New Rotor Concepts for Future Offshore Wind Farms

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10th European Fluid Mechanics Conference EFMC10, 14-18 September 2014, DTU Lyngby, Denmark

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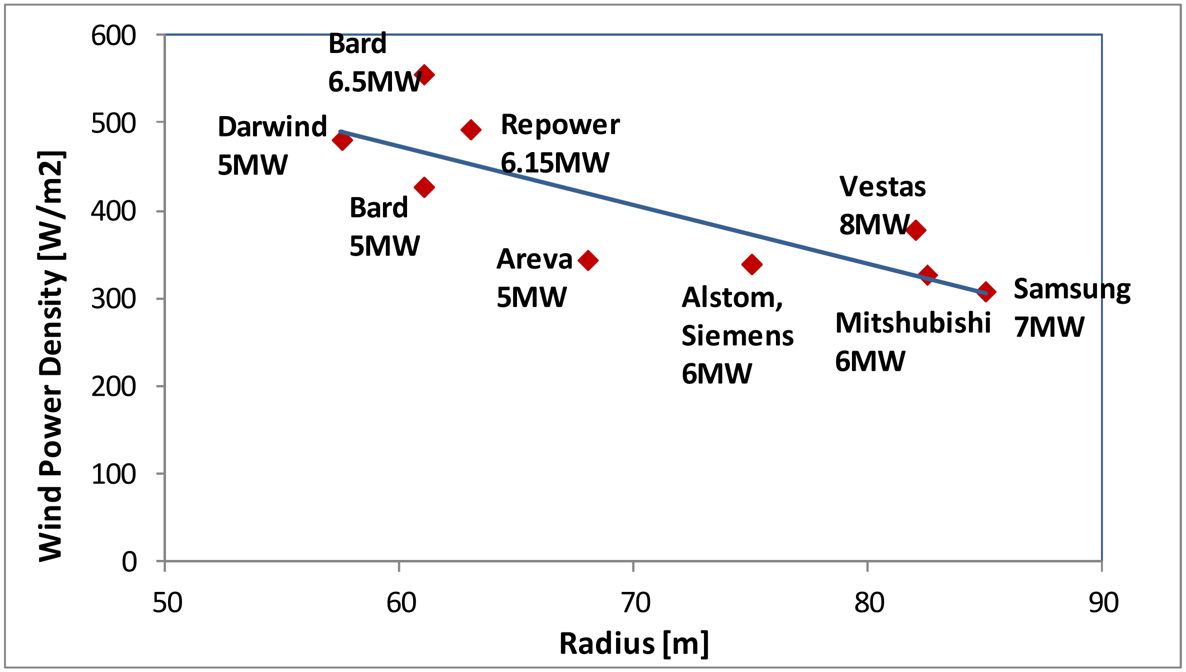
Introduction and Purpose

- Decreasing power density of offshore wind turbines.
- Offshore wind turbines will be used inside offshore wind farms, not stand alone.
- Possibility of bringing a different perspective to rotor designs for large offshore wind turbines.



Method

Method

INNWIND.EU 10MW RWT

Parametrical study for Rotor design

Reduced power density from 400W/m^2 to 300W/m^2

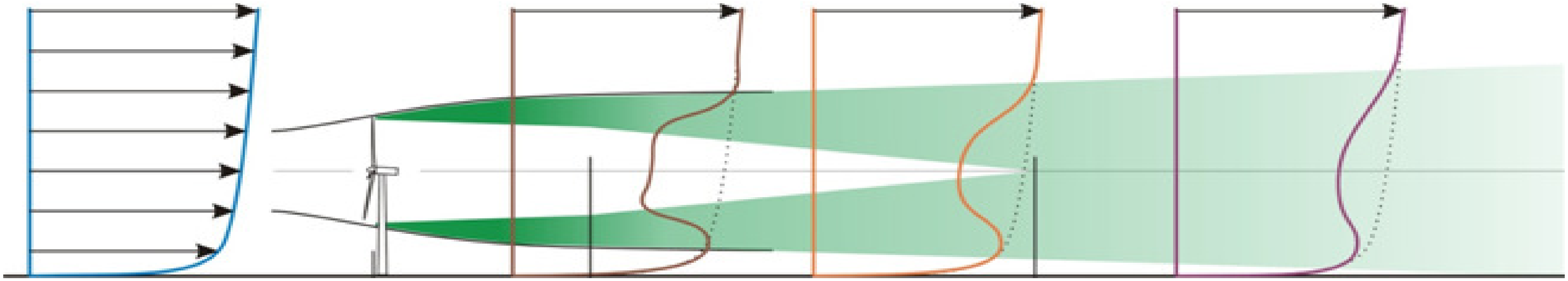
Evaluate the results in WT level

(BOT software is used)

