Home
Guided tour

Wind

Turbine siting

Roughness & shear

Speed calculation

Escarpments

The roughness rose

Variable winds

Turbulence

Wind obstacles

Wind shade

Calculator guide

Shade calculator

Wake

The park effect

The tunnel effect

Roughness and Wind Shear

High above ground level, at a height of about 1 kilometre, the wind is hardly influenced by the surface of the earth at all. In the lower layers of the atmosphere, however, wind speeds are affected by the friction against the surface of the earth. In the wind industry one distinguishes between the roughness of the terrain, the influence from obstacles , and the influence from the terrain contours, which is also called the orography of the area. We shall be dealing with orography, when we investigate so called speed up effects, i.e. tunnel effects and hill effects , later.

Roughness

In general, the more pronounced the roughness of the earth's surface, the more the wind will be slowed down.

Forests and large cities obviously slow the wind down considerably, while concrete runways in airports will only slow the wind down a little. Water surfaces are even smoother than concrete runways, and will have even less influence on the wind, while long grass and shrubs and bushes will slow the wind down considerably.

Roughness Classes and Roughness Lengths

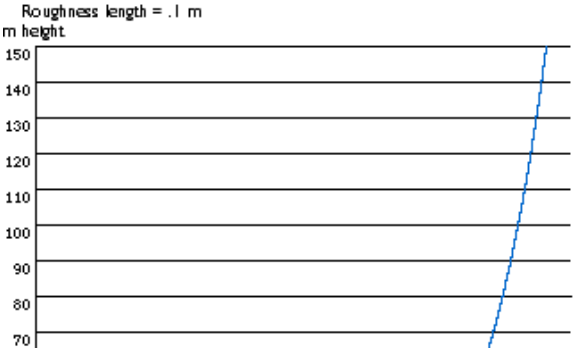
Sheep are a wind turbine's best friend. In this picture from Akaroa Spit, New Zealand, the sheep keep the roughness of the landscape down through their grazing. Photograph Soren Krohn © 1998 DWIA

In the wind industry, people usually refer to roughness classes or roughness lengths, when they evaluate wind conditions in a landscape. A high roughness class of 3 to 4 refers to landscapes with many trees and buildings, while a sea surface is in roughness class 0.

Concrete runways in airports are in roughness class 0.5. The same applies to the flat, open landscape to the left which has been grazed by sheep.

The proper definition of roughness classes and roughness lengths may be found in the Reference Manual. The term roughness length is really the distance above ground level where the wind speed theoretically should be zero.

Wind Shear



The hill effect

Turbine siting

Offshore winds

Wind map Europe

Wind map Denmark

Energy output

How does it work?

Generators

Turbine design

Manufacturing

R & D

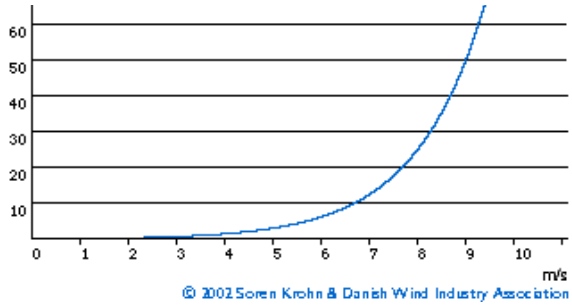
Electrical grid

Environment

Economics

History of wind energy

Wind energy manual



This graph was plotted with the wind speed calculator on the next page. It shows you how wind speeds vary in roughness class 2 (agricultural land with some houses and sheltering hedgerows with some 500 m intervals), if we assume that the wind is blowing at 10 m/s at a height of 100 metres.

The fact that the wind profile is twisted towards a lower speed as we move closer to ground level, is usually called wind shear. Wind shear may also be important when designing wind turbines. If you consider a wind turbine with a hub height of 40 metres and a rotor diameter of 40 metres, you will notice that the wind is blowing at 9.3 m/s when the tip of the blade is in its uppermost position, and only 7.7 m/s when the tip is in the bottom position. This means that the forces acting on the rotor blade when it is in its top position are far larger than when it is in its bottom position.

Wind Shear Formula *)

The wind speed at a certain height above ground level is:

$v = v_{ref} \ln(z/z_0)/\ln(z_{ref}/z_0)$

v = wind speed at height z above ground level.
v_{ref} = reference speed, i.e. a wind speed we already know at height z_{ref}. ln(...) is the natural logarithm function.
z = height above ground level for the desired velocity, v.
z_0 = roughness length in the current wind direction.
Roughness lengths may be found in the Reference Manual.
z_{ref} = reference height, i.e. the height where we know the exact wind speed v_{ref}.

In the above example, assume we know that the wind is blowing at 7.7 m/s at 20 m height. We wish to know the wind speed at 60 m height. If the roughness length is 0.1 m, then
$v_{ref} = 7.7$
$z = 60$
$z_0 = 0.1$
$z_{ref} = 20$ hence,
$v = 7.7 \ln(60/0.1) / \ln(20/0.1) = 9.2966$ m/s

*) = The formula assumes so-called neutral atmospheric stability conditions, i.e. that the ground surface is neither heated nor cooled compared to the air temperature. Further details may be found in the engineering handbook Guidelines for Design of Wind Turbines from Risoe National Laboratory and DNV.

© Copyright 1997-2003 Danish Wind Industry Association
Updated 1 June 2003
http://www.windpower.org/en/tour/wres/shear.htm