SMALL WIND TURBINES WIND RESOURCE ASSESSMENT

SOME BASIC ISSUES

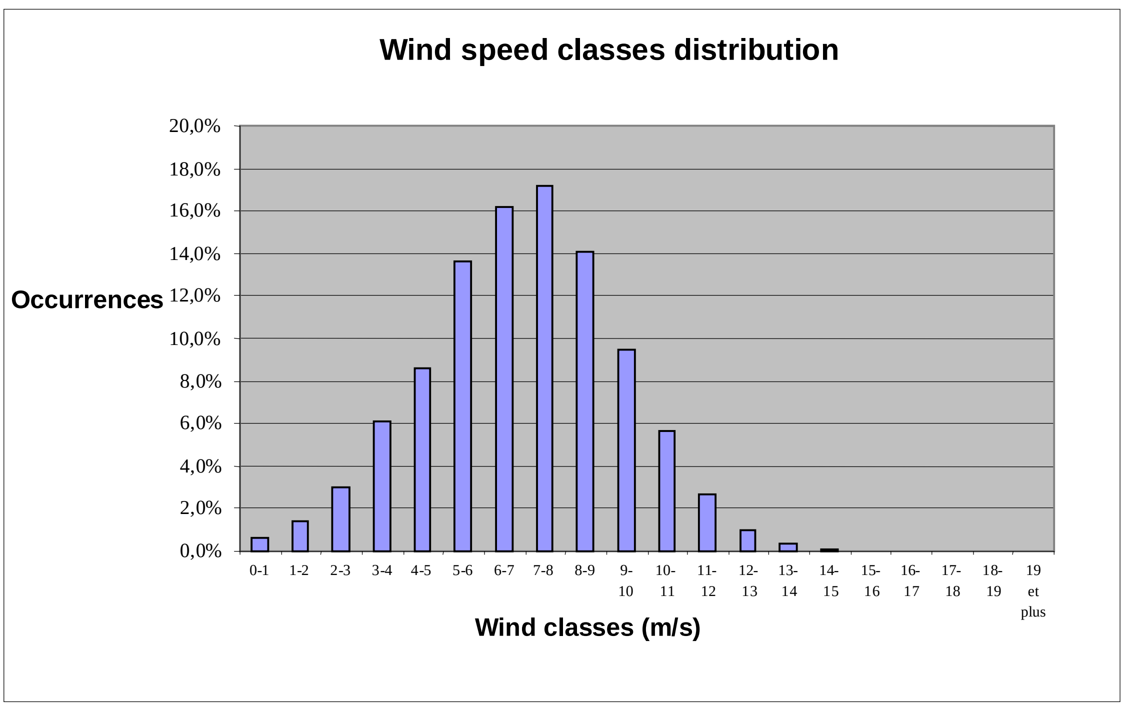
ATTACHMENT No 1

1. WIND SPEED CLASSES DISTRIBUTION

Electricity production obtained from a wind potential with a given wind speed and wind turbine type, varies a lot with the wind speed distribution around the mean value.

For example, on a site where the wind is 50% of the time V_{av} = 12 m/s and 50% of the time V_{av} = 0 m/s, a wind turbine would produce much more electricity than on a site where the wind speed is 100% of the time V_{av} = 6 m/s. This is due to the fact that wind energy in theory is proportional to the cube of the wind speed.

It is essential to know the **distribution of wind speeds** on the project site. As shown below, wind distribution is expressed in % of occurrence for each class of 1m/s (0 to 1m/s, 1 to 2m/s, etc).



