of wind direction bins from the drop down menu. The standard number of direction bins is 12. There is also an option to “Remove seasonal bias” which is by default turned on. Click Export and a Save As box will prompt the user for the folder in which to save the file.

Step 38. To export the wind speed and direction frequency distribution as a wind rose, select the radio button labelled “Create wind rose”. There are options to customise the number of wind direction bins and the number and width of the wind speed bins. There is also an option to “Remove seasonal bias” which is by default turned on. Click the Export button and a window will pop up automatically generating the wind rose as shown below. Right click the window to name, edit or save the wind rose.



Step 39. The “Export .wti file” option allows the creation of a .WTI file. This records the turbulence intensity at the mast as a function of wind speed and/or direction, and can be used by WindFarmer for turbulence intensity assessments at turbine locations. For this function to be available, the anemometer must have measured the standard deviation of wind speed, and the user requires a licence of the WindFarmer Turbulence Intensity module

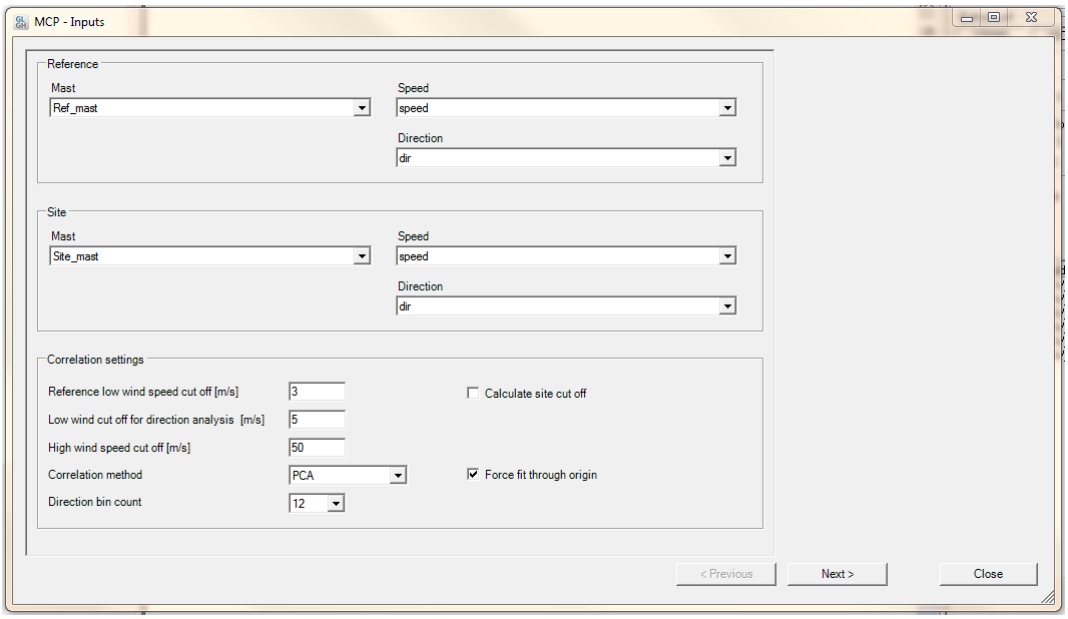
Step 40. Close the Frequency Distribution window.

2.4 Running an MCP analysis

The next steps explain how to apply the MCP (Measure Correlate Predict) methodology. The target is to start with the reference mast and use the correlation of the reference mast to the site mast to derive the long-term frequency distribution .TAB file at the site mast. In this operation the user can also assess the quality of the correlation by evaluating, both graphically and numerically, the scatter between the concurrent data at the two masts in the 12 direction sectors.

These steps describe the mechanical process of running the MCP analysis in WindFarmer. Refer to the Theory and User manuals for more information on the theory behind the process.

Step 41. Click MCP or go to MCP+ > MCP…. A dialog box will appear as shown below.

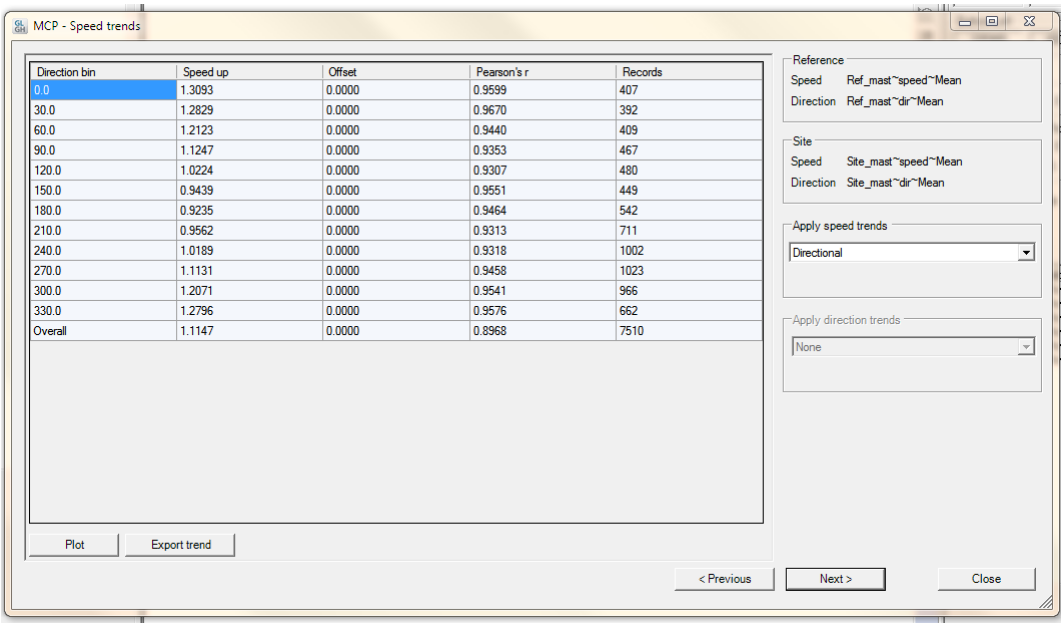


Step 42. Using the drop down boxes, select “Ref_Mast” as the reference mast and “Site_Mast” as the site mast. In this case each mast has only one wind speed and one direction sensor. If this is not the case, the user can use the other drop down boxes to select the required sensors.

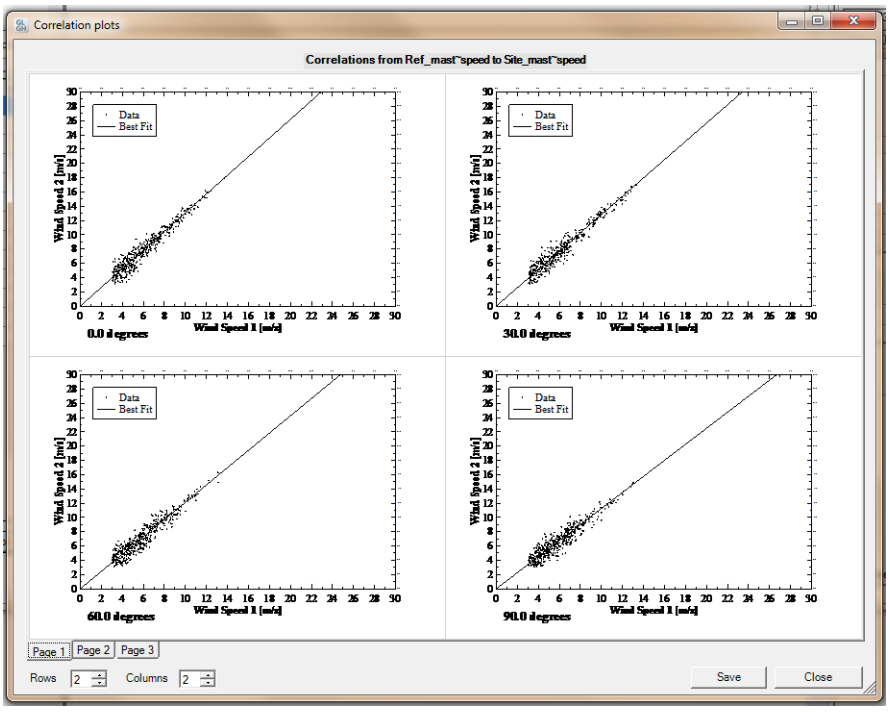
Step 43. In the Correlation Settings box, in the lower half of the window, the user can adjust settings for the cut off wind speeds used for the correlation analysis; the method for assessing the correlation scatter; whether to force the linear fit through the origin, and the number of direction bins to be used in the correlation analysis.

Note that options for setting cut offs to remove very low or high wind speed data from the correlation are provided because anemometer accuracy may be reduced at those wind speeds. Use judgment in changing the default values. Note that even with cut off low and high wind speed values, the low and high wind speed data will still be used in to synthesise data; they just will not be built into the correlation.

Step 44. Click Next. MCP+ will take a few seconds to process and then will produce the window shown below. Note that the spreadsheet on the left contains the following information: centre points of wind direction sectors, speed up between reference and site (in this case the site mast is windier than the reference mast), Offset (in this case the line is forced through the origin), Pearson’s r (correlation coefficient as an indicator of the level of scatter) and number of concurrent data records of the two masts that contributed to define the correlation.



Step 45. Click the Plot button to view the quality of the correlation. The window below will appear showing the correlation in the various direction sectors. At the bottom of this window, use the page buttons to switch to the other correlation plots for the other direction sectors and the direction correlation. These images can be saved, if desired. Close the window to return to the previous dialog box.

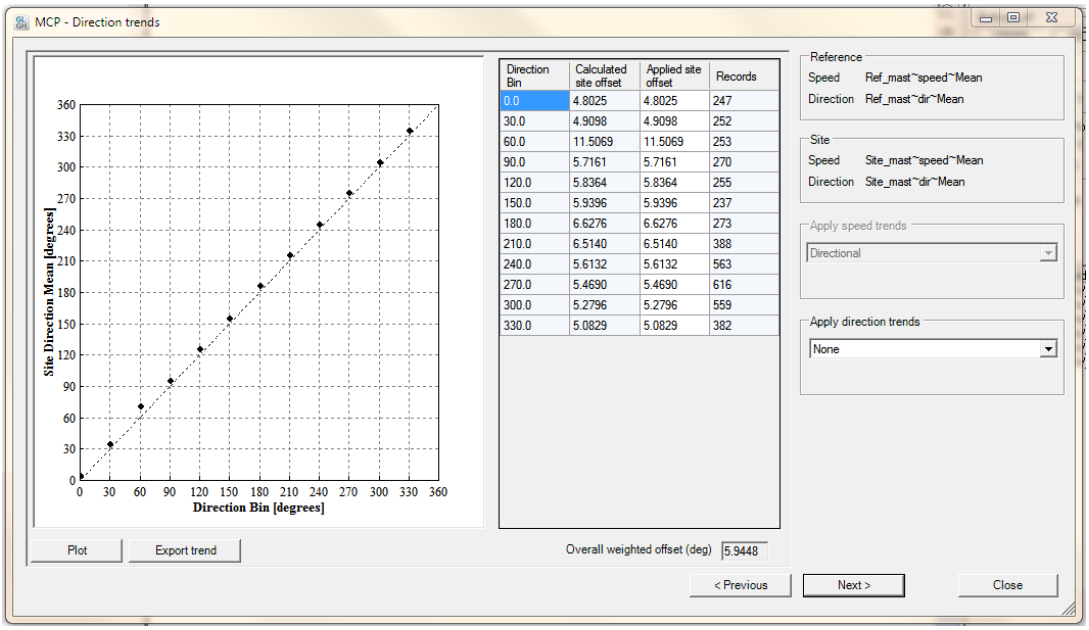


Step 46. Click the Export Trend button in order to export a file documenting the proposed speed up values by direction sector.

