Trees, Forests and Wind Turbines

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A Manufacturer's View

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Basic Problem Fields

The combination of trees, forests and wind turbines causes problems in different fields:

- The resource assessment may be severely compromised if the tree effects are not taken properly into account
- The trees will cause increased turbulence that has to be added to the ambient turbulence and the turbulence generated by wakes. This will affect loads and power performance
- The trees will cause displaced, increased and possibly distorted shear. This will affect loads and power performance

Resource Assessment

Bonus always urges caution:

- Validated models lacking
- Experience shows that developers often underestimate or overlook the presence of forests and trees
- Experience shows that effects of trees and forests persist for longer distances than predicted by developers
- Experience shows that trees grow

Current best estimate:

- Risø recommendations
- Supplement if possible with alternative models, not to replace WASP but to estimate uncertainty

Risø Recommendations

Risø invited to workshop, but unavailable.

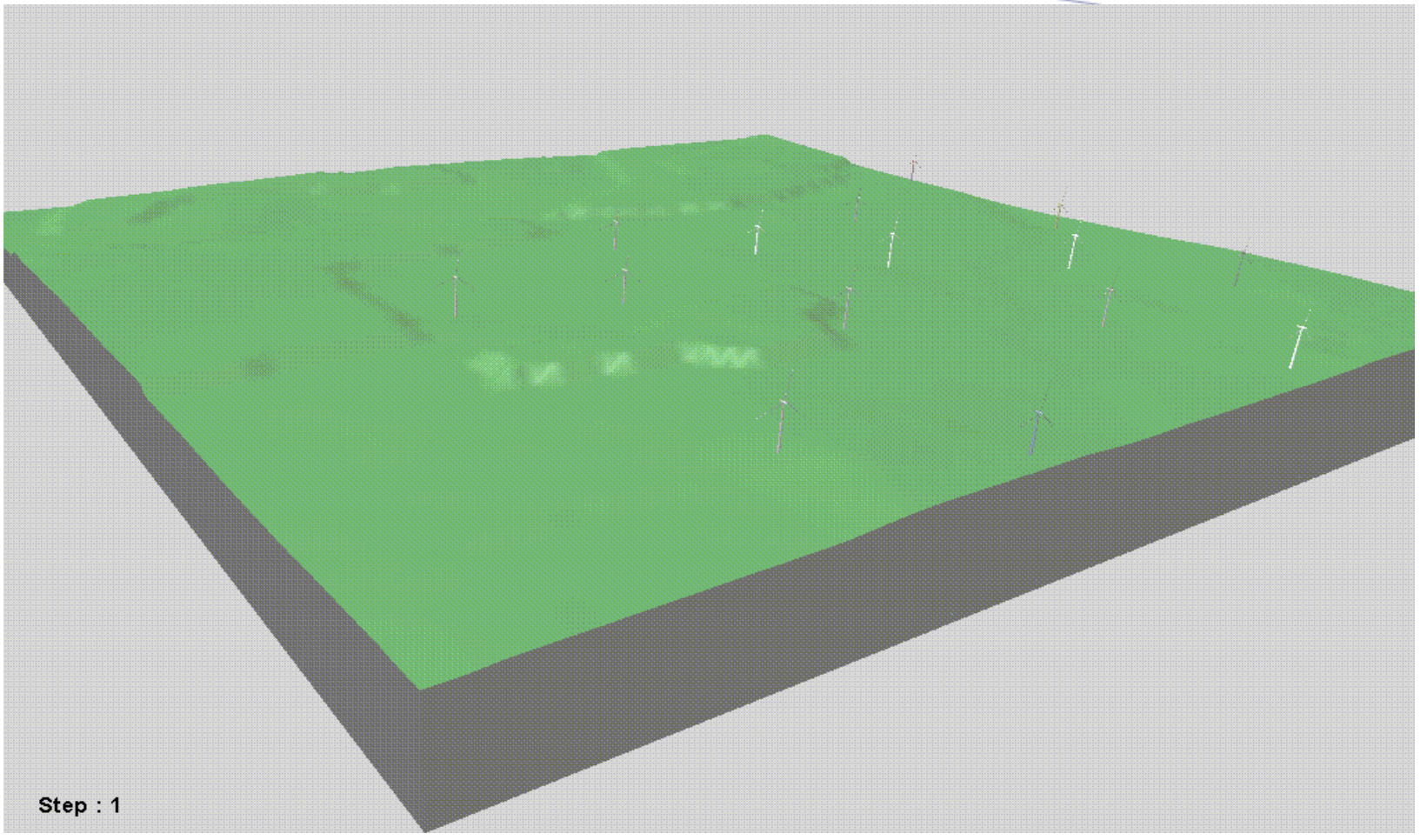
The following slides represent Risø's position with regards to trees and wind turbines.

