

Wind Turbine FAQ

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- Grid Connected Wind Generators PDF by David Hayes
- Wind Energy Systems (the book) 9 Chapters as PDF files by Gary Johnson



Wind Turbines



The Power of Wind

Air moving at 40 Kph through one square metre theoretically has an energy content of 400 watts if it were stopped. The power extracted from the wind cannot exceed 59% of the power in the wind.

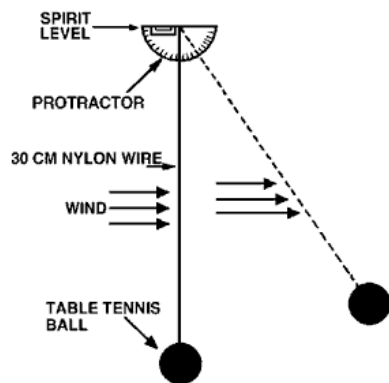
Wind Variations

Whereas with Solar or Hydro-electric power the batteries receive some recharge on a daily basis, at times there may not be any significant wind for charging the batteries for weeks on end. Winds are notoriously variable, and most installations must include an auxiliary generating system to recharge the batteries in low wind periods.

Winds are the result of differences between temperatures in the atmosphere, the turning motion of the planet and the varied topography of the earth's surface. The winds that are significant to a discussion of wind-plants may be divided into two categories: the planetary winds and local winds.

A Simple Evaluation Method

A very simple method of measuring the strength of the wind can be carried out as follows. You need 30 cm of thin fishing line (or similar), a table tennis ball, a protractor, and a spirit level. You fix the ball to the end of the fishing line, and fix the other end of the fishing line to the centre of the protractor. When the wind blows the ball moves and the angle of the line changes. By reading the angle on the protractor and using the chart below you can estimate the strength of the wind. The spirit level is used to make sure that the top edge of the protractor is horizontal.



Measuring the Wind

Planetary Winds

Planetary wind systems, normally called prevailing winds, are those great moving air masses that dominate whole areas and show constant directional characteristics, varying only with the movement of high or low pressure systems and with the seasons of the year.

In many locations these are the dominant winds, and good wind-plant sites are those that take maximum advantage of prevailing winds. Included among such sites are exposed hill tops; shore lines facing the prevailing winds; an open plain or plateau; the floor of an open valley running parallel to the prevailing winds, or the windward side of a gently sloping hill.

Local Winds

Local winds, by contrast, are caused by temperature differences created by local topographic conditions. Land-sea breezes, for example, will blow from the land towards the sea by night, simply because land temperatures are more subject to change than the great mass of the ocean.

Mountain and valley breezes are caused by the same local effects. On a warm sunny day winds may rise strongly off the floor of a valley and up the slopes of adjacent hills. The best site for a wind-plant is one where dominant planetary wind patterns are reinforced by local winds.

Site Evaluation

In order to know if a wind powered system is either feasible or cost competitive you need to have some facts and figures. Because of the site preparation and work that needs to go into a wind tower, you need to have done all of your home-work before you take the big step.

Unless you have a particularly good wind site, it is recommended that either you have a hybrid system (ie wind and solar or wind and diesel) or no wind system at all.

In order to find out if you have a good wind site you may need to spend a few hundred dollars on an anemometer to give you the data. If you want to save yourself this cost or do a feasibility study on whether even the cost of the anemometer is worth it, then the following information may be of use to you.

Getting Results

Sampling the wind variations over a period of a few weeks will not necessarily give an indication of the yearly wind cycle. Since most people don't want to twiddle their thumbs for a year while taking readings, then approximate schemes must be found.

A good start (after talking to the locals) is to establish a correlation between your site and the nearest meteorological station that you can obtain wind-speed data for. A period of one month is hopefully a sufficient time to take measurements over to establish this correlation.

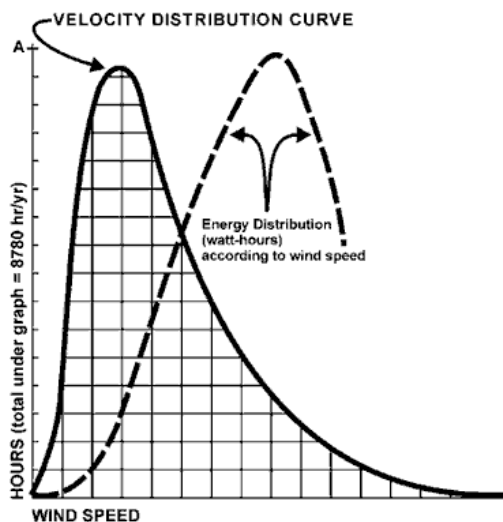
Does the average of the figures acquired at the weather bureau equal the ten year average for that month? If it is not even close you may end up with particularly optimistic or pessimistic results.