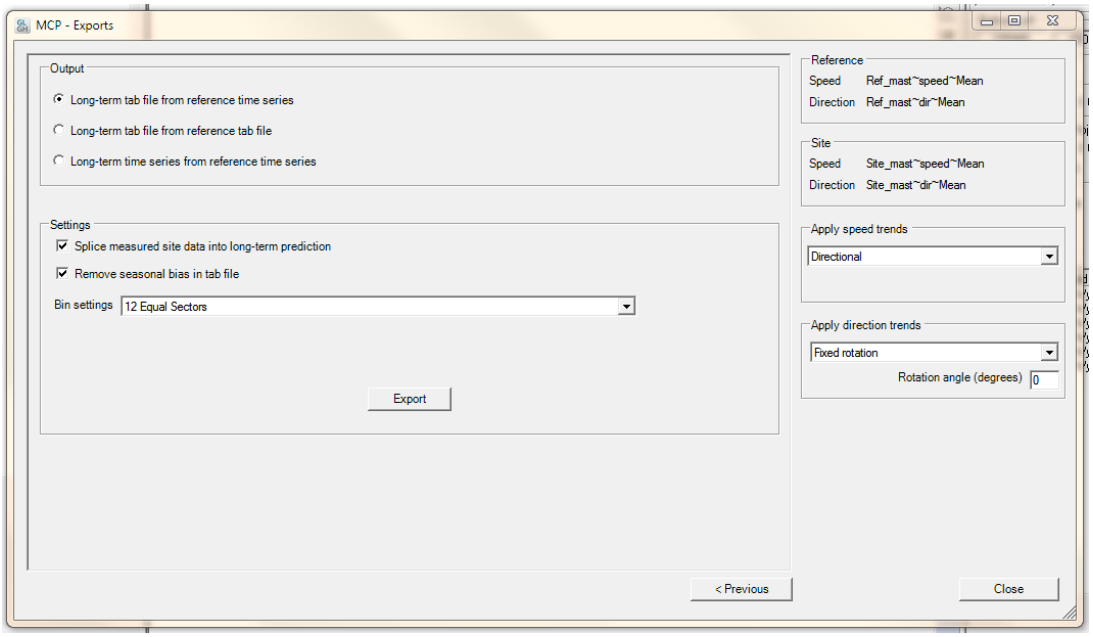
Step 47. Click the drop down menu labelled “Apply speed trends” on the right hand side of the window to select to apply the directional speed ups calculated.

Step 48. Click Next. The MCP – Direction Trends window appears as shown below. Similar to the MCP – Speed Trends window, the Plot button allows the user to view and export the correlations, the Export Trend button allows the user to save the

calculated offset values, and the drop down menu labelled “Apply direction trends” can be used to select how directional speed ups are applied.



Step 49. Click Next. The MCP – Exports window appears as shown below. Select the radio button labelled “Long-term tab file from reference time series”.



Step 50. Under the Settings box, there are options to “Splice measured site data into long-term prediction” and/or “Remove seasonal bias in tab file.” These are selected by default. The spliced time series is the combination of the synthesised data created from the reference mast data, which have been factorised using speed ups and direction shifts from the correlation, and the measured data at the site mast. In the case when the splice time series box is unchecked, the time series will contain only the data synthesised on the site mast and none of the actual measurements.

Step 51. Select how to split the data into direction bins with the drop down menu labelled “Bin settings.” When finished making the selections, click the Export button and choose where to save the .TAB file.

Step 52. Close the MCP window. End of the exercise.

3. TURBULENCE INTENSITY MODULE

The Turbulence Intensity Module gives the user increased capabilities when inputting the turbulence intensity characteristics. It allows the turbulence intensity to be input as a function of wind speed and/or direction. This is particularly beneficial to users with the MCP+ Module, which can derive turbulence intensity data from wind speed measurements. The Turbulence Intensity Module also provides the user with access to the individual turbine data generated during the energy calculation, including turbulence intensity values calculated in the Eddy Viscosity Wake Model. This allows users to determine the turbulence intensity due to the turbine wakes at each wind turbine in the wind farm layout. The data generated can be exported via the Flow and Performance Matrix.

See Section 8 of the User Manual for more details.

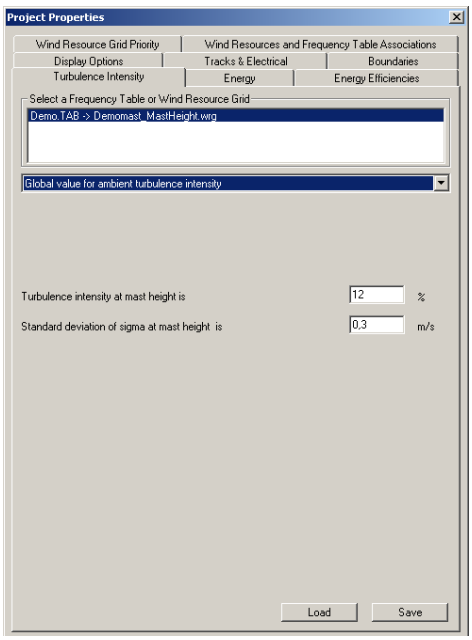
It should be noted that this exercise requires the full version of the software, and cannot be completed with only the demo software.

3.1 Advanced turbulence input

Step 1. Open the file “Demosite.wow” located in the demodata directory of the WindFarmer library. Refer to the Base Module Tutorial to understand how the WOW file has been created.

Step 2. Click  or go to “View > Project Properties”. The “Project Properties” window with multiple dialog boxes will appear.

Step 3. Click on the “Turbulence Intensity” tab. The window below will appear.



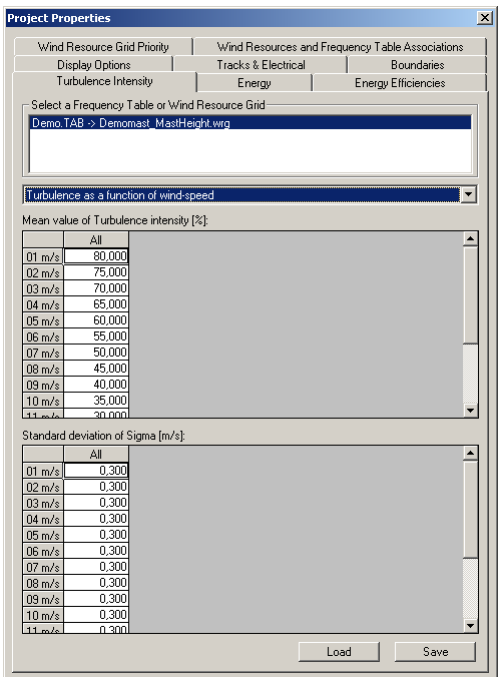
Step 4. The value of turbulence intensity set in “Demosite.wow” is a default global value of 12%. Click on the drop down box to display and familiarise yourself with all the different options of turbulence input.

Step 5. For this specific exercise we want to set turbulence intensity as a function of wind speed. Select this option from the pull down menu. Edit the configured

spreadsheet with arbitrary values starting with 80% at 1m/s and dropping by 5 % every 1 m/s (80%, 75%, 70%... down to 10% at 15 and 16m/s+). However, in a real scenario, these values should be calculated using the wind speed standard deviation recorded at the anemometer. Furthermore they decrease following an exponential trend rather than a linear trend. Note that turbulence intensity from 16 m/s and above usually tends to be asymptotic. The following window shows how the turbulence input will look. Note that the MCP+ module allows the calculation of turbulence intensity, which can be saved as a WTI file and then imported into Project Properties.

Step 6. Press APPLY to store the changes.

Step 7. It is optional to save the turbulence input by pressing SAVE. A file in WindFarmer's own format (*.wti) can be created. Note that if a WindFarmer turbulence file has been created for a specific sensor (usually by using the MCP+ module) this can be imported by clicking "Load".



Step 8. Press OK to close the "Project Properties" window.

Step 9. Click  or go to "View > WF Control Panel".

Step 10. Switch to the "Energy" window.

Step 11. Set "Eddy Viscosity Model" as the wake model using the drop down box on top of the Energy window. Because we entered such high values for turbulence intensity, you should increase the "Maximum allowable Turbulence Intensity (%)" in the "Eddy Viscosity Model" section of the window in order to perform the calculation without warnings of illegal layout. In this specific example you should enter the maximum value of 100% - in a real world example the default value of 20% may be appropriate.

Step 12. Press APPLY to store the changes.

Step 13. Press OK to close the WF Control Panel.

Step 14. Use "File > Save Workbook As…" to save the workbook with the changes carried out so far.

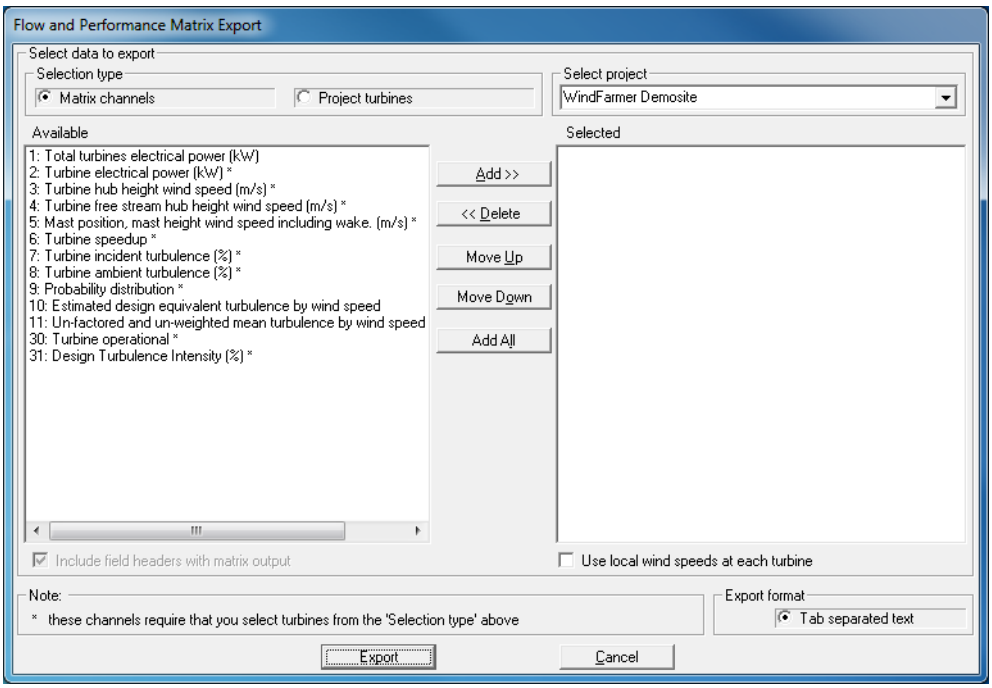
3.2 Exporting the Flow and Performance Matrix

The Flow and Performance Matrix is only available with a licensed version of WindFarmer. Users with the Demo version will not be able to complete this exercise.

