QUICK GUIDE – IEC 61400-12-1 ANGLE & TERRAIN CHECK

Purpose:

This module focuses on Annexes A and B of the IEC 61400-12-1 standard. To properly measure a power curve, wind measurement equipment (WME) such as masts or remote sensing devices (RSD) must be placed in locations which ensure uninterrupted flow for both turbine and WME.

This module helps in assessing which sectors are free from flow disturbance due to significant obstacles and turbines, while also evaluating the terrain complexity. This helps you choose a good location for your WME.

Outline of Guide:

1. **Identifying measurement sectors in accordance with Annex A**
2. **Determining terrain complexity in accordance with Annex B**
3. **Mitigating semi-complex terrain features**
4. **Small details**

1. OUTLINE OF WORKFLOW

The IEC 61400-12-1 module supports both editions of the standard. The two editions of the standard follow the same procedure, which is reflected in the workflow in windPRO:

1. Place the WME between 2 and 4 rotor diameters (RD) from the turbine under test. Ideally 2.5 RD.
2. Assess which objects cause *flow disturbance*:
   a. Neighbour turbines influencing the test turbine
   b. Neighbour turbines influencing the WME
   c. Test turbine influencing the WME
   d. Obstacles influencing the test turbine
   e. Obstacles influencing the WME
3. Assess *slope of terrain* for **both** WME and test turbine in specific sectors and distances
4. Assess *terrain variation* for **both** WME and test turbine in specific sectors and distances

2. IDENTIFYING MEASUREMENT SECTORS IN ACCORDANCE WITH ANNEX A

Open the module in the Tools tab (click on the module name IEC-61400-12-1 tool):

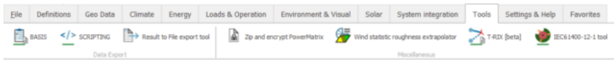


Figure 1: Module is listed under Tools group.

Then select an IEC standard. The edition 2 (2017) is recommended. Select a METEO object from the dropdown list or on the map. This will represent your future measurement mast or RSD for performing power curve validation. Any METEO object can be used.

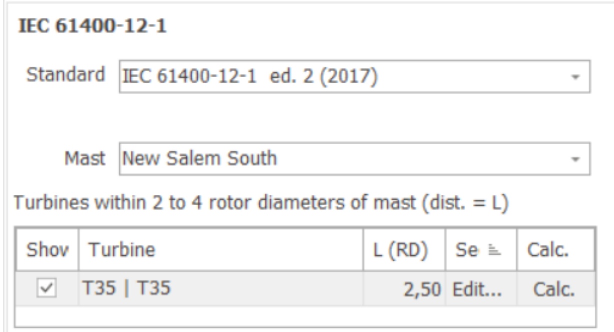


Figure 2: Selection of standard, mast and listing of turbines within 2-4 RD.

Any visible New WTGs or Existing WTGs within 2-4 RD of the selected METEO object will be displayed in the list underneath the mast selection dropdown and the ***combined*** measurement sectors for turbines and WME within 2-4 RD are then shown on the map:

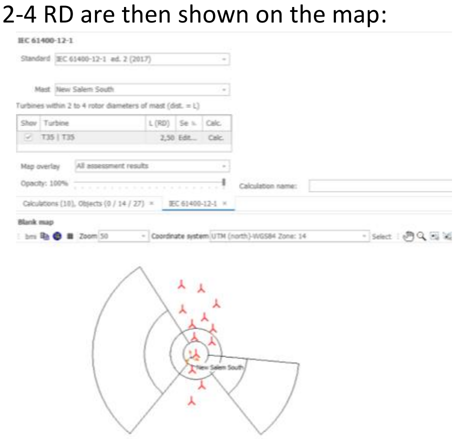


Figure 3: Example of the ***combined*** measurement sector for a WME and turbine pairing, after running the procedures described in Annex A of the standard.

Each segment in the figure represents the different areas to be later considered in the terrain complexity check. If multiple turbines can be serviced by the same WME, multiple measurement sectors will be shown on the map. These can be toggled on/off using the "Show" checkbox in the turbine list.