You may either keep collecting data until you find a good, consecutive period that, at the weather bureau station, averages out to close to the ten year average for that month, or adjust the figures for that month from the weather bureau and your site by the same amount to be a little closer to the ten year average.

Now find what factor you should multiply the selected weather bureau data by to get the yearly average. Multiply the average at your site by this number as well to get a close approximation of the yearly average.

To ensure that a wind generator produces a worthwhile output, an annual average wind speed in excess of about 15 kph is desirable. Knowing the average wind speed, we can immediately extrapolate certain things from the chart below.

Angle	m/s	Kph	Description
90°	0.0	0.0	Calm; smoke rises vertically
85°	2.6	9.3	Light breeze; smoke drifts; leaves rustle
80°	3.6	13.1	Gentle breeze; leaves and twigs in motion
75°	4.5	16.2	Moderate breeze; raises dust and loose paper
70°	5.3	18.9	Fresh breeze; small trees sway
65°	5.9	21.4	Fresh to strong breeze; crested waves form on inland waters
60°	6.6	23.9	Strong breeze; large branches in motion
55°	7.3	26.4	Strong breeze; difficulty with umbrellas
50°	8.0	28.9	Near gale; whole trees in motion
45°	8.7	31.4	Near gale; impedes progress
40°	9.5	34.2	Gale; Breaks twigs off trees
35°	10.4	37.4	Gale;
30°	11.5	41.3	Strong gale; slight structural damage
25°	12.8	45.9	Strong gale; tiles lift off roof
20°	14.4	52.0	Storm; seldom experience inland
			Anything beyond this is a violent storm or a hurricane accompanied by widespread damage



The chart is called the velocity distribution curve. It is a similar shape for all wind power locations, and gives a good indication of amount of time the wind blows at a particular wind speed.

Having established the relationship between windspeeds at the two sites, you can also use the meteorological bureau figures to estimate the seasonal variations at your site. This information can give you an idea of the seasonal variations of the output of the wind-plant.

Wind Velocity and Rotor Diameter

The power from the wind increases as a function of the cube (third power) of the wind velocity. Increasing the diameter of the rotor increases the power output as a square function. Power from the wind can be derived by the formula:

$$W = 14.3 PAV^3$$

where:

P = air density (2.3 x 10⁻³)

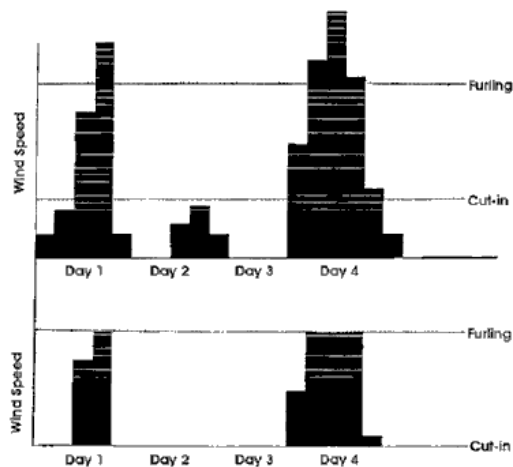
A = area swept by turbine blades (sq. metres)

= radius (m) squared x 3.1416 (B)

V = wind velocity in kph

The air density figure is for sea level. Power from a 30 kph wind will be 10% less at an elevation of 1,000 metres, 25% less at 3,000 metres.

The following graph was generated from a wind survey, taking 4 wind samples per day (sunrise, midday, sunset, 10 pm) over 6 days. This graph was then modified, using the characteristics of the wind generator considered for the site. The information used was the cut-in wind speed and the furling wind speed. The cut-in wind speed is the amount of wind required before the generator starts producing power.



The furling wind speed is the amount of wind required to produce the maximum power that the generator is capable of; any wind in excess of this will not generate more than this maximum.

Choosing the Correct Tower Height

The two most important considerations in planning the tower height for a wind turbine are avoidance of turbulent air flow produced near ground level by the 'roughness' of the terrain over which the wind flows, and avoidance of excessive ground drag which lowers wind velocity near the ground and severely restricts the performance of a wind turbine.

