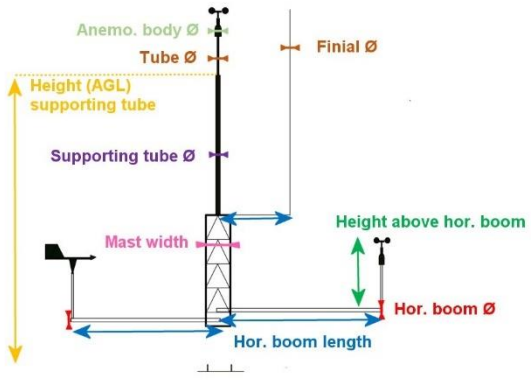
Compliancy Checks, IEC 61400-12-1 ED 2.0

The input made in the Sensor/equipment installation table is used to check the configuration of the mast against the most important requirements defined in Annex G of the IEC standard 61400-12-1 Ed.2.0 Wind energy power generation systems – Part 12-1: Power performance measurements of electricity producing wind turbines.
The compliancy checks available in windPRO are described in this document.

In case of missing data, the checks cannot be performed: verify that the **required input** listed thereafter for each check is available in the Sensor/equipment installation table.

A color code is used to give a quick overview of the result of the compliancy check. Green color is used for compliancy, Red for non-compliancy and orange for either partial compliancy (when a check involves two conditions and only one is fulfilled) or for a non-critical non compliancy.

Under the Guide button above the Sensor/equipment installation table, a schematic drawing presents the input of dimensions.



1. Distortion from Mast

1.1 Regarding Mast width

For Top anemometer (single or side-by-side):

The following conditions have both to be met:

a) The mast structure has to be within the 11:1 half cone as defined in IEC 61400-12-1 ED.2.0 , section G2. For that, it is checked whether the angle of the half cone formed from the cone vertex between the vertical

and the border of the mast at its top is greater or smaller than ATAN (1/11). The cone vertex originates for single top anemometer at the anemometer cup, defined by the anemometer height input, and for side-by-side top anemometer at the average height of theses but centered on the mast.

Required input: "height of mast structure AGL", "mast width" for the top anemometer and height of top anemometer to define the vertex.

b) The height of anemometer must be at least 1.5m above the top of the mast

Required input: "height of mast structure AGL" , "anemometer height" defined as Top anemometer

For side mounted anemometer

The distortion from the mast on side mounted anemometers depends on the distance between the mast and the anemometers (which depends on the horizontal boom length) and on the mast's width and type. This check gives an OK and Acceptable in the table when the flow distortion results in a wind speed deficit of respectively max 0.5% and max 1%. The distortion is calculated differently whether the mast is tubular or lattice, so make sure to select the proper Type of Mast in the top right corner of the tab. According to IEC 61400-12-1 ED.2.0 :
- for tubular mast: the flow distortion of max 0.5% or 1% occurs relatively when the length of the horizontal boom to the center of the mast is at least 8.2 or 6.1 times the mast width
-for lattice tower, it is checked whether the length of the horizontal boom (R) to the center of the mast is at least as calculated by equation G2 in IEC 61400-12-1 ED.2.0, where Ud is set to 0.995 for 0.5% distortion or 0.99 for 1% distortion

$$R = \frac{L}{\frac{1-U_d}{\left(0,062C_T^2 + 0,076C_T\right)} + 0,082}$$

The check also depends on the thrust coefficient (Ct) of the mast. Table G1 in IEC 61400-12-1 ED.2.0 gives some examples of ranges of Ct values for different type of cross-section. In the configuration table, Ct is set by default to a value of 0.5 which corresponds to a conservative scenario for square cross-sections with round members according to Table G1 in IEC 61400-12-1 ED.2.0 .Triangular cross-section mast will typically have a Ct between 0.2 and 0.4 according to Table G1 whereas square cross section with sharp edge can reach a Ct of 1.1. The Ct value can be changed manually in the configuration table.