Step 15. Click  or go to “Calculate Energy/Test” to carry out the energy calculation.

Step 16. Close the “Report” excel spreadsheet displayed at the end of the test.

Step 17. Go to “File > Export > Export Flow and Performance Matrix”. The window below will appear.



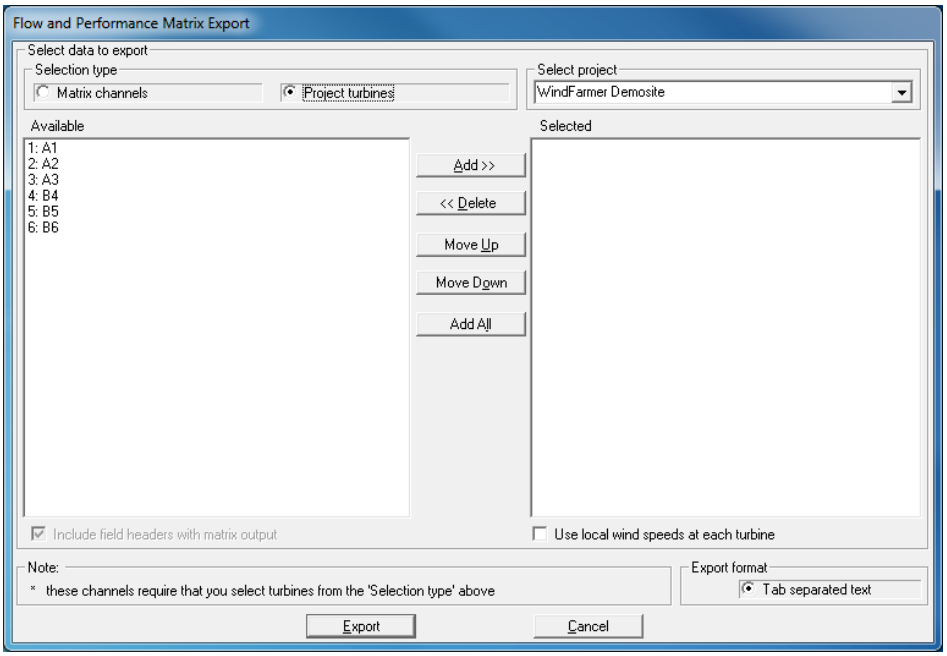
Multiple options are available for the type of output (Matrix channel), the turbines for which information is required (Project turbines) and the selection of the project.

For this specific example the target is to know more about the “Turbine Electrical Output” broken down for wind speed and direction bins at Turbine 1.

Step 18. In the “Flow and Performance Matrix Export” window click “2: Turbine electrical power (kW)*” on the left section of the window. It will be highlighted in blue.

Step 19. Click “Add >>” to transfer the highlighted element to the right section of the window.

Step 20. Click on “Project Turbines” in the “Selection Type” section. The window will display the turbines of the project as shown below.



Step 21. Click on “1:A1” to highlight Turbine 1.

Step 22. Click “Add >>” to shift the turbine to the right.

Step 23. Go to the drop down box of “Select Project” if multiple projects have been loaded in the same workbook. This is not the case for the demo WOW file.

Step 24. Click “Export” to create the matrix.

Step 25. Save the file as TXT in a suitable directory.

Step 26. Open the output file in Excel and after applying tab separation check the contents of the matrix. In this example the matrix is describing in detail how Turbine 1 performs in terms of instantaneous power output for each wind speed (rows of the matrix) and each wind direction (columns of the matrix). This is using the wind condition at the met mast – ticking the ‘use local wind speeds at each turbine’ checkbox in the Export dialogue box will change the reporting to be relative to the free stream wind at the turbine location..

Step 27. Repeat the previous steps exporting information from other channels. Note that if the GH BLADED LINK module is licensed then further channels are available. The outputs from these channels are then usable in GH Bladed for loading calculations. See the Theory and User manuals for further details.

End of the exercise.

4. ELECTRICAL MODULE

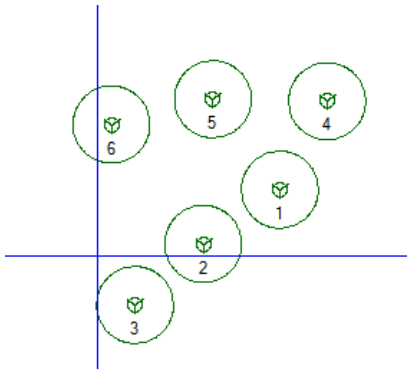
The Electrical Module allows the user to design the electrical network of the proposed wind farm, calculate the electrical performance in terms of losses and reactive power consumption, estimate the required lengths of cabling, and so on.

See Section 9 of the User Manual for more details.

4.1 Setting up the electrical network

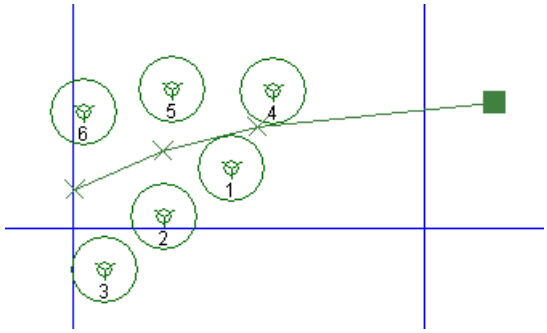
Step 1. Open the file “Demosite.wow” located in the demodata directory of the WindFarmer library.

Step 2. Turn off DTM, terrain, boundaries and boundary points in the “Map Object” and “Map Data” bar. Note that this is not a requirement - it simply provides a better view of the layout, as shown below.



Step 3. Click  or go to “Add > Cables” in the toolbar.

Step 4. Cables in WindFarmer run between objects such as turbines or meters, and nodes. Right click in the map to add a meter – this is shown as the green square in the image below, and represents the point of connection between the wind farm and the electricity distribution network. Then right click three more times to place three nodes (the green crosses), passing between the groups of turbines 1-2-3 and 4-5-6..Note that several mouse functions are described in the user manual to help the user to draw electrical cables.



Step 5. Connect each of the six turbines to their nearest node. Note that turbines cannot be connected to the metering point. In order to do so click  or go to "Modes > Cabling".

Step 6. Click on node 2 in the Control bar- Information tab located under "Group ID".

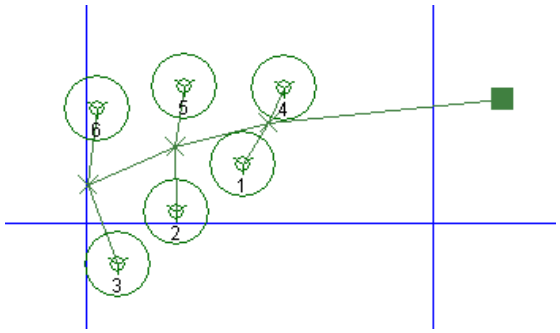
Step 7. By holding down the control key (Ctrl) left click on turbine 1 and turbine 4. The two turbines will be connected to the main cable at node 2.

Step 8. Click on node 3 in the Control bar- Information tab located under "Group ID".

Step 9. By holding down the control key (Ctrl) left click on turbine 2 and turbine 5. The two turbines will be connected to the main cable at node 3.

Step 10. Now click on node 4 in the Control bar- Information tab located under "Group ID".

Step 11. By holding down the control key (Ctrl) left click on turbine 3 and turbine 6. The two turbines will be connected to the main cable at node 4. The final cable layout suggested in this example is shown in the next figure.

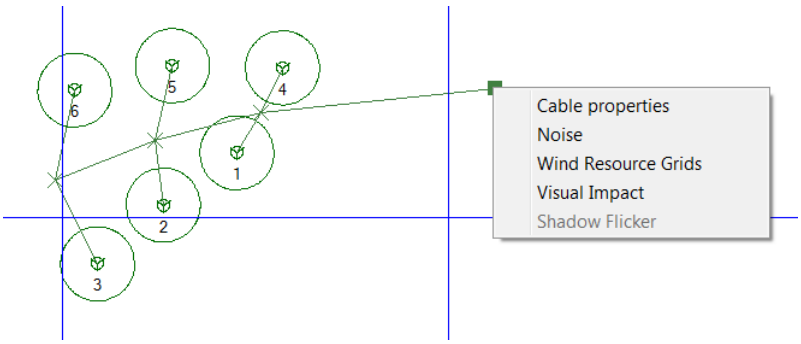


Step 12. Go back to working mode by either clicking  or double clicking in an empty part of the workspace.