Turbulence

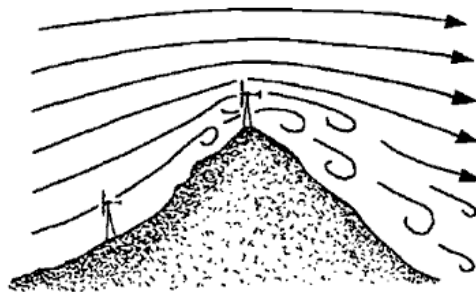
A wind turbine must never be located such that it is subject to excessively turbulent air flow. Light turbulence will decrease performance since a turbine cannot react to rapid changes in wind direction, while heavy turbulence may reduce expected equipment life or result in wind turbine failure. You can detect turbulence by streaming a long ribbon from a guyed pole or mast to see if it streams easily in high winds from various directions. The mast should be roughly as high as you would envisage the wind tower to be.

Turbulence may be avoided by following a few basic rules:

1. If possible, the wind turbine should be mounted on a cleared site free from minor obstructions such as trees and buildings for at least 100 m in all directions and free from any major obstructions such as abrupt land forms for at least 200m. Even over clear ground, however, the minimum recommended tower height is 12 metres.
2. If it is not possible to avoid obstructions as above, tower height should be increased to a value of approximately 9 metres greater than the height of obstructions within 100 metres.
3. A good "rule of thumb" is to locate the turbine at a minimum height of three times that of the tallest upwind barrier.

The drawings which follow illustrate some of the do's and don'ts of siting and tower height with respect to turbulence.

The period over which there is no wind with sufficient force to generate power is the period when either the battery storage or another energy source must provide the required power.



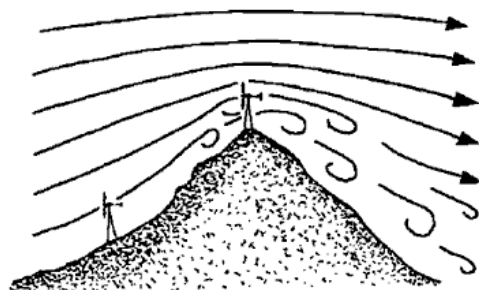
Ground Drag

The avoidance of ground drag will increase performance dramatically. Up to a considerable height, the least expensive way to increase your power output from a wind turbine is to increase tower height.

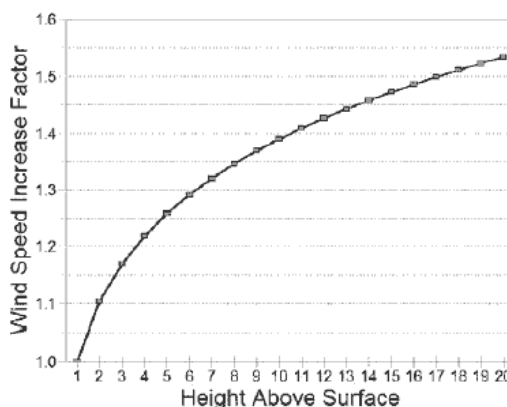
High, rough hilltops may produce substantial turbulence in the windstream. Tower number 1 is located on the relatively gentle smooth lower slope and will be clear of most turbulence when the windstream is left to right in the drawing, but will be in the wind shadow of the hill when the wind reverses.

Tower number 2 is too low and while exposed to high velocity winds is also located in severe turbulence which may destroy the wind generator.

This drawing illustrates the proper location and height for a tower on this hill. It is fully exposed to the high velocity winds and is above the region of harmful turbulence.



A generally recognised 'rule of thumb' is that wind speed increases as the 1/7th power of the height above ground. The following curve illustrates this theoretical increase in wind speed with increasing height above ground:



The grove of trees in this example will produce turbulence. A higher tower close to the trees places the wind generator above the turbulence. A shorter tower is safe if placed far enough away from the trees.

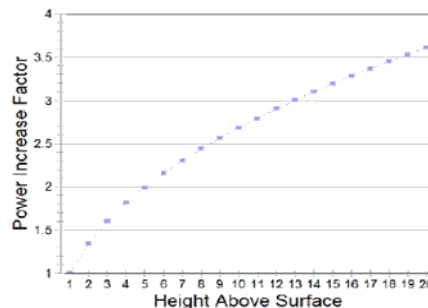
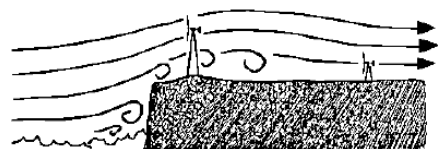


As an example in the use of this curve, if a windspeed of 15 kph were measured at 2 metres above the surface, the windspeed at 20 metres height can be predicted from the curve.