Required input: Type of mast, mast width, Ct for lattice, length of horizontal boom of the anemometer

For wind vane

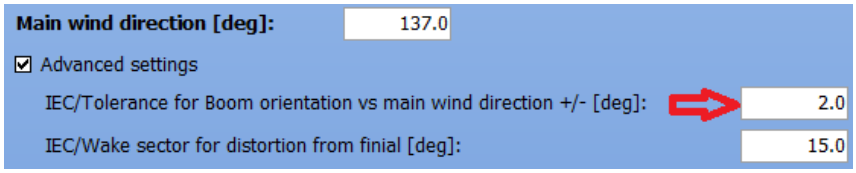
For vanes, the requirement of minimum distance is half the one for side mounted anemometer (as defined above).

Required input: Type of mast, mast width, Ct for lattice, length of horizontal boom of the wind vane

1.2 Boom orientation versus main wind direction

According to IEC 61400-12-1 ED.2.0 the boom of side mounted anemometer shall be ideally mounted:
a) +/-45 degrees from the main wind direction in the case of tubular tower
b) +/-90 degrees from the main wind direction in the case of lattice tower

The check gives OK when the conditions above are met, including a tolerance of few degrees to compensate for the fact that the boom orientation might not exactly be mounted 45 or 90 degrees from the main wind direction. The main wind direction has to be input manually in the corresponding cell below the table (by default it is set to 0 degree, North). The tolerance is by default set to 2 degrees. It can be changed by checking "Advanced settings":



Required input: Main wind direction, horizontal boom Direction

The check is also made for side-by-side top anemometer.

2. Distortion from boom & tubes

The distortion of the flow around the booms (horizontal rods) and the tubes (vertical rods) mainly impacts the accuracy of the wind measurements by anemometers. So the checks only concern the later type of sensor.

2.1 Height above horizontal boom

It is checked whether the anemometer cups are placed at a vertical distance equal to at least 20 times the diameter of the horizontal boom that they are placed above. This check is not relevant for single top anemometer (no horizontal boom).

Required input: height above horizontal boom, diameter of horizontal boom

2.2 Distance to supporting tube & diameter

The supporting tube is the additional tube used to stabilize the smaller tube attached to the body of single or side-by-side top anemometers. The check returns OK if the following two conditions are met:
1) the cups of top anemometers are more than 0.75m from this supporting tube.
2) the diameter of the anemometer body is at least equal to the diameter of the supporting tube.

Required input: height of anemometer and height of the supporting tube Above Ground Level (AGL), diameter of anemometer body, diameter of supporting tube

2.3 Anemometer body diameter greater than tube

The tube on which the anemometer is fixed shall have a smaller diameter than the diameter of the anemometer body.

Required input: anemometer body diameter, tube diameter

3. Distortion from lightning finial

3.1 Distance to top anemometer

The distance between the lightning finial (rod) and the top anemometer is checked.
The check is OK if the horizontal distance between the anemometer and the finial is more than 30 times the diameter of the rod. This check is made only for top anemometers (single or side-by-side). If no “top” anemometer has been defined, the check will then concern all side mounted anemometer(s) at an arbitrary vertical distance of 3 m from the top of the finial.
The horizontal distance between the finial and a given top anemometer is calculated automatically in windPRO for most of the common combination of anemometer and finial mounting, as presented in the following table. The calculated distance can be modified manually in the configuration table (“Distance to anemo.” Column).

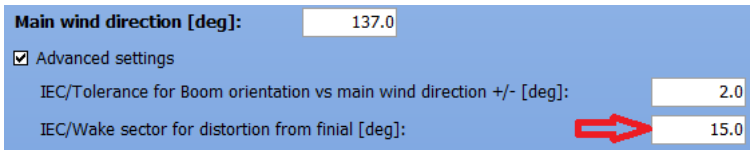
Table 1. Automatic input of distance and alignment direction between finial and anemometer in configuration table used for the IEC checks about distortion from finial

Combinations of anemometer and finial		Automatic input in Configuration table	
Anemometer mounting	Finial mounting	Distance to anemometer	Finial-anemometer alignment direction
single, top (centred)	on a boom	length of finial boom	direction of finial
single, side mounted	top (centred)	length of anemo. boom	180 + direction of anemo. boom
single, side mounted	on a boom	-	-
side-by-side, top	top (centred)	length of anemo. boom	180 + direction of anemo. boom
side-by-side, top	on a boom	-	-

Required input: height and diameter of the finial, distance to anemometer either from manual input or, for automatic calculation, from mounting of anemometer and finial, direction and horizontal boom length of anemometer and finial if not centered on the mast.