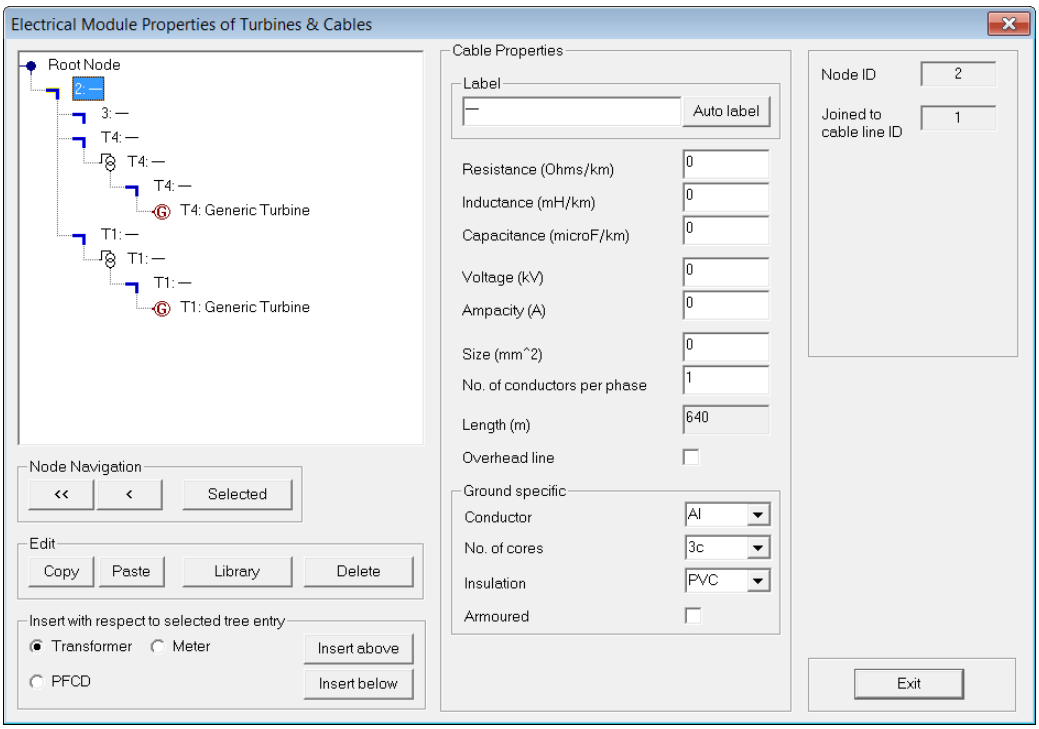
4.2 Editing cable properties

At this stage, the electrical properties have to be associated to each element of the electrical network. Notice that in a real scenario electrical equipment should be chosen with careful judgement since all the elements combined (cables, transformers, etc.) should give the lowest electrical losses as possible within reasonable costs. It is not scope of this exercise to investigate the best equipment but rather give a demonstration of how this information is loaded into the model.

Step 13. Right click over the meter (the square) to display the options shown below



Step 14. Left click on “Cable properties” to open the “Electrical Module Properties of Turbines and Cables” window shown below for this specific project



About Cable Properties:

In this window all the settings related to the electrical specifications can be set. In detail:

The left side of the window shows all the connections refereed to the specific node. In this case it can be seen that node 2 is linked to node 3, turbine 4 and turbine 1.  *indicates the wind turbine generator, WTG,*  *indicates transformer,*  *is cable and*  *is root node (where the meter is usually located).*

By clicking on each of these elements the user can edit cable (resistance, inductance, capacitance, voltage, etc.), transformer (rating, primary voltage, secondary voltage, etc.) and generator properties on the right of the window.

In "Node Navigation" it is possible to switch to the upper node.

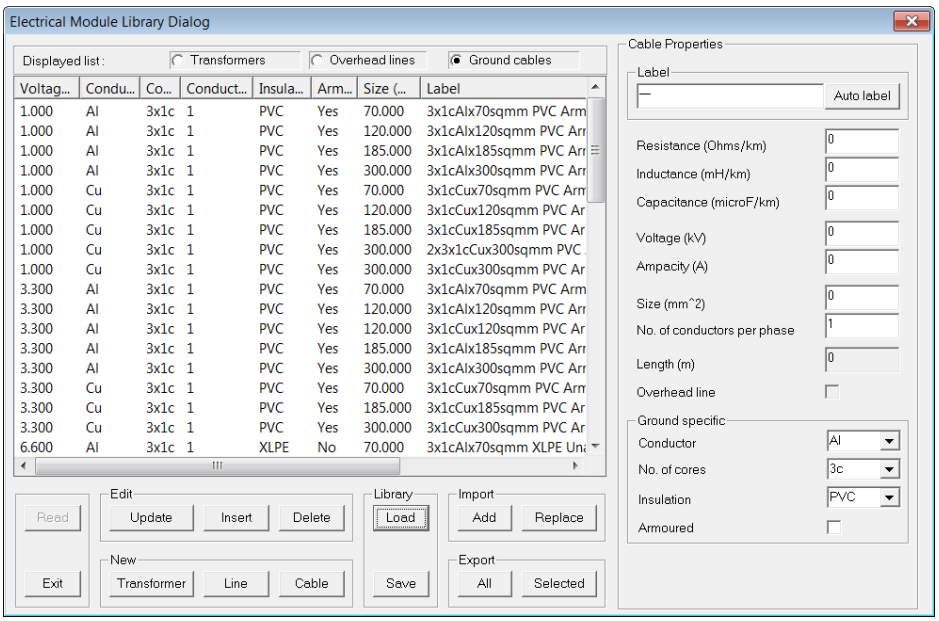
In "Edit" the user can copy properties to be pasted in other similar elements of the project or pick up properties directly from a library.

Meters, Transformers and PFCD can be inserted at any point of the network where required.

Step 15. The properties of the WTG have already been set in "Wind Turbine Studio > Turbine Power Curve" ().

Step 16. Click on the cable  between turbine T4 and the transformer  above it.

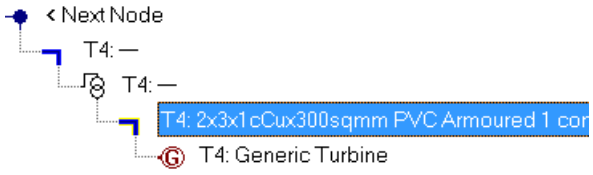
Step 17. WindFarmer allows you to maintain a library of electrical components to use in your network. Click "Library" to open it. To load in an initial set of data, press the "Load" button in the "Library" section of the window and select the file Elec_Library.elb provided in the Demodata folder of WindFarmer. The library below will be displayed.



Step 18. Select the 8th ground cable from the top (with size 300 mm²). Note that for this example no particular care has been given to the cable selection, only that it can support a voltage which is greater than the nominal voltage of the turbine (in this case 0.69 kV).

Step 19. Click the box “Read” on the left bottom corner of the window.

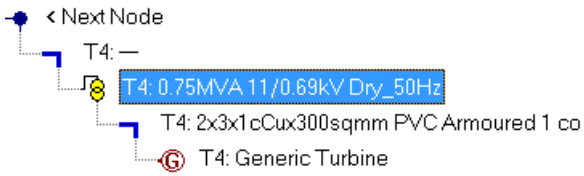
Step 20. The selected cable will be loaded as shown below.



Step 21. Click on the for transformer T4, next to the cable that has been just loaded.

Step 22. Click “Library” to load a suitable transformer.

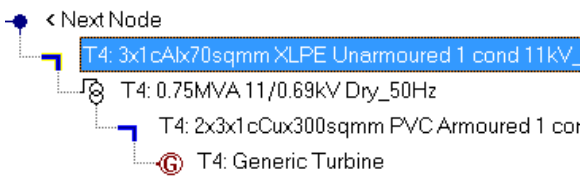
Step 23. Select the top one in the list and press “Read”. The window will now show the transformer as indicated below.



Step 24. Click on the cable above (between T4 transformer and the “next node”) to define the cable that will link the transformer of turbine 4 to node 2.

Step 25. Click “Library” and select the first cable with nominal voltage of at least 11 kV (the high voltage side of the transformer).

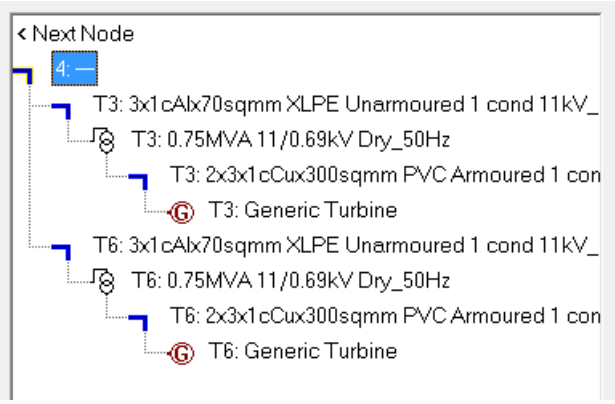
Step 26. Click “Read” to load the cable and get the layout shown below.



Step 27. Click on any of the three elements that have been just loaded and press “Copy”.

Step 28. Navigate through the nodes (bottom left of the Electrical Properties window) or the turbines (top right of the Electrical Properties window) to “Paste” this information to exactly the same tree location for the other 5 remaining turbines (the target is to assume same specifications generator-cable-transformer-cable-node).

Step 29. Now the only information to load is about the main cable from node 1 to node 4. Move with the node navigation to node 4 as shown below. Note, from the previous step, that all the specifications from the generator to node 4 have been loaded.



Step 30. Click “Library” to access again to the cable library.

Step 31. Select the last cable in the list and press “Read”.

Step 32. Copy and paste the specifications of this cable to all the other remaining nodes (3 and 2) by moving to “Next Node”.

Step 33. Click “Exit” on the right bottom corner to close the window.

At this stage all the specifications for the electrical network have been loaded. The demo data library has simplified the work of loading data from scratch and can be partly useful for addressing users who are inexperienced with electrical issues.

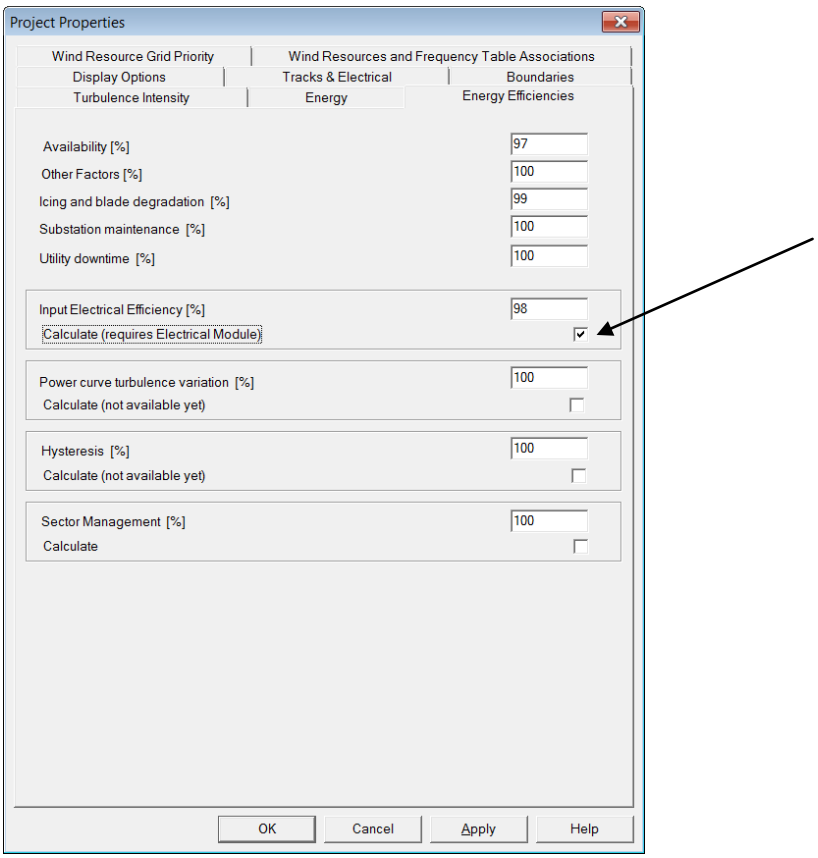
4.3 Calculation of electrical losses

The next step is to calculate the net energy production taking into account the electrical losses given by the designed network.