Replace the turbines in Horns Rev with studied concepts

Evaluate the results in WF level
(Farmflow software is used)

FARMFLOW: Parabolized k-ε/Actuator disc model



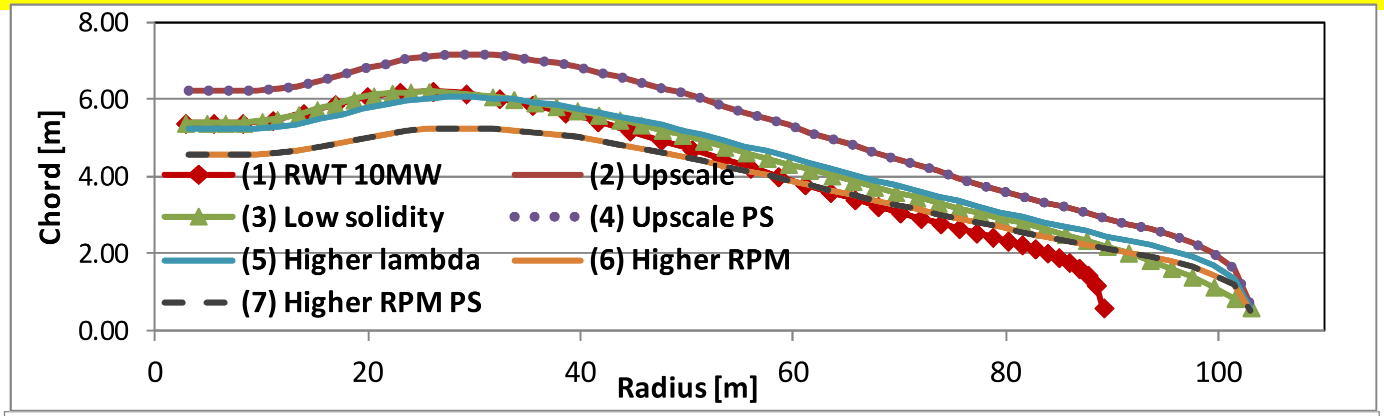
- Parabolisation: Fast, but how to solve the near wake where axial pressure gradients are significant?
- Solution:
  - Prescribe axial pressure gradients from free vortex wake method!
    - Fast database approach
    - Wake interaction fully modeled including the effect of a non-zero pressure gradient and retaining the (fast) parabolisation
- Adjusted k-ε turbulence model parameters in near wake to account for actuator disc assumption, based on:
  - Measurements from ECN's research farms and Horns Rev farm
  - Detailed wake measurements in TUDelft wind tunnel currently analysed *)