Example: The wind blows between 6 and 7 m/s about 16% of the time

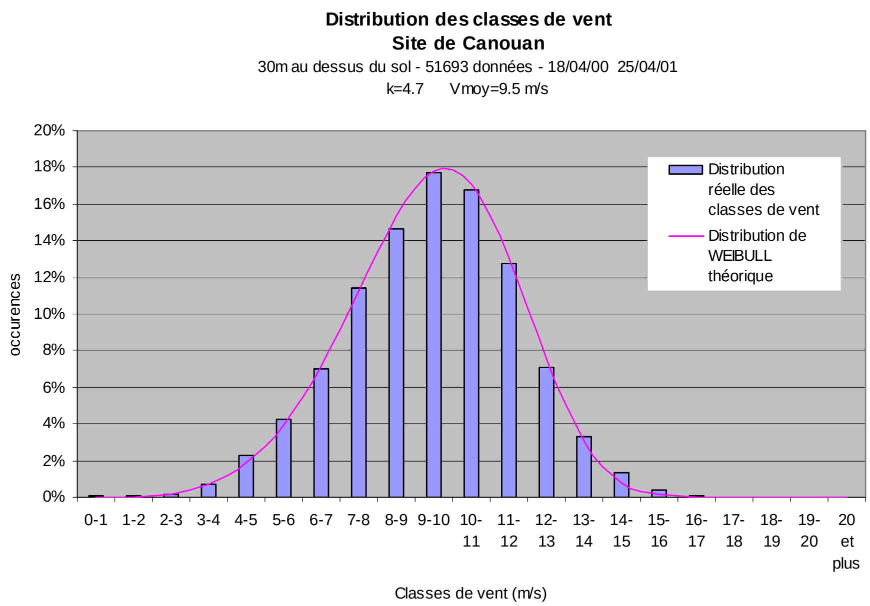
2. WEIBULL MODEL OF WIND SPEED DISTRIBUTION

A mathematical principle taking into account the characteristics of a typical wind potential gives the wind distribution for all classes with only two parameters. The function that gives the wind speed distribution is called the Weibull probability function. It gives the probability p to get a wind speed V:

$p(V) = (k/A)*(V/A)^{k-1}*\exp(-(V/A)^k)$

k: Weibull shape parameter

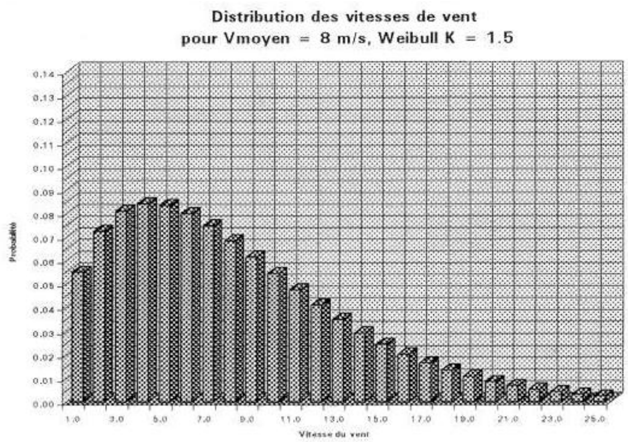
A: Weibull scale parameter

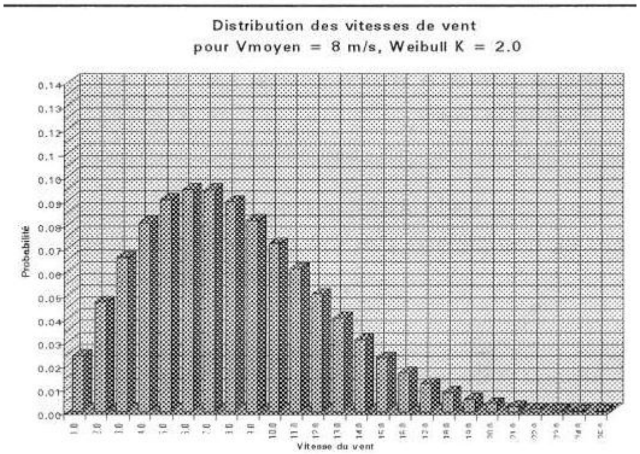


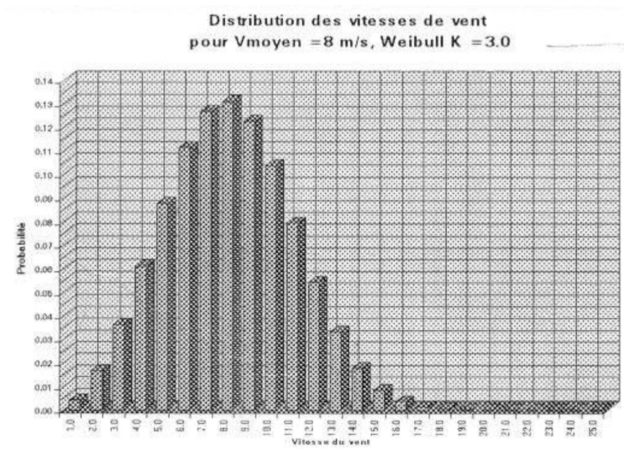
k and A parameters are specific to each type of wind profile. But typical values of k could be given for each region in the world, according to the wind regime of this region.

Trade wind zones are characterized by a k parameter ranging from 3 to 5.

Other zones, like Europe, in the world are characterized by a k parameter around 2.







The k parameter could be determined from the wind speed distribution using a graphic method.

A parameter could be calculated from the average wind speed and k:

$A = V_{moy\ site}/(1+(1/k)) = V_{moy\ site}/EXP(LNGAMMA(1+(1/k))$

[A and k] (or [V_{av} and k]) are the typical data required by any software used to evaluate the wind production of a wind turbine or a wind farm.

3. VERTICAL WIND SHEAR

Vertical wind shear could be measured from wind speed measurements at two different heights at the same place: for example 20m and 30m.

Wind shear exponent α is given by:

$V_{30m}/V_{20m} = (30/20)^{\alpha}$

$\alpha = \ln(V_{30m}/V_{20m})/\ln(30/20)$

Wind shear is related to the type of terrain upwind the measuring point. It varies according to the wind direction, and should be evaluated for various wind azimuths sectors.

Wind direction at 30m on site ° geographical	**Number of occurrences**	**Direction distribution** %	**Wind speed at 30 m** V_{30m} m/s	**Wind speed at 20 m** V_{20m} m/s	**Wind shear exponent α** $\alpha = \ln(V_{30m}/V_{20m})/\ln(30/20)$
North					
10					
20					
350					
TOTAL		**100 %**	**Weighted average**	**Weighted average**	

Table used for wind shear exponent calculation

The wind shear exponent α could be compared to typical values :

Roughness	α
Very low roughness (sea)	0.10
Low roughness (lowland, fields)	0.16
Average roughness (woods, bush)	0.20
Average roughness (villages, spead houses)	0.28
High roughness (town with high buldings)	0.40

NB : Sites where relief, vegetation are important (cliff, trees, houses) are not well suited to the wind shear model using the exponent α. The result of the formula $V_{h3} = V_{h1}*(h3/h1)^{\alpha}$ becomes only indicative and cannot be taken as the real wind speed at hub height.

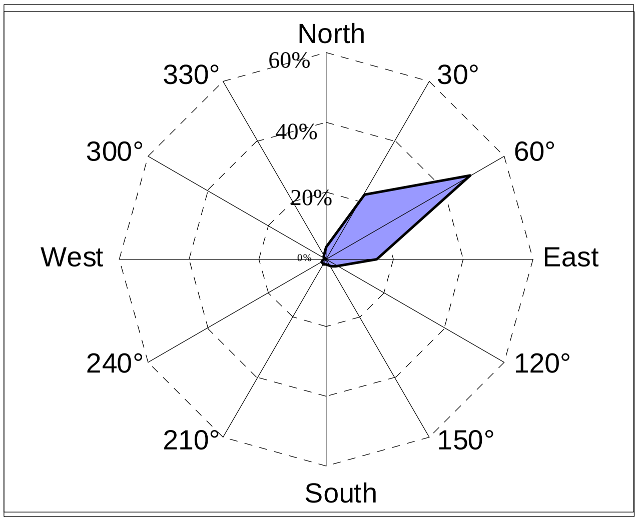
4. WIND DIRECTION

Directions are given in geographical degrees, i.e. magnetic degrees (given by a compass) corrected with the deviation between magnetic North and geographic North.