Click  or go to “View > Project Properties”.

Step 34. Switch to the “Energy Efficiencies” window.

Step 35. In the section “Input Electrical Efficiency” tick the “Calculate” box as shown below



Step 36. Press APPLY to store the changes and OK to close the window.

Step 37. Click  on the mapping toolbar or go to “Calculate > Energy/Test” in the menu.

Step 38. The spreadsheet report displayed on screen now shows the electrical efficiency calculated with the given electrical network.

End of the exercise.

5. SHADOW FLICKER MODULE

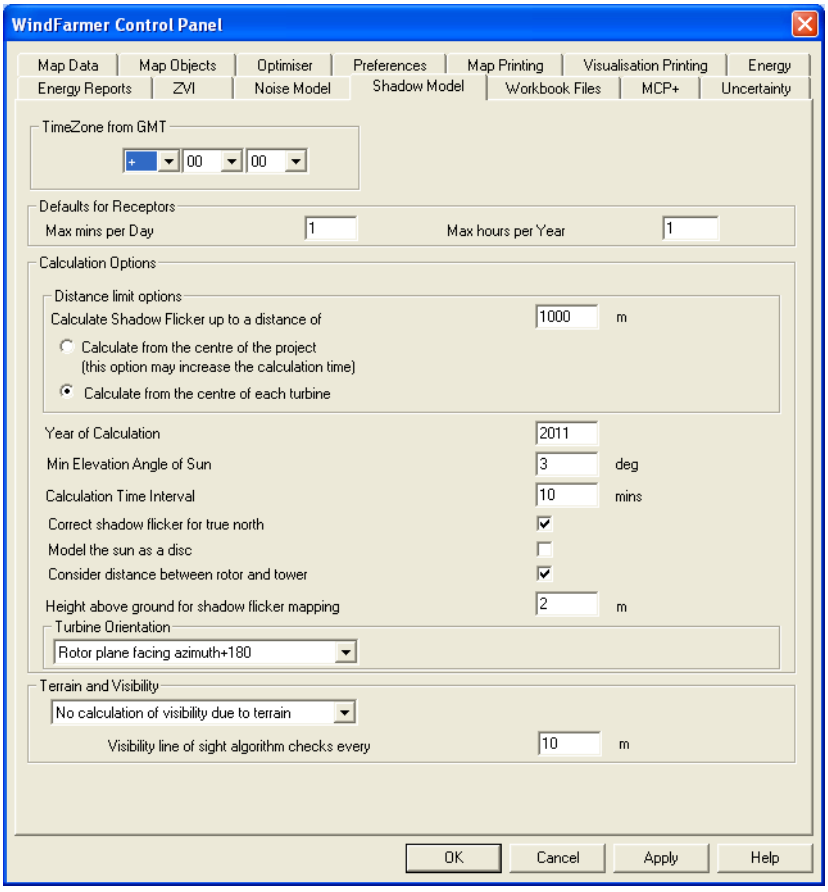
The Shadow Flicker Module contains the tools required to assess the potential period of shadow flicker caused by a wind turbine. The module allows you to create maps of shadow flicker occurrence and to analyse the shadow flicker at specific points, known as receptors. This information can be used to design and operate the wind farm in a way that minimises the annoyance to people. See Section 10 of the User Manual for more details.

5.1 Calculation options

Step 1. Open the file “Demosite.wow” located in the demodata directory of the WindFarmer library. In general note that a DTM map is required in order to run the shadow flicker model.

Step 2. Click  or go to “View > WF Control Panel”.

Step 3. Switch to the “Shadow Model” dialog box within WF Control Panel. The window is shown below. The next steps will provide explanation of each input of this window. It is recommended to play with different combinations to understand the behaviour of the model.



Step 4. The “GMT time zone” is required to know precisely the time zone. This is useful if a turbine shut down procedure has to be implemented at some hours of the day to minimise the annoyance of shadow flicker at some locations.

Step 5. The “Defaults for Receptors” inputs can be ignored for now.

Step 6. In the "Calculation Options" box there is "Distance limit options" box where it is possible to choose the maximum calculation distance from either the centre of the project or from the centre of each turbine.

Step 7. In the input box "Year of Calculation" the user can set the year for which the shadow flicker calculation will be carried out. The calculation can be carried out for years between 1950 and 2050.

Step 8. Also in "Calculation options" it is possible to set the minimum elevation of the sun to be used for calculations. If for example the wind farm is located in a wide flat terrain 3 degrees can be suitable. However if the wind farm is located in a valley surrounded by high mountains it is possible to set a greater elevation since the nearby mountains will shelter the wind farm at greater elevation of the sun – this will reduce the time required by WindFarmer to perform the calculations.

Step 9. The "Calculation Time Interval" is set as default to 10 minutes. This means that WindFarmer will check the position of the sun and shadows every 10 minutes through the year. Increasing this time will speed up the calculation but reduces the accuracy, and vice versa.

Step 10. By checking the box "Correct shadow flicker for true north" it is possible to remove the effects of magnetic declination from the shadow flicker calculations.

Step 11. By checking the box "Model the sun as a disc" it is possible to consider the sun for its real dimension rather than a point.

Step 12. By checking the box "Consider distance between rotor and tower", WindFarmer will include that small offset in its calculation.

Step 13. The "Height above ground for shadow flicker mapping" allows you to set the height at which you would like to calculate the shadow flicker observations.

Step 14. In the "Turbine Orientation" three options are available: "Rotor plane facing azimuth+180" (Rotor plane always perpendicular to sun) "User defined rotor orientation" (User specified orientation) and "Sphere around rotor centre" (Shadow generated via sphere shape, not plane)

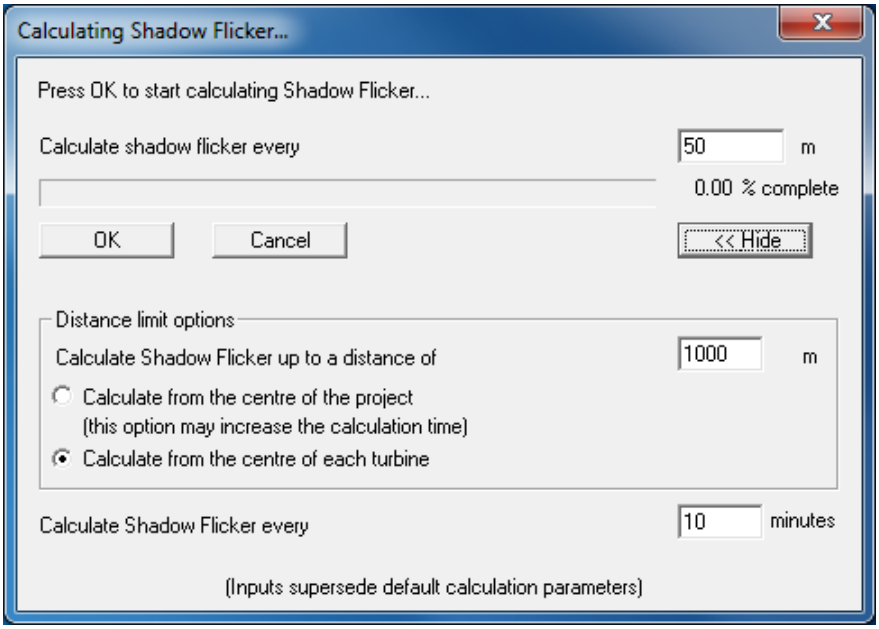
Step 15. In "Terrain and Visibility" three options are available: "no calculation of visibility due to terrain" (assumption of flat terrain), "use terrain to calculate turbine visibility" (if the line turbine section-shadow receptor intercepts the terrain the shadow flicker time will not be counted) and "use terrain to calculate turbine and sun visibility" (if the line sun-turbine section-shadow receptor intercepts the terrain the shadow flicker time will not be counted).

Step 16. The "visibility line of sight algorithm checks every (10 m is default)" is the resolution in the line of sight check described in step 11 (in the same way as the "Calculation Time Interval" indicated in the previous step is the resolution of the sun path). Usually $1/5^{th}$ of the DTM resolution is the minimum recommended for reaching accurate results.

Step 17. Click 'Apply' if you have made any changes, and then 'OK' to leave the control panel.

5.2 Running a shadow flicker calculation

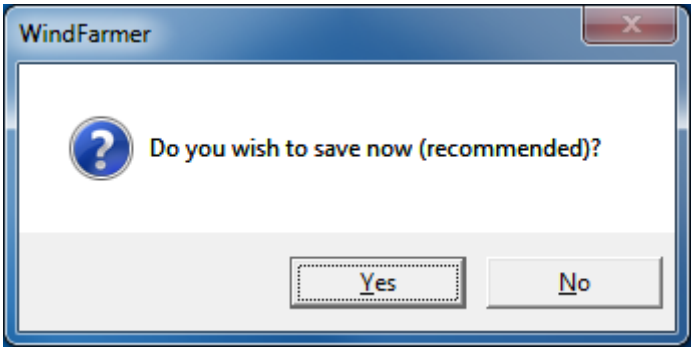
Step 18. Calculate the shadow flicker map by clicking “Calculate > Shadow Map” or clicking the “Shadow Flicker” box in the Display bar. WindFarmer may produce a warning that it has detected changes, and asking if you would like to assess the Shadow Flicker – if it does, then you should click ‘Yes’. A new dialogue box will open - click “Options>>” to expand it to the one shown below.



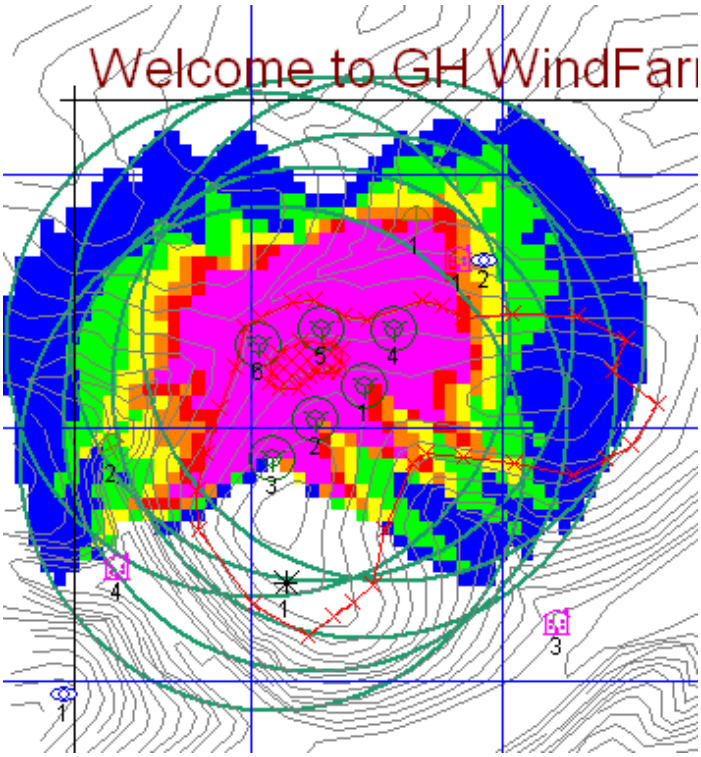
Step 19. In “Calculate shadow flicker every…” the resolution of the shadow flicker map will be set. “Distance limit options” and “Calculate shadow flicker every…” can also be set to supersede the inputs given in “WF Control Panel > Shadow model”.