Risø Recommendations

Bonus uses Risø recommendations - but with caution, as suggested by Risø:

- Model only valid downwind
- Model only valid in non-separated regions, i.e. at considerable distance from edges of forest

Alternative Tool - WindSim



Problems Relating to Loading

Trees and forests create increased turbulence:

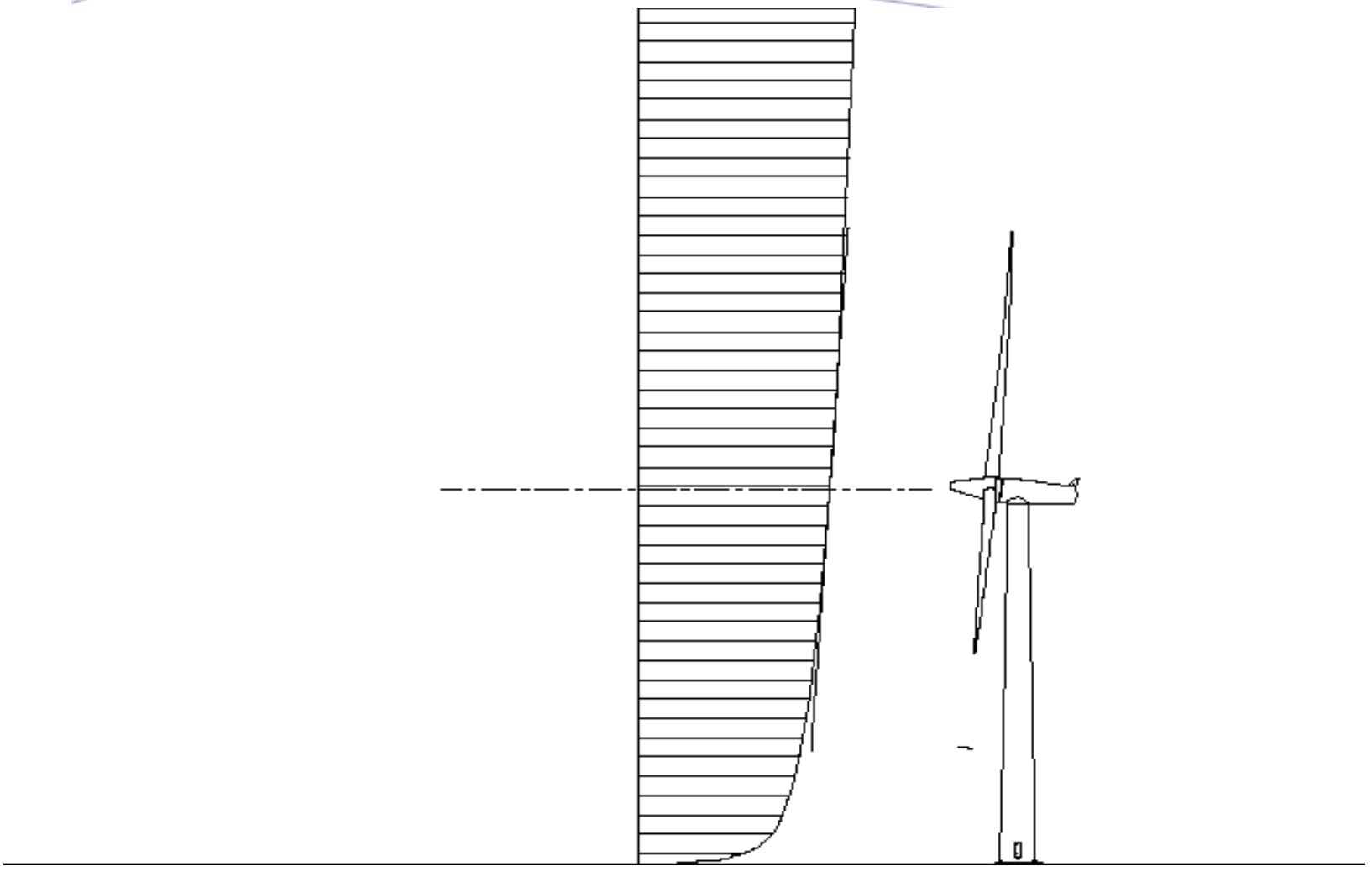
- The contribution to turbulence from trees and forests should be added to the ambient turbulence and the turbulence created by wakes
- Take caution regarding modelling of turbulence from trees and forests
- Apply principles in Sten Frandsen model to addition of turbulence