At 2 metres height, the 1/7th power is 1.104, and at 20 metres it is 1.534. Dividing 15 kph by 1.104 and then multiplying by 1.534 yields the predicted windspeed of 20.8 kph at 20 metres.

However, the energy in the wind, and therefore wind generator output, is proportional to the cube of the windspeed. So, in this example, by increasing the tower height from 2 metres to 20 metres increases the wind-turbine output by 2.67 times.

Severe turbulence may be created by the sea cliff in this example. As above, a higher tower will be required near the cliff while a shorter tower will be safe if placed at a great enough distance from the cliff.



Noise

Wind generators may produce a fair amount of noise, particularly in high winds. Beyond a couple of hundred metres, the noise of the wind itself generally drowns out the noise of the wind generator.

Australian Wind Assessment

High wind areas are often associated with coastlines. Away from the coast you are away from high winds.

Tower Construction

The smaller wind generators (up to 100 watts) can be mounted on a sturdy pipe with guy wires. The larger machines would need a more substantial tower in which case it is advisable to contract a person experienced in the erection of wind generator towers.

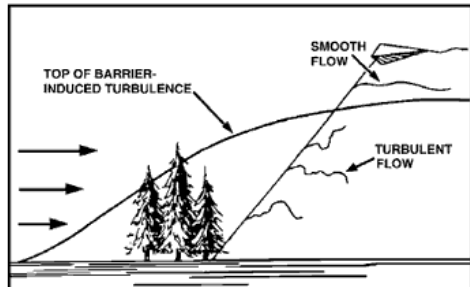
Check with the local Council to see if there are any regulations concerning the erection of poles or towers, especially if you live in an urban area.

Safety

Do not place a wind-plant in a turbulent area, to avoid severe stress on wind turbine components and tower. All the controls, necessary safety (governing and feathering) devices to protect against excessively high wind speeds, instruction manual etc should come with the machine that you purchase. What may not be provided is a suitable regulator to prevent your battery from being overcharged.

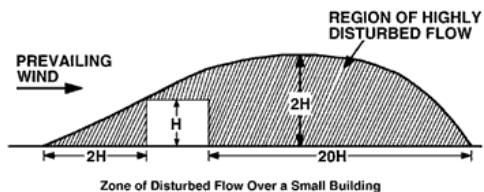
The Kite Test

A sturdy kite with crepe paper or thin cloth ribbons or strips can give a good indication of variable air turbulence of site under different wind conditions.



The Kite Test

The Effect of Obstacles A wind turbine needs to be sited away from the turbulent air flow, preferably upwind or a long way down wind (considering prevailing wind direction). Otherwise you may need a very high tower.



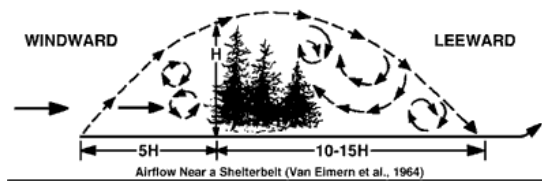
Zone of Disturbed Flow Over a Small Building

Wind Speed Conversion Factors

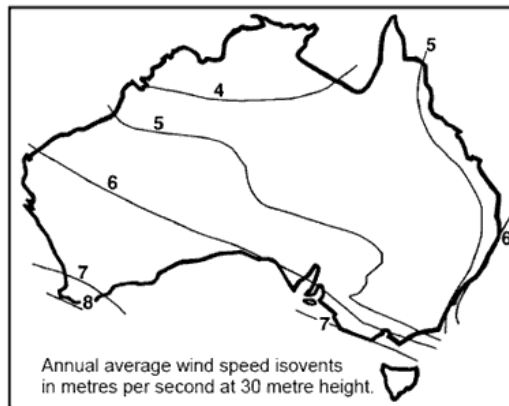
	mph	ft/sec	knots	kph	m/s
1 mph	1	1.467	0.608	1.609	0.447
1 ft/sec	0.682	1	0.592	1.097	0.305
1 knot	1.152	1.689	1	1.853	0.515
1 kph	0.621	0.911	0.540	1	0.278

Visualising Wind Turbulence

Wind turbulence can be visualised by studying a small fast flowing stream with obstacles such as rocks and boulders. The wind follows the same flow patterns.



Airflow Near a Shelterbelt (Van Eimern et al., 1964)



Annual average wind speed isovents in metres per second at 30 metre height.