Step 20. Press OK. The calculation may take several minutes, or even longer, depending on the complexity of the site.

Step 21. At the end of the calculation click ‘OK’ and the following window will be displayed (except in the demo version):

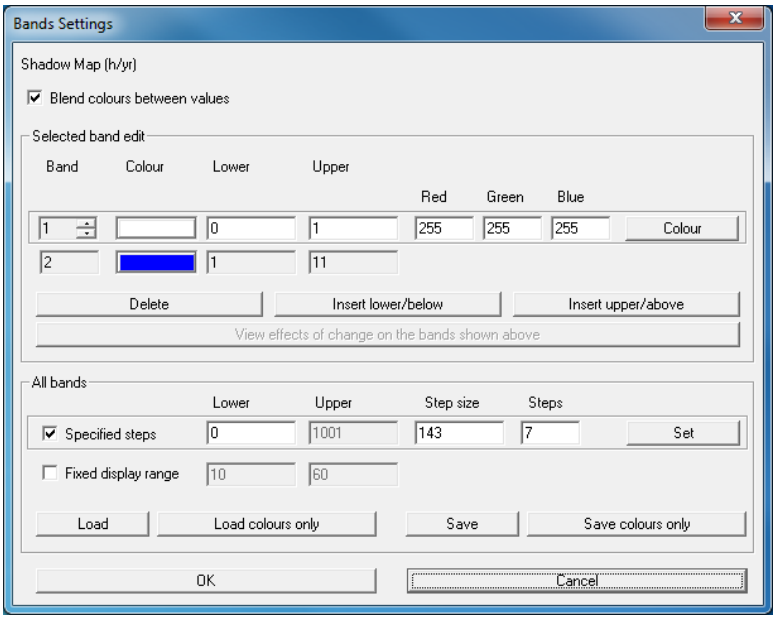


Step 22. By clicking YES the calculation will be saved and this will increase the size of the WOW file. Alternatively by clicking NO the map will be displayed without retaining the information if the WOW file is closed without saving the latest changes. The map, using default settings, will appear as shown below:



5.3 Shadow flicker map display options

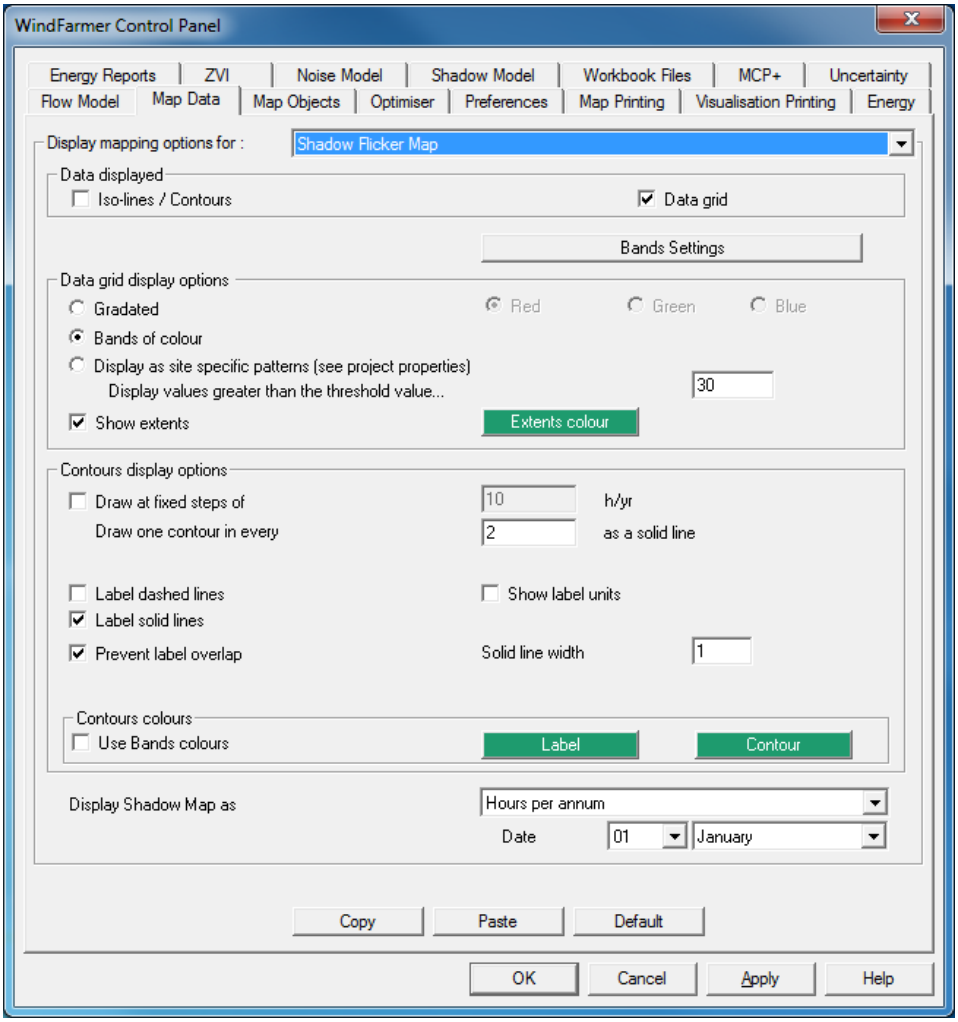
Step 23. By clicking “Control bar > Legend tab” (bottom right corner of the screen) it is possible to view the range of each colour band (in hours per year) and by double clicking on any colour it is possible to edit the colour band and insert more ranges. The window below will appear to allow the user to do so



Step 24. With the reference to the “Bands settings” window above by clicking “Colour” it is possible to change the colour of a specific band, “Delete” to eliminate the band, “Insert lower/below” and “Insert upper/above” to increase the number of bands between band delimiters. With the “Specified steps” box it is possible to either select the lower and upper limits (unticked) or specify the number of steps and the step size. In “Fixed display range” it is possible to choose which range to visualise in the map. “Load” and “Save” are used to store the changes (as *.ban files) and utilise them for other projects.

Step 25. Another way to edit the map, with even more options, is by clicking > Map Data or alternatively "View > WF Control Panel > Map Data".

Step 26. In "Display mapping options for:" select "Shadow Flicker Map". The window below will be displayed.



Step 27. In "Data display" the user can choose to display the map as contours and/or data grid.

Step 28. "Bands setting" brings the user back to the steps described above.

Step 29. "Data grid display options" give options on the display of the data grid. By unticking "Show extents" the user can remove the circles showing the extent of the calculation.

Step 30. "Contour display options" gives the available options if the map is displayed as contour lines.

Step 31. In "Display shadow map as" it is possible, by using the drop down menu, to select a map that shows the "hours per annum" (default) or have a more specific "minutes for a specified date" (below that in the window the date can be selected).

Step 32. Press APPLY and OK to store the changes.

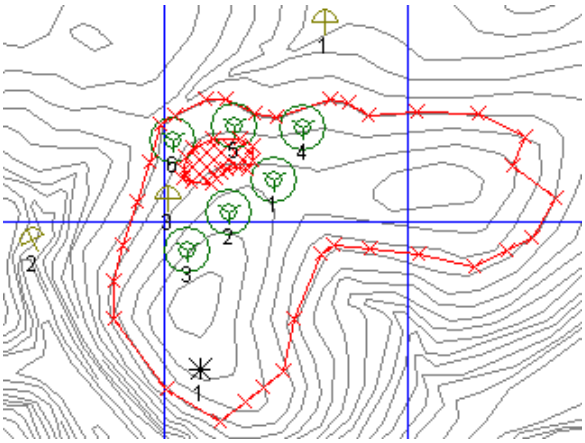
5.4 Shadow receptors

Besides generating shadow flicker maps, the Shadow Model can also be used to assess shadow flicker at specific “Shadow Receptors”, where shadow flicker in a dwelling can be determined. The user can also produce detailed Shadow Flicker Reports specific for each turbine. These can be implemented for turbine shut down procedures of the wind farm when the wind farm is operational.

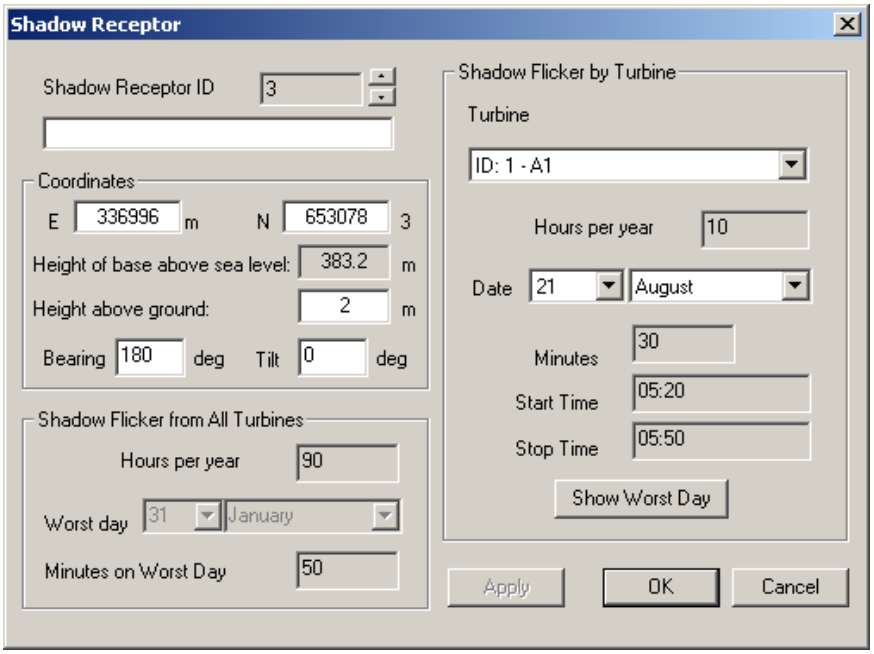
Step 33. Turn off the shadow flicker map in the display bar.