Problems Relating to Power Curves

High shear creates problems with power curves:

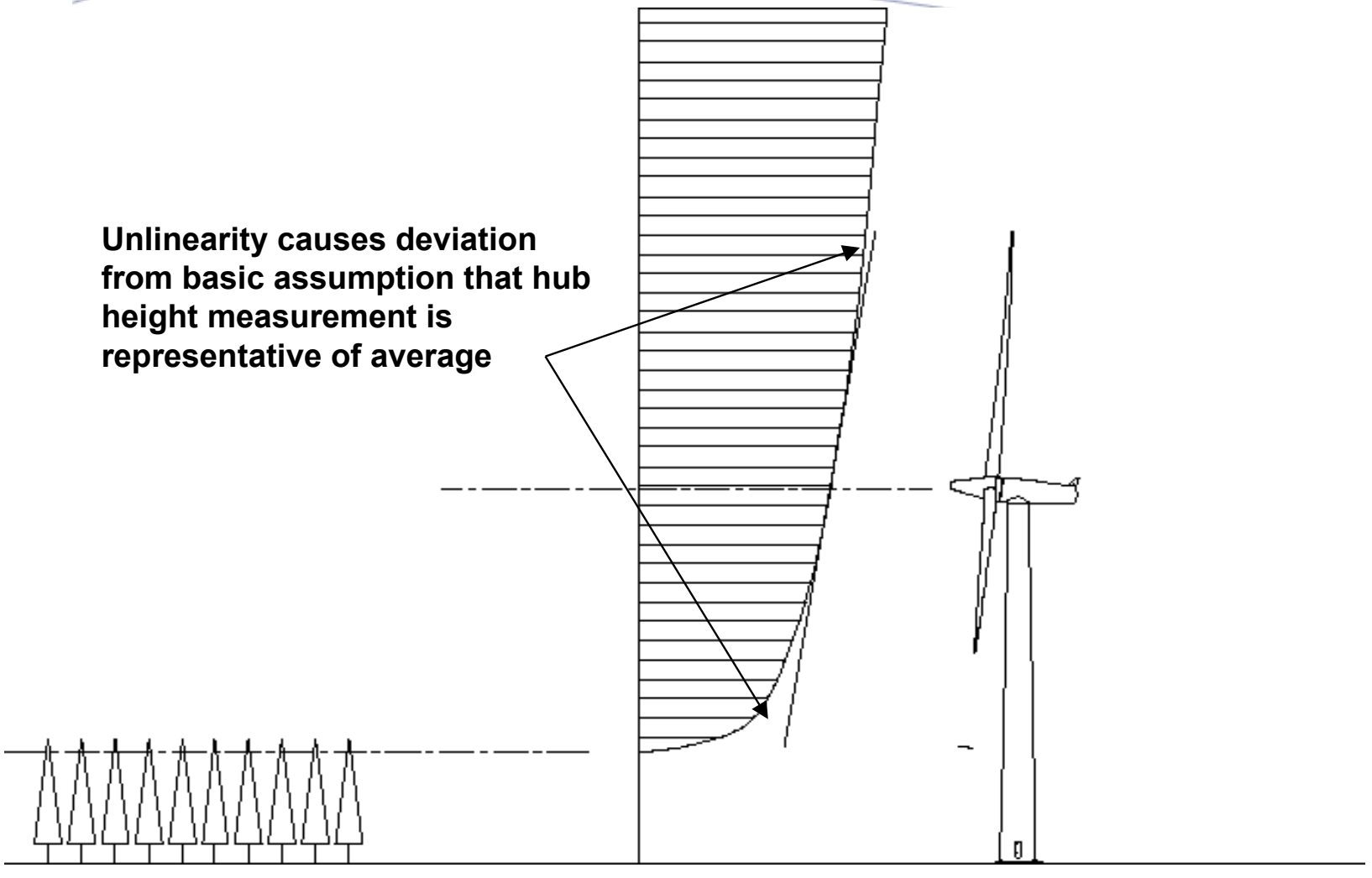
- The basic assumption is that the hub-height wind speed represents the average wind speed across the rotor disc
- This assumption is not bad for normal shear and no trees. The slight unlinearity of the wind profile is taken into account in normal power curve calculation
- For high shear and a zero-displacement the unlinearity becomes important
- A 2.3 MW with 82.4 m rotor and 60 m hub height has 3.5% less apparent power at 10 m/s if sited near a 20 m forest with m = 0.25 than if sited in open terrain with m = 0.14