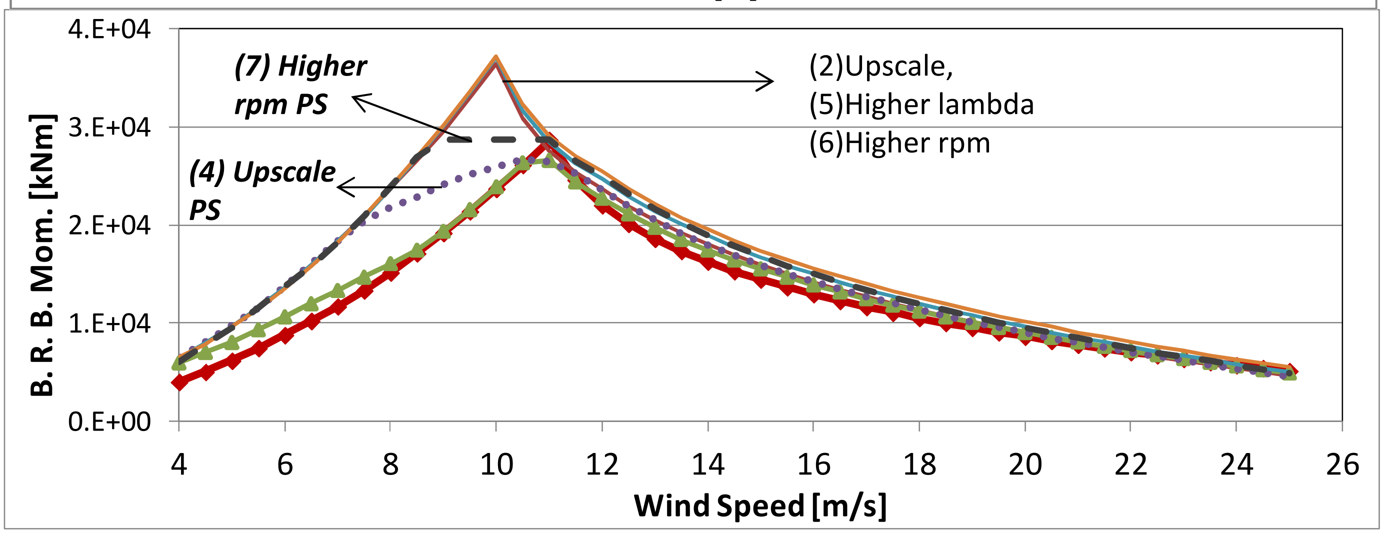
Rotor Parameters

Name of concept→	(1)RWT	(2)Upscale (3)Low Solidity (4)Upscale PS	(5) Higher Lambda	(6) Higher RPM (7)Higher RPM PS
Capacity [MW]	10	10	10	10
Tip Speed [m/s]	89.6	89.6	103.6	113.5
Lambda	7.5	7.5	8.66	9.50
Rpm	9.6	8.31	9.6	10.53
Radius [m]	**89.2**	**103**	**103**	**103**
P. Dens. [W/m²]	**400**	**300**	**300**	**300**

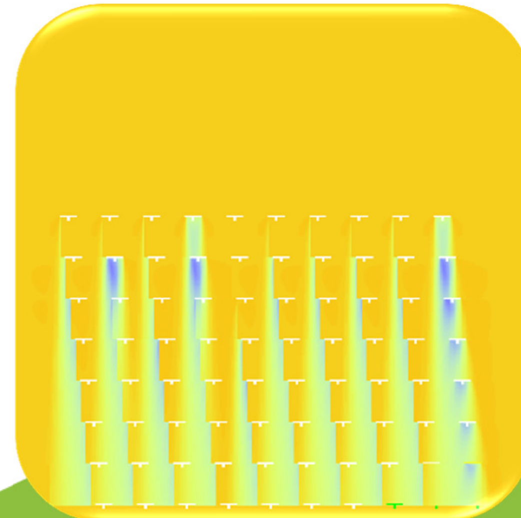
Number 8 and 9 is equal to 1 and 3, with ECN airfoils