Step 34. Click  on the map toolbar or go to “Modes > Shadow Receptor”

Step 35. As you see in the Control bar >Information tab” on the right of the screen two shadow receptors are already present on site (southwest and northeast of the wind farm). Fix a third receptor very close to the wind farm between Turbines 3 and 6 by right clicking with the mouse.



Step 36. Double click on shadow receptor 3 in the “Control bar > Information tab” while in Receptor mode or alternatively, if back in working mode using  , right click over the receptor and select ‘Shadow receptor properties’. The dialog box below will be displayed.

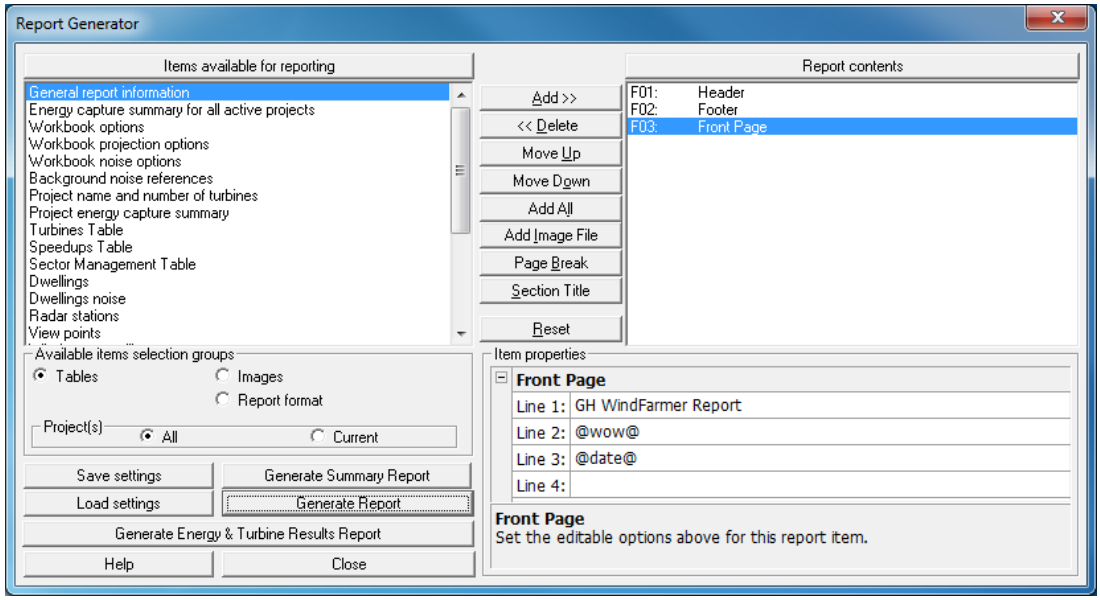


Step 37. In the "Shadow Receptor" dialog box the user can fix the geometrical properties of the receptor and evaluate from individual turbines at any date of the year, or the worst day of the year, the minutes of shadow flicker that occur. In this case, using default settings, the worst day is the 31st of January. By flicking through other dates and clicking APPLY it is possible to evaluate the minutes in other days.

Step 38. Note that the button APPLY has to be pressed to store any editable input before closing the window.

5.5 Exporting shadow flicker reports

Step 39. Click "File > Generate Report" to display the window below



Step 40. On the list on the left click on "Shadow Flicker Data" to highlight it in blue.

Step 41. Click "Add >>" to shift it under "Report Contents".

Step 42. Click "Generate Report".

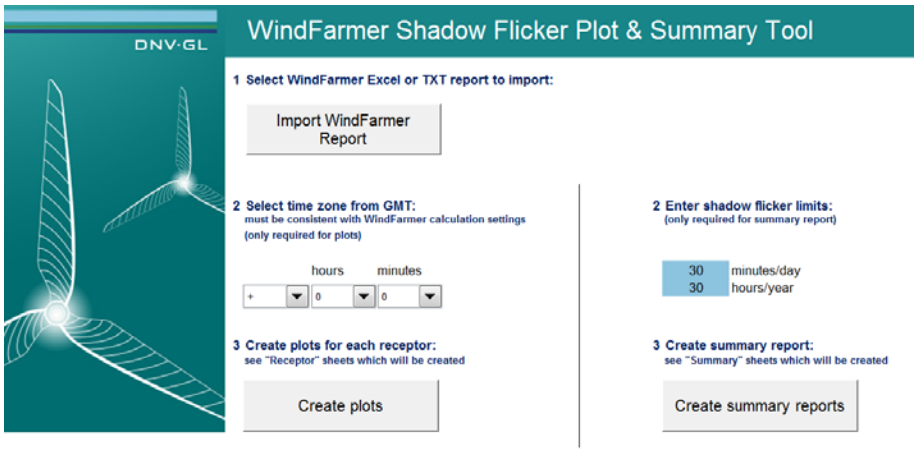
Step 43. Save the file in word, excel or txt format. If saved as *.doc GH reporter will be activated to generate the file.

Step 44. Open the Shadow Flicker report to gain familiarity with its content. Chapter 1 shows some of the relevant input data of the model. Chapter 2 shows a sequence of tables where, for each receptor, the days and the hours of shadow flicker from a specific turbine are indicated with high detail. Shut down strategies of the wind farm to avoid annoyance from shadow flicker at the receptors can be planned using this information.

5.6 WindFarmer Shadow Reporter Tool

WindFarmer includes an extra tool to generate plots of the Shadow Flicker occurrence at shadow receptors. These are extremely useful for getting a visual understanding of the extent of the phenomenon.

Step 45. Go to "File > Launch Shadow Reporter..." An Excel spreadsheet will be automatically opened. You should give permission to MS Excel software to use external macros if this is disabled by default.

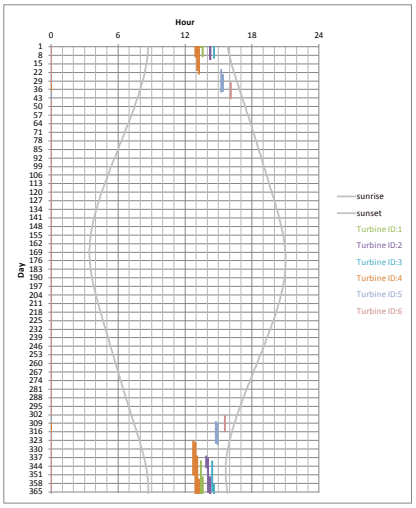


Step 46. Click on the "Import WindFarmer report", and select the Shadow Flicker report previously generated in Section 5.5. This can either be in .txt format or .xls format. Doc format is not supported for this purpose.

Step 47. The WF Report tab will automatically populate. This means the report has successfully been loaded.

Step 48. Enter the time zone of your wind farm site. This must be the same as you used in WindFarmer - you can check it in "Control Panel > Shadow model > TimeZone from GMT".

Step 49. Click on the "Create Plots" button. A new worksheet will be created in the spreadsheet, for each shadow receptor which has registered the flickering effect. The plots show the start and stop times of the phenomenon per turbine; sunrise/sunset times are also displayed for reference. The Y axis represents the day of the year and the X-axis is the time within the day.



Step 50. A brief summary report of the results can be generated. On the “Setup” worksheet, first enter the limits for acceptable shadow flicker, both as minutes/day and hours/year.

Step 51. Click on “Create Summary Reports” button and have a look at the ”Summary project 1” worksheet that it is automatically created. If limits are exceeded, an orange background will show.

receptor ID	receptor name	annual shadow flicker [hh:mm]	number of days with flicker	number of days for which the limit is exceeded	worst day	minutes on worst day	turbines causing flicker	turbine 1	turbine 2	turbine 3	turbine 4	turbine 5	turbine 6
1	S1	51:20	104	32	24/12/2011	70	1, 2, 4, 5, 6	6:30	7:20		24:10	9:40	3:40
2	S2 - 160 deg	7:20	41	0	22/04/2011	20	2, 3		3:40	3:40			

Step 52. Finally, you can save these plots and reports as an Excel spreadsheet (*.xls).

End of the exercise.

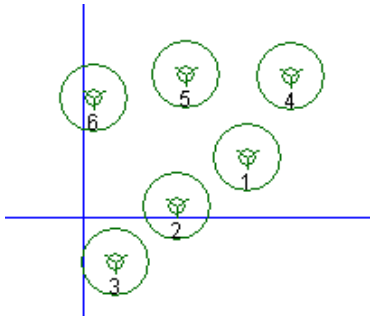
6. FINANCIAL MODULE

This is in the form of a Microsoft Excel compatible spreadsheet with the flexibility to allow the incorporation of existing spreadsheets as most organisations like to design their own financial models. See Section 7 of the User Manual for more details.

6.1 Setting up electrical network and roads

Step 1. Open the file “Demosite.wow” located in the demodata directory of the WindFarmer library.

Step 2. Turn off the DTM and the Terrain in the “Map data” bar and “Boundaries” and “Boundary points” in the “Map object bar”. This is only made to make the workspace clearer to view as shown below



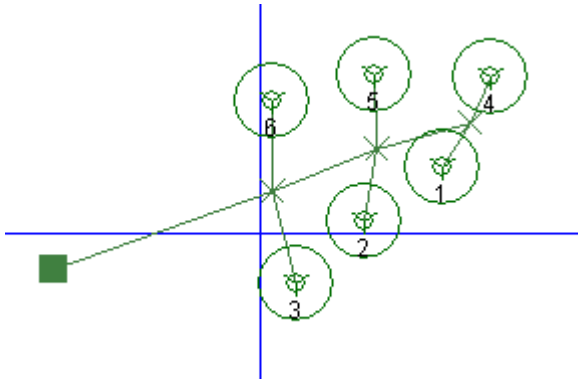
Step 3. The first target is to draw a simple electrical grid and a road network which will be counted as a cost in the financial spread sheet.

Step 4. Click  on the mapping toolbar or go to “Modes > Cabling” in the menu.

Step 5. Insert a cable route between the two groups of turbines 1-2-3 and 4-5-6 by right clicking in the map. For the specific example make sure to draw a meter and three nodes. See the User Manual and Electrical Module Tutorial for more advice on how to draw an electrical network.

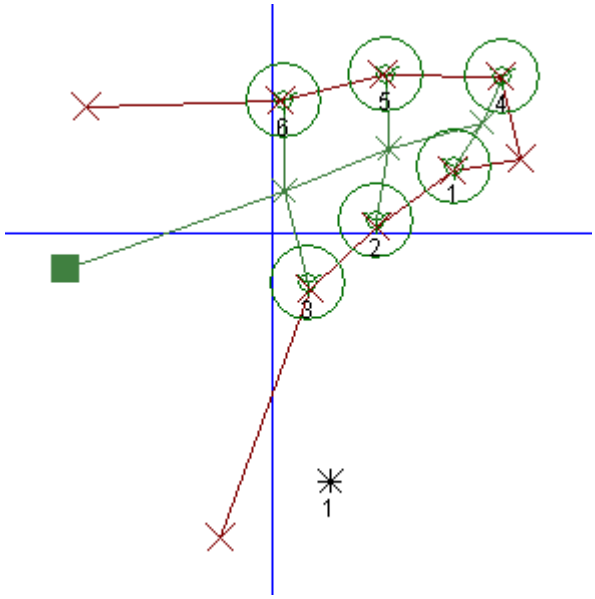
Step 6. Click  and add the connection turbine to node at each turbine by clicking the node of connection in “Control bar > Information tab”.