One does not speak of mean direction, but of dominant direction. The wind on a site may have one or more dominant directions.

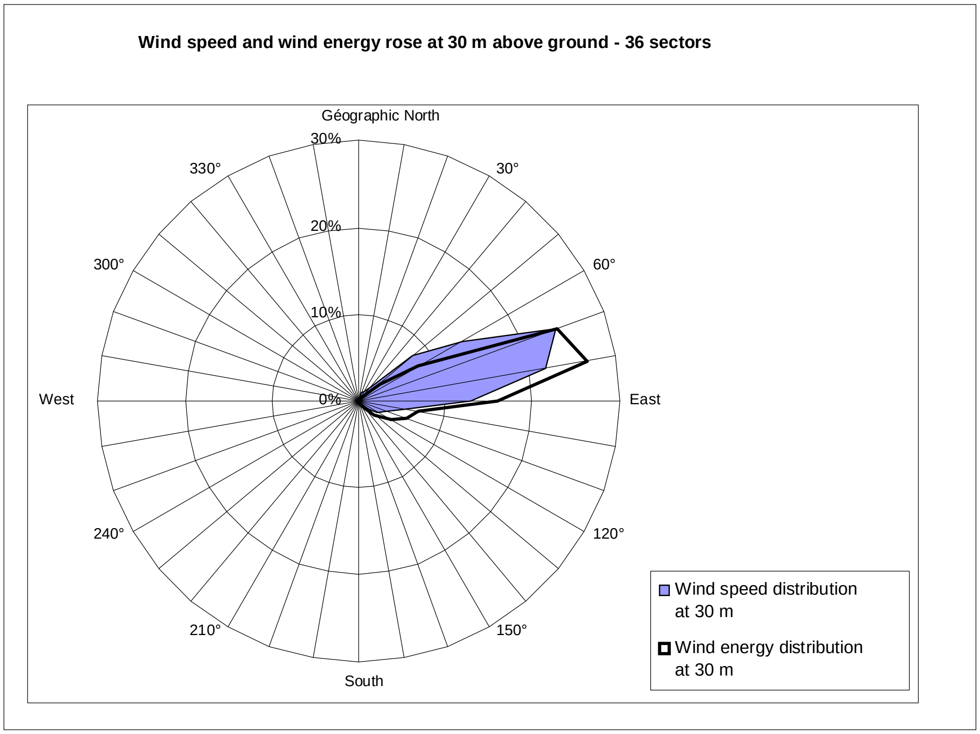
The distribution of wind directions is shown on a graph called "**Wind Rose**":

Example: wind rose with 12 sectors.



The wind blows from the direction 60° about 50% of the time, and between 45° and 75° about 90% of the time. Although the wind turbines are able to orientate their rotor facing the wind, it is useful to know the dominant wind directions to check that the wind turbine will not suffer from disturbances coming from another wind turbine, a building, trees sited in the same direction as dominant winds.

In fact, the useful information is the dominant energetic direction, i.e. the wind direction that gives the maximum energy output. Most often there is a limited gap between the dominant wind speed direction and the dominant wind energy direction.



5. TURBULENCE

The turbulence represents the rapid variations (<10min) of the wind speed. It is given in m/s, and is the standard deviation (σ) of instantaneous wind speeds recorded every 2 sec during 10mn.