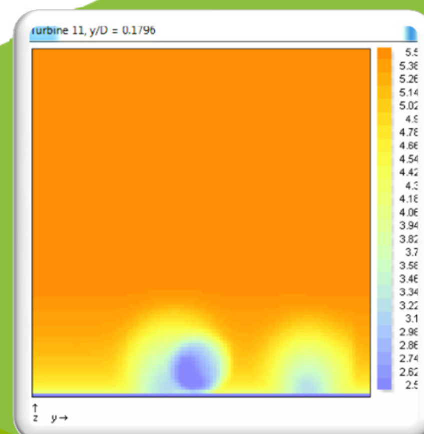
Rotor Concepts Compared

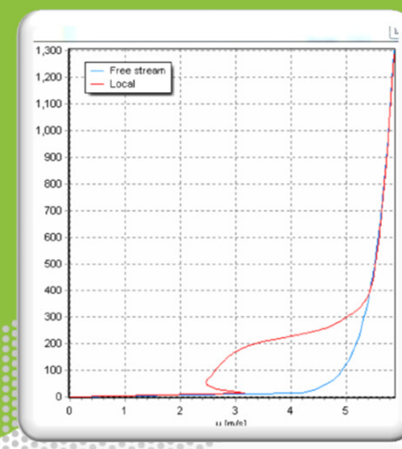




RESULTS

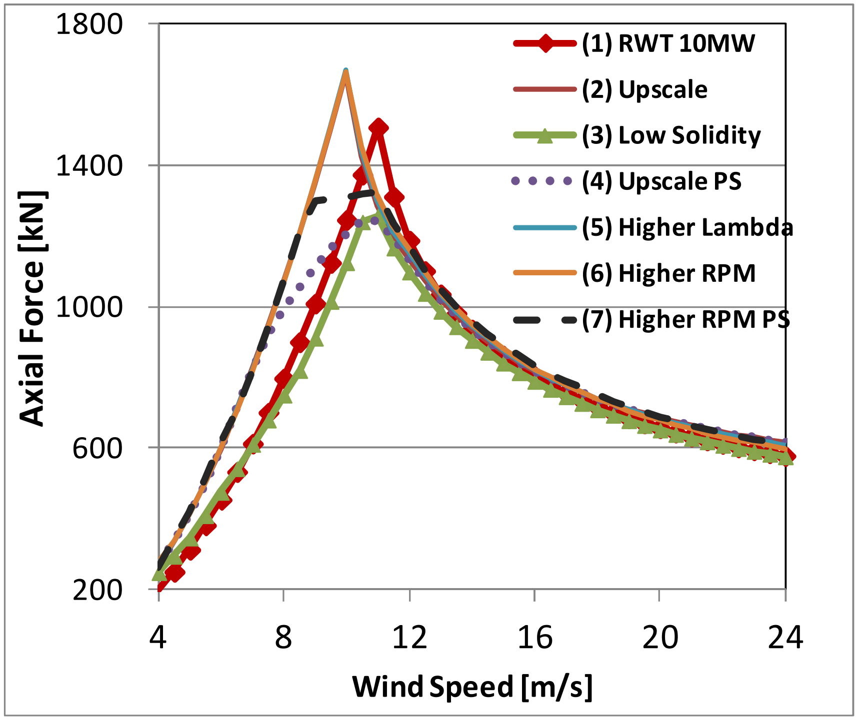






Wind turbine level comparisons

	ΔAEP [% RWT]	ΔMax. Fax [% RWT]
(2)Upscale	10.8	10.7
(3)Low Solidity	**5.2**	**-17.0**
(4)Upscale PS	**8.0**	**-17.0**
(5) Higher Lambda	11.2	11.4
(6) Higher RPM	11.4	11.1
(7) Higher RPM PS	**9.9**	**-11.7**
(8) RWT ECN Airfoils	**0.1**	**-4.0**
(9) Low Solidity ECN A/f	**5.5**	**-17.0**

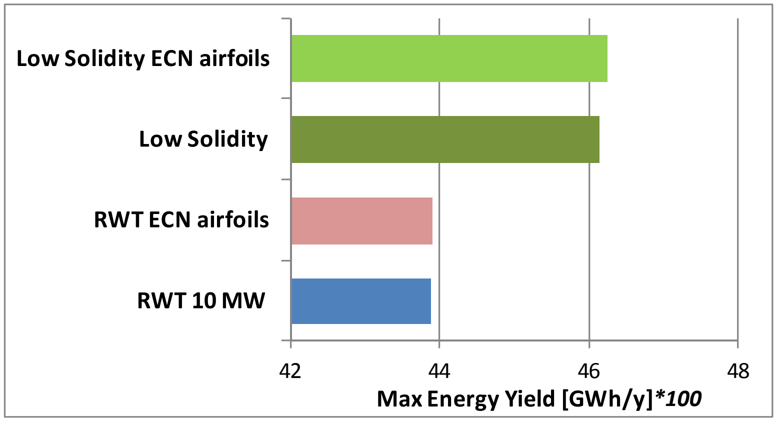


Wind farm level comparisons

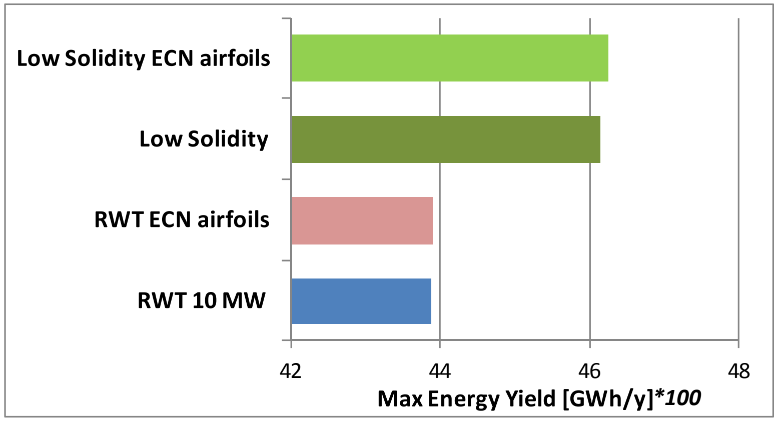
	Absolute dist. kept (2.7D east-west)		Relative dist. kept (7D east-west)	
	ΔAEP [% RWT]	Efficiency [%]	ΔAEP [% RWT]	Efficiency [%]
(1)RWT		71.98	-	85.83
(2)Upscale	10.78	71.84	13.25	87.57
(3)Low Solidity	**10.5**	**75.67**	**9.64**	**89.54**
(4)Upscale PS	**11.52**	**74.42**	**11.37**	**88.62**
(5) Higher Lambda	11.2	71.97	13.56	87.64
(6) Higher RPM	11.39	72.09	13.64	87.71
(7) Higher RPM PS	**11.6**	**73.15**	**12.9**	**88.24**