Step 7. Left click on the turbine in the map holding down the control key (Ctrl). This operation is repeated for each cable connection turbine to node. The suggested cable layout obtained from these two steps is shown below



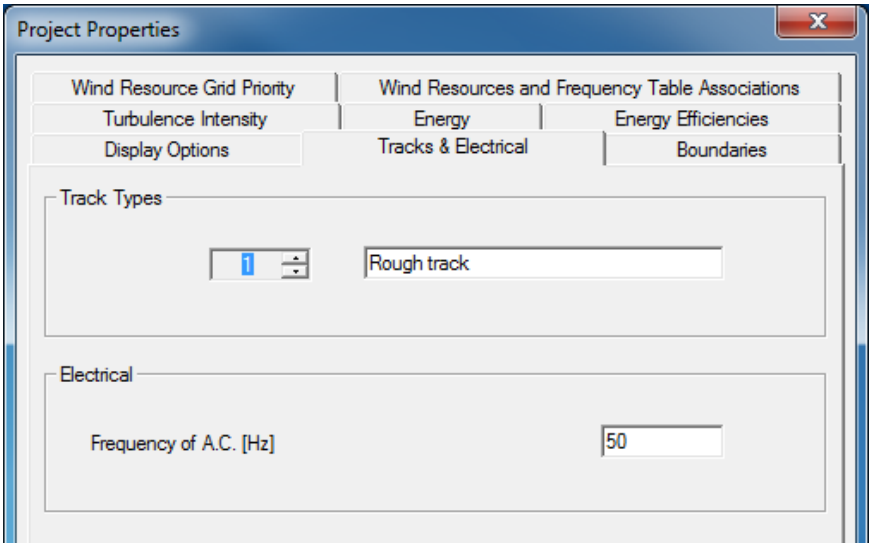
Step 8. Click  on the mapping toolbar or go to “Modes > Roads” to add the main road to the site.

Step 9. In “Road mode” draw the main road by right clicking around the wind farm. Make sure that each turbine is close enough to a specific node. See the figure below as example.



Step 10. Click  on the main toolbar or go to “View > Project Properties”.

Step 11. Switch the window to “Tracks & Electrical”. The top of the window is shown below.

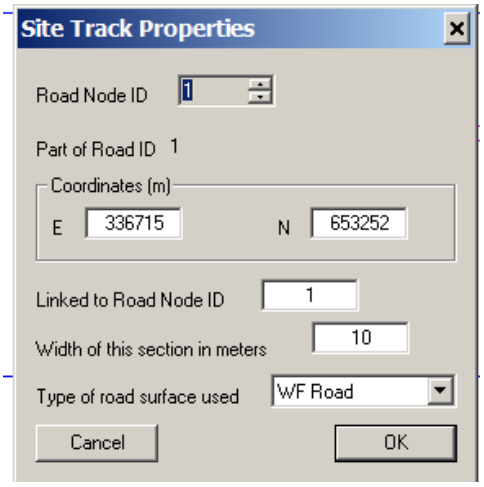


Step 12. As an example enter “WF Road” as Rough track. For the specific example we will assume one track type for the entire site.

Step 13. Press APPLY and OK to store the changes

Step 14. Click  on the mapping toolbar

Step 15. Double click any of the nodes under “Group ID” to open the following dialog box.



Step 16. This window allows you to change the properties of the track. Click "OK" once you are familiar with it.

Step 17. Run the energy test for the given layout by clicking T or going to "Calculate > Energy/Test" in the menu. For this exercise we are not interested in the settings used for the energy calculation or in detailed specification of the cable network. Refer to the tutorial of the Electrical Module for more details on how to load specifications for the electrical equipment.

Step 18. Close the Energy Report that will be displayed at the end of the energy test.

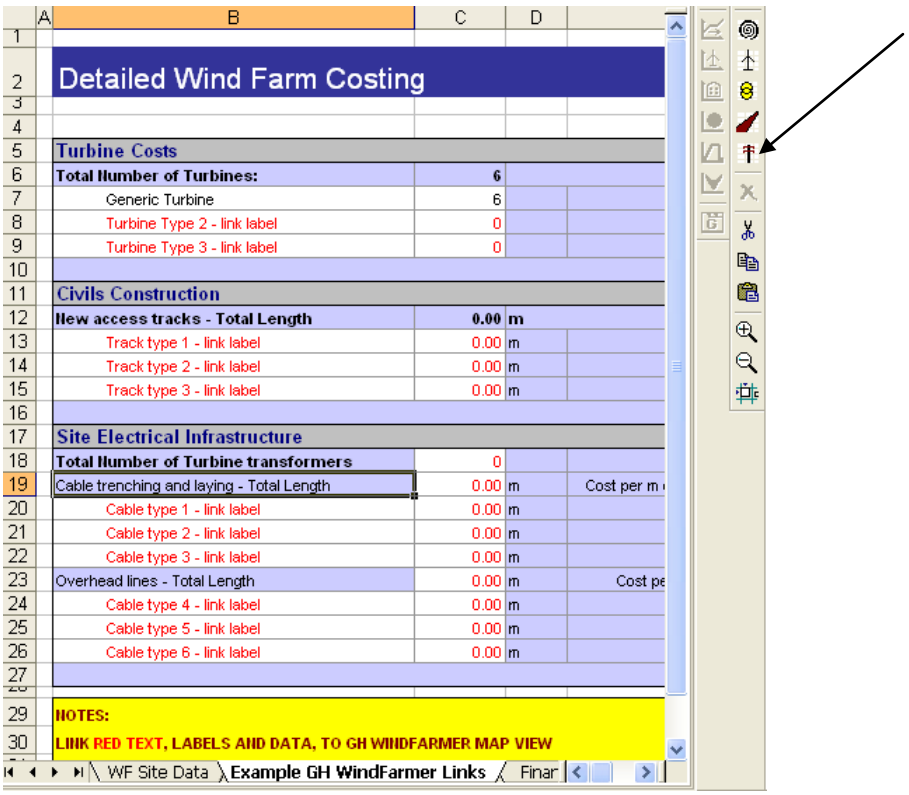
6.2 Using the Finance window

Step 19. Click  or go to “Window > Finance Window” in the menu.

Step 20. WindFarmer will issue a warning, because not all the details of the electrical network have been configured. Click OK to close the warning. In this example, only the cable cost per metre will be calculated, because of this incomplete set up.

The default financial spreadsheet displayed is shown below. The user can decide to use it as it is or customise it on the basis of new information collected during the development process. A good knowledge of economics of the wind farm is essential in order to input the correct values. The main feature of this spreadsheet is that it allows the user to create an automatic interlink between the project as set in the “Mapping Window” and the content of the spreadsheet. Therefore changes of road layout, changes of turbine model or layout and other changes are automatically fed through as inputs to the financial model. Furthermore the user can optionally input the cost per MW, per WTG, per unit or a fixed cost. In this tutorial the aim is to produce a very simplified example of a cost sheet and demonstrate how to use the links. Costs are given as illustrations only.

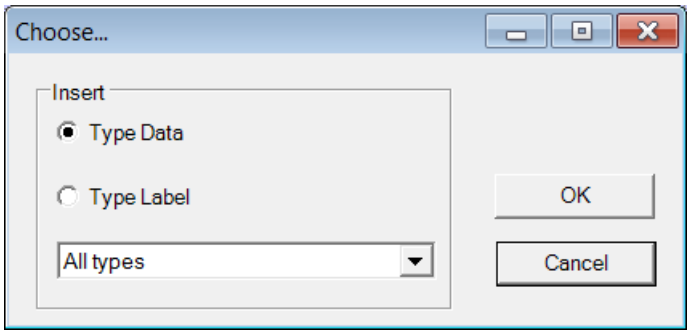
Note that the financial toolbar will have appeared on the screen (see arrow):



Step 21. You will see at the top of the spreadsheet that the number of turbines and, if you scroll to the right, the net annual production are displayed.

Step 22. Click on “Track type 1 – link label” in the “Civil Construction” table (cell B13).

Step 23. Click  on the financial toolbar or by selecting “Insert Length of Track” from the insert Menu. The dialog box below will appear.



Step 24. Click “Type Label”, select “1 - WF Road” in the dropdown and press OK.

Step 25. Now click on cell C13. Click on the financial toolbar or by selecting “Insert Length of Track” from the insert Menu. Click “Type Data” and select “1- WF Road” from the dropdown. Then click OK. The total road length, as laid out in the mapping window, will appear. For reference this road length is calculated considering the local topography.

Step 26. Input 10 as cost per m of road (cell F13).

Step 27. The total cost for the road is automatically calculated and displayed in H13.

Step 28. Input 30000 as cost per turbine (cell F7). Note that the cell is linked to the number of turbines (cell C7) to produce a total turbine cost of 180000 in cell H7.

Step 29. Go to “Cable trenching and laying – Total Length” in the “Site electrical Infrastructure” and set a cost per m of 60 (cell F19).

Step 30. Go to cell C19 and click on the financial toolbar or go to “Insert > Length of cable” in the menu.

Step 31. Choose “Type Data” and select “All Types” to assume same cost per unit for all cables. If the user has input more specific names of cables in the Electrical Module the user has the option to associate different costs per unit at each cable type.

Step 32. If you are using the Demo version of WindFarmer, this next step will have been completed for you: In the worksheet “Financial Assumptions” input the number of turbines in cell C5 by clicking or selecting “Insert > Number of Turbines”, select “Type Data” and select the Generic Turbine. Select cell C10 and add the net energy yield (P50) by clicking or selecting “Insert > Annual Energy Yield”. Select “Type Data” and select the Generic Turbine. Enter the turbine capacity (0.75 MW) in cell C6.

Step 33. Look at the other worksheets “operational cashflow”, “debt cashflow” and “debt and retained earnings chart” to see the resulting financial analysis.

End of the exercise.

Note that the spreadsheet used in this tutorial is a template spreadsheet provided with the Demo CD for demonstration purposes.

The main focus of this tutorial is to show the user how links project-financial spreadsheet work. It should be noted that by clicking on top of the financial toolbar or through “File > Load spreadsheet” it is possible to load other ready-made financial spreadsheets and then link to the project. This is only available in the full version of WindFarmer.