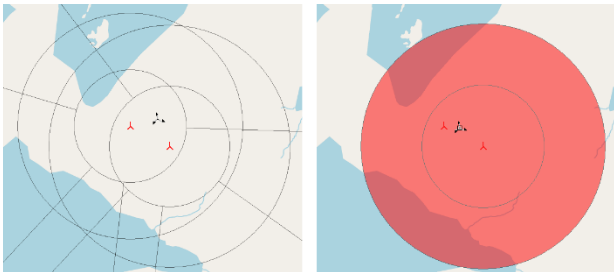


Figure 4: Example of two turbines being serviced by one WME. A red circle appears if the test turbine is too close to the WME or another turbine.

Moving the WME or turbine around on the map updates the measurement sector display on the fly.

3. DETERMINING TERRAIN COMPLEXITY IN ACCORDANCE WITH ANNEX B

Once an initial position has been selected for the WME the terrain complexity can be calculated. This is based on the active TIN terrain data.

Click "Calculate" to calculate the terrain complexity checks for the selected WME and test turbine pairing.

The areas in the measurement sector figure will then be colored green if they pass the terrain complexity calculation and colored red if they fail.

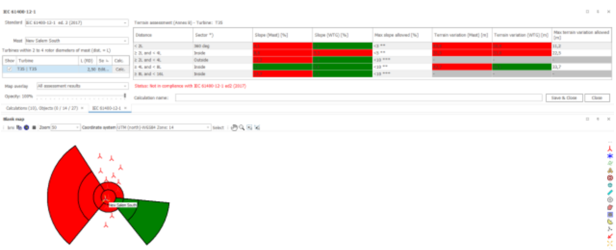
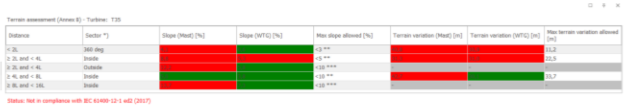


Figure 5: Evaluation of terrain complexity check. The 4-8L area is colored red, meaning it does not pass the terrain complexity check.

Along with the figure on the map, a table also displays the results of the terrain complexity check. The table shows the slope and terrain variation for both the WME and the test turbine in different areas. The coloring of the table corresponds to the coloring on the map.



Terrain assessment (Annex B) - Turbine: T35

Distance	Sector *)	Slope (Mast) [%]	Slope (WTG) [%]	Max slope allowed [%]	Terrain variation (Mast) [m]	Terrain variation (WTG) [m]	Max terrain variation allowed [m]
< 2L	360 deg	[illegible]	[illegible]	<3 **	[illegible]	[illegible]	11,2
≥ 2L and < 4L	Inside	[illegible]	[illegible]	<5 **	[illegible]	[illegible]	22,5
≥ 2L and < 4L	Outside	[illegible]	[illegible]	<10 ***	-	-	-
≥ 4L and < 8L	Inside	[illegible]	[illegible]	<10 **	[illegible]	[illegible]	33,7
≥ 8L and < 16L	Inside	[illegible]	[illegible]	<10 ***	-	-	-

Status: Not in compliance with IEC 61400-12-1 ed2 (2017)

Figure 6: Table of results for terrain complexity.

In cases where the terrain complexity check fails due to an exceedance of the terrain variation, you can visually inspect what causes the check to fail. Simply change the map overlay to "Terrain assessment results"

Figure 7: Changing the map overlay

The map now shows in red which terrain elements exceed the terrain variation thresholds, whilst green areas show what is within the threshold.

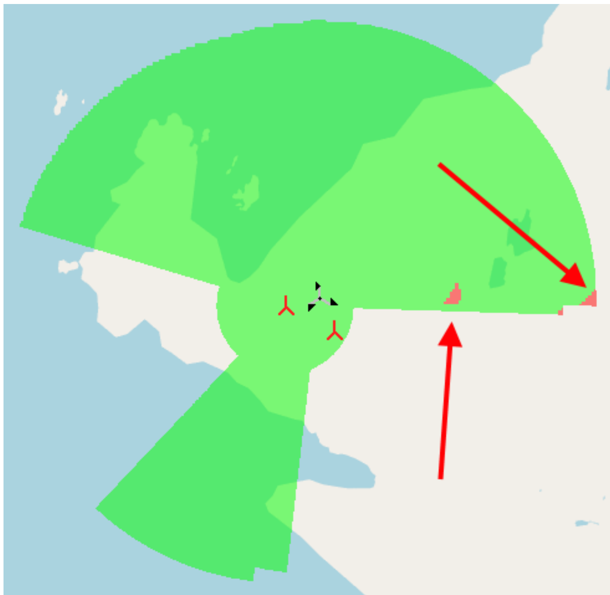


Figure 8: Map overlay showing areas in the east exceeding the terrain variation thresholds.