One use also the turbulence intensity in %

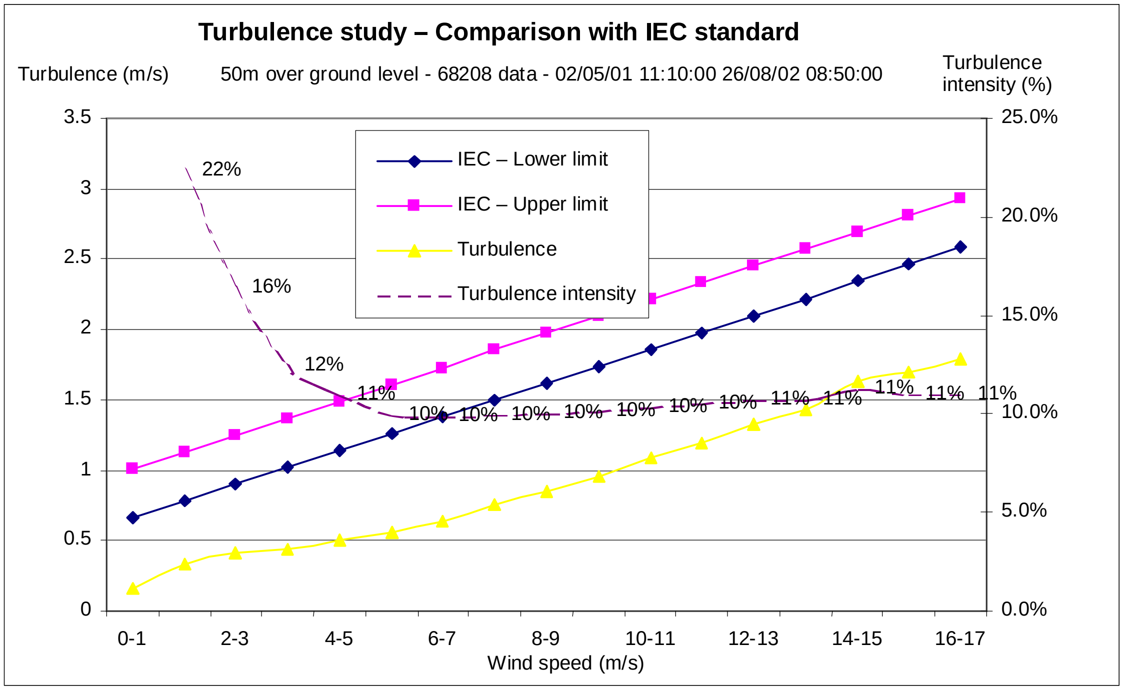
$I = \sigma / Vav$ (%)

The turbulence measured on the project site should be compared to IEC standardized values, to check that the wind turbine can stand the variations of the wind speed during its lifetime without major trouble.

IEC standard gives:

The turbulence high upper limit: Turbulence = 0.12 * Vav + 0.95

The turbulence low upper limit: Turbulence = 0.12 * Vav + 0.60



If the turbulence measured is under the low upper limit, the turbulence is acceptable.

If the turbulence measured is above the high upper limit, the turbulence is too high, and the wind turbine should not be installed.

If the turbulence measured is between the low and high upper limits, there is a risk for the wind turbine, and more frequent inspections should be done.

You should always indicate the wind speed at which the turbulence is measured.

6. CORRELATION METHODS TO GET LONG TERM RESULTS

Even if the duration of the measuring campaign is long (1 year), results are not representative for the long term average wind speed on the project site during a number of years equivalent to the duration of the project (15 to 20 years). The one year measuring period could have been exceptionally windy (or not windy).

It is necessary to know the wind speed over a period of at least 11 to 15 years to take into account the variations of the annual average wind speeds over the years and meteorological cycles.

It is therefore almost essential to perform a correlation of the campaign data with the wind data of a reference station where reliable wind measurements have been performed for more than 10 years.

If V_{ref} is the pluri-annual wind speed of the reference station, one should find the relation with the average wind speed measured on the project site:

$V_{site} = f\ (V_{ref})$

6.1. CHOICE OF THE RÉFÉRENCE SITE

Very often, the reference site will be the nearest meteorological station. If a number of stations are possible, you should select the station that is most representative for the regional wind profile (upwind the relief), even if time series available are shorter for this station.