3.2 Wake on anemometer

Considering the main wind direction, the finial is assumed to give wake on top anemometer(s) placed downstream. The wake is assumed to occur within a sector which width is arbitrary set by default to 15 degrees. This sector can be changed manually under the Advanced settings.



In order to determine whether the anemometer is in the wake of the finial, the alignment direction between the finial and the anemometer is calculated as presented in the previous table, assuming all points in a horizontal plane. The value can also be manually entered. For example, the alignment direction of 90 degrees means that the finial is upstream of the anemometer when the wind direction equals 90 degrees (from east). So a wake on the anemometer is supposed to occur and the check will return a NO. Considering a 15 degree wide wake sector implies that the check returns NO for wind direction between 82.5 and 97.5.

Required input: Alignment direction with anemometer either from manual input or, for automatic calculation, from mounting of anemometer and finial, direction and horizontal boom length of anemometer and finial if not centered on the mast.

4. Distortion from lower sensors/device on top anemometers

It is checked whether sensors or devices (temperature sensors, aviation light) defined in the configuration table can cause distortion on the top anemometers. If, against the best practice, no anemometer has been installed/defined as top anemometer (that is with mounting as single top or side-by-side top), the highest side-mounted anemometer will then be considered as the “top”/primary anemometer for which the test is made.

The check gives OK if the sensor or device is:

a) more than 4 m below (vertical distance),
b) or, if less than 4 m, then still more than 1.5 m from the top anemometer and within the 11:1 cone as defined in IEC 61400-12-1 ED.2.0. To check the later, it is calculated whether the angle of the half cone formed from the cone vertex between the vertical and the sensor/device is smaller than ATAN (1/11). The 11:1 cone check uses the length of horizontal boom of the sensor/device. So, if the device has a significant width (like weather station), half of the width should be added to the horizontal boom length in order test if the outer part of the device is within the cone or not.

Required input: top anemometer heights, height and horizontal boom length of the lower sensor/device

5. Distortion between side-by-side anemometers

Only in the case of side-by-side anemometer, it is checked whether the distance between the two top anemometers is larger or equal to 2.5 m and smaller or equal to 4.0 m.

Required input: top anemometers defined as side-by-side top, their height and horizontal boom length

6. Distance to top anemometer

According to IEC 61400-12-1 ED.2.0, control anemometers, wind vanes and temperature/humidity/pressure sensors shall be installed within a certain distance from primary/top anemometers in order to be representative. The compliancy check only relates to top anemometers. If several sensors have been defined as top anemometer, the check has to be passed for each, in order to return an “OK”. If, against the best practice, no anemometer has been defined as a top anemometer (that is with mounting as single top or side-by-side top), the highest side-mounted anemometer will then be considered as the “top”/primary anemometer.

For side mounted “control” anemometer, the vertical separation to a primary anemometer shall be in the range between 4 and 6 m. Side mounted control anemometer are identified as the highest anemometer besides (and below) the top anemometer(s).
For a wind vane, the vertical distance to the primary/top anemometer shall be in a range of 4 and 10 m.
For weather station (temperature/humidity/pressure), the vertical distance to top anemometer shall be between 1.5 and 10 m.

The check is conducted for all anemometers and vanes aware that it is supposed to be passed only by the highest anemometers and wind vanes (below the top anemometer). The non-compliancy to this recommended distance for representativity is marked by a “NO” with an orange background (instead of red) because it is not considered as a crucial discrepancy in most cases.

Required input: top anemometers height, height of sensors to test