4. MITIGATING SEMI-COMPLEX TERRAIN FEATURES

Start by reviewing the table of results and determine where the problem occurs. Consider repositioning the object failing the check (i.e. the WME or the test turbine).

If the innermost 360° measurement circle fails one of the checks, the only solution is to move the WME or test turbine to a less complex location or use another pair. If this is not possible then you may need to consider a site calibration. See Annex C of the IEC 61400-12-1 standard.

For a check failure in any area outside the innermost circle, either reposition the test turbine or WME, or consider reducing the measurement sector to avoid problematic terrain elements. This is done by clicking the “Edit” button in the turbine list.

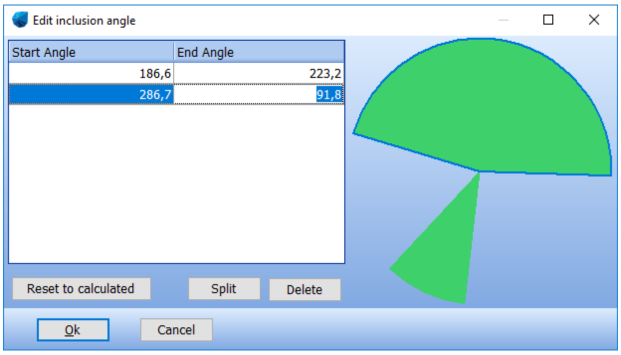


Figure 9: Editing the angles of the measurement sector. A sector can only be reduced from the calculated measurement sector. A sector can also be split in two.

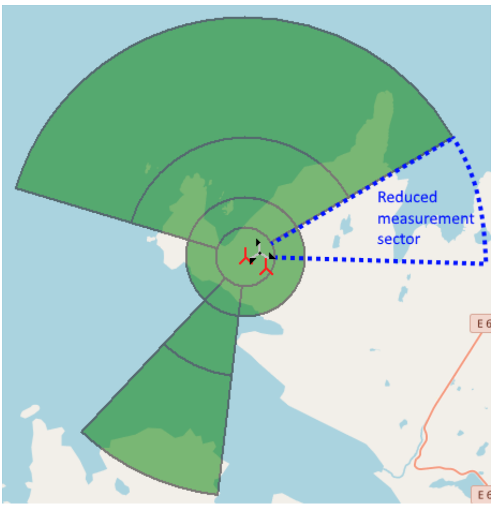
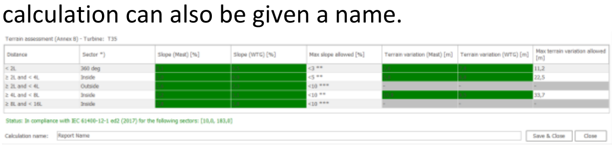


Figure 10: Example of how reducing the size of the measurement sector seen in Figure 5 can help pass the terrain checks.

5. SMALL DETAILS

How are the checks documented?

Once the terrain complexity has been calculated, a report can be generated by clicking “Save & Close”. The calculation can also be given a name.



Terrain assessment (Annex B) - Turbine: T35

Distance	Sector *)	Slope (Mast) [%]	Slope (WTG) [%]	Max slope allowed [%]	Terrain variation (Mast) [m]	Terrain variation (WTG) [m]	Max terrain variation allowed [m]
< 2L	360 deg	[illegible]	[illegible]	<3 **	[illegible]	[illegible]	11,2
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≥ 8L and < 16L	Inside	[illegible]	[illegible]	<10 ***	-	-	-

Status: In compliance with IEC 61400-12-1 ed2 (2017) for the following sectors: [10,0, 183,0]

Calculation name: Report Name | Save & Close | Close

The report can be found in the Calculations window.

What happens to the fitted plane when splitting up a measurement sector?