Shear at Normal Terrain, m = 0.14



Shear Near Forest, m = 0.25

Unlinearity causes deviation from basic assumption that hub height measurement is representative of average



Rule of Thumb regarding Power Curve

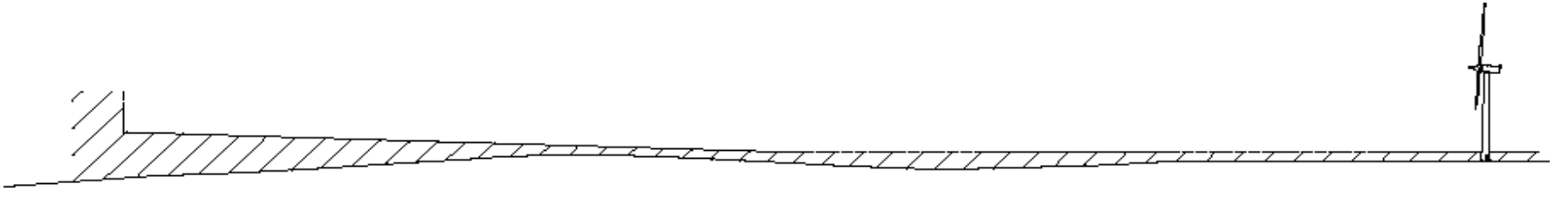
Bonus uses following rules of thumb for evaluation of possibility of power curve measurement:

- Shear not to exceed 0.20
- This shear expected possible if tree height does not exceed a horizontal level of
  - Hub height - 2/3 D for R <= 5 D
  - Hub height - 1/2 D for R = 10 D
  - A linear increase in the range 5-10 D
- No restrictions apply for R > 10 D

Rule of Thumb regarding Power Curve

The height of trees in the vicinity of a WTG, measured above the horizontal level of the WTG bottom flange, should not exceed the following limits, where R is the distance from the WTG to the trees, Hh is the hub height above the tower bottom flange and D is the rotor diameter:

- **For R <= 5D: Hh - 0.67D**
- **For 5D < R <= 10D: Hh - 0.67D + 0.17D*(R/(5D)-1)**



Conclusions

Primary conclusion:

- Do not site wind turbines near trees

- But in Real Life...

Conclusions, Continued

… so if trees are unavoidable:

- Do not underestimate the effect of trees on the resource
- Apply the Risø suggestions to the flow models
- Apply more than one model if possible to estimate the uncertainties
- Take account of increased turbulence in turbine certification
- Do not attempt power curve measurements if shear exceeds 0.2.
- If no other shear information available then apply rule of thumb regarding tree heights in vicinity of turbine