Usually, a correlation is valid only between sites having the same k shape parameter (same shape of wind speed distribution)

NB: met stations of the synoptic world network record 8 times a day (every 3 hours) the "synoptic "wind speed (10mn average wind speed), during the 10mn before each hour (00, 03, 06, 09, 12, 15, 18 and 21 UTM).

6.2. SYNCHRONOUS DATA BASE

You should establish a synchronous database, with measurements made on the project site and at the meteo station **at the same time**, on the same period.

Usually comparisons are made between daily average values. If the weather station if far from the project site (more than 40km), weekly average values should be used.

6.3. DURATION OF THE PERIOD OF MEASUREMENT OF THE DATA COMPARED

The comparison will be the most accurate using a long period of simultaneous measurements . The minimum duration is 3 months. The appropriate duration depends on the seasonality of the wind regime; so at least one year.

If the wind regime is very different at different times in the year, the period of comparison should be expanded.

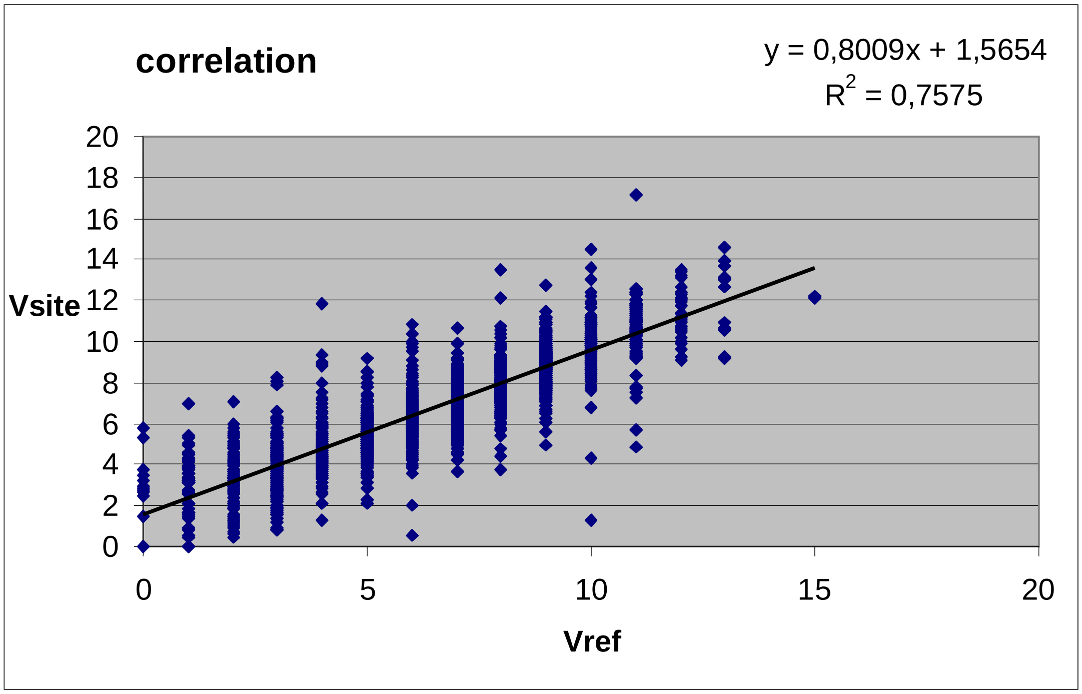
6.3.1. EXAMPLE OF CORRELATION GRAPH

The result of the correlation exercise is the equation of the relation between the wind speed on the project site and at the meteo station.

$V_{site} = f\ (V_{ref}) = a \times V_{ref} + b$.

From the long-term wind speed at the meteo station, it is then possible to know the long-term wind speed on the project site.

Example



6.3.2. ACCURACY

The accuracy of a good correlation is around ± 0.5 m/s.