The fitted plane is calculated for each sector and passes through the tower base. Splitting a measurement sector in two, will result in two fitted planes. As this *can* be used maliciously, any manual changes to the calculated measurement sectors are documented in the report. Any overlapping sectors are automatically merged into one sector.

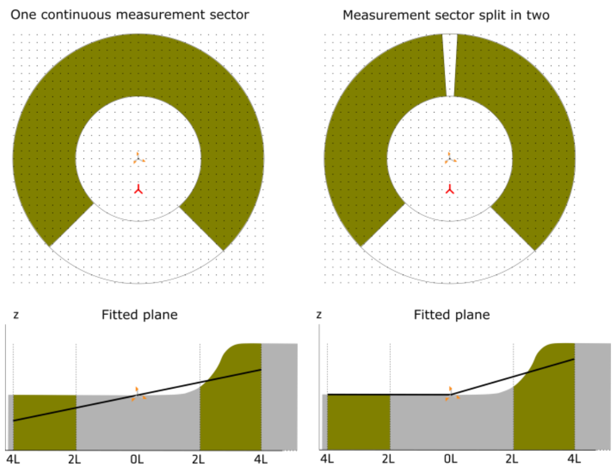

Figure 11: Illustration of how splitting the measurement sector can change the fitted plane.

How is the elevation data handled and resampled?

The edition 2 (2017) of the standard requires a digital terrain model with a grid resolution of 30m or finer. For both editions, windPRO will always resample the active TIN elevation data to a 30-meter square grid centered around the METEO object. windPRO requires terrain data in a radius of 2*16L+4L from WME and turbine. 1 L is equal to the distance between WME and test turbine.

How can non-operational turbines be accounted for?

The only way to account for non-operational turbines, is to replace the turbine with an “Obstacle” object.

How are coordinate systems handled?

All calculations are done in geographical coordinates WGS84, and then shown in your selected coordinate system. The resulting measurement angles are given relative to true north.

Which grid points are included in a sector?

The standard does not describe how to handle grid data. In windPRO the grid cell corner must be inside the sector, before including the grid cell value in the terrain calculations.

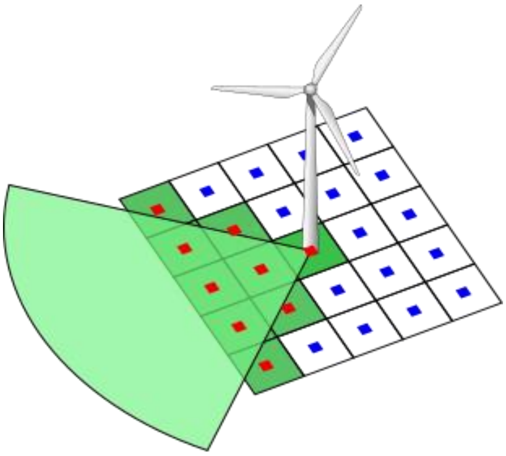

Figure 13: Illustration of how grid cells are included in sectors. Green cells are included. White cells excluded.

How is the distance and width of an obstacle calculated?

Obstacles are usually at an angle to both the WTG under test and the mast. The distance from a WTG or mast to an obstacle is defined as the line perpendicular to the obstacle's center point. The width of the obstacle is defined by (1) taking the distance between to rays touching the obstacle's visible corners and (2) spanning a line between the two rays intersecting the obstacle center orthogonally to the distance line.

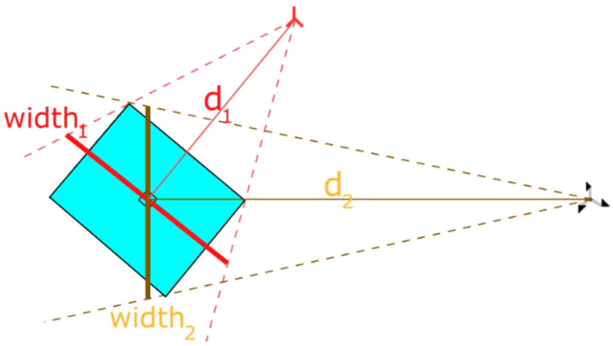

Figure 14: Illustration of how the width of an obstacle changes depending on the viewpoint.