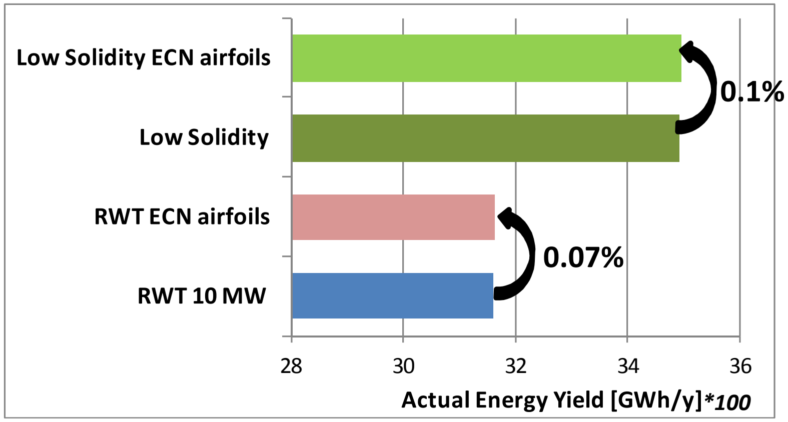
Wind Farm Level – Effect of Airfoils

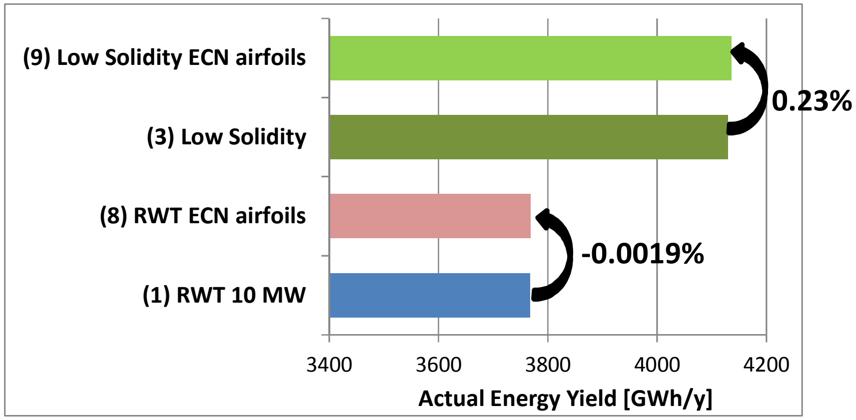
Absolute distances are kept



Relative distances are kept







Conclusions and Discussion

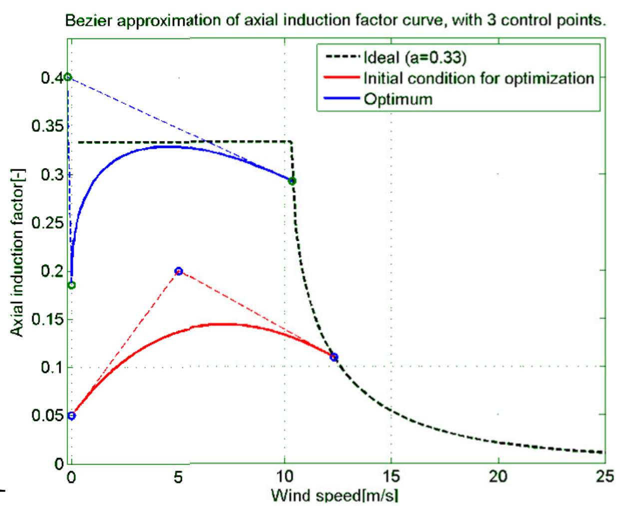
- Longer blades, more energy in wind farm independent from distances between turbines. Proven benefit of decrease in power density.
- Performance of the wind farm is more relevant than the performance of the individuals turbines in the farm.
- Effect of peak shaving strategy in power output of a wind turbine can be much less in a wind farm.
- These results are highly dependent on the chosen farm parameters and the accuracy of the models used. Nevertheless, they still indicate the potential of the integral design for future wind farms.
- Larger distances between the turbines in wind farm will lead to higher costs in other aspects, such as electrical infrastructure and O&M.
  - ECN's aerodynamic wind farm tool Farmflow has been linked with ECN's electrical wind farm tool EEFARM [1])
- Next step is to design the turbines for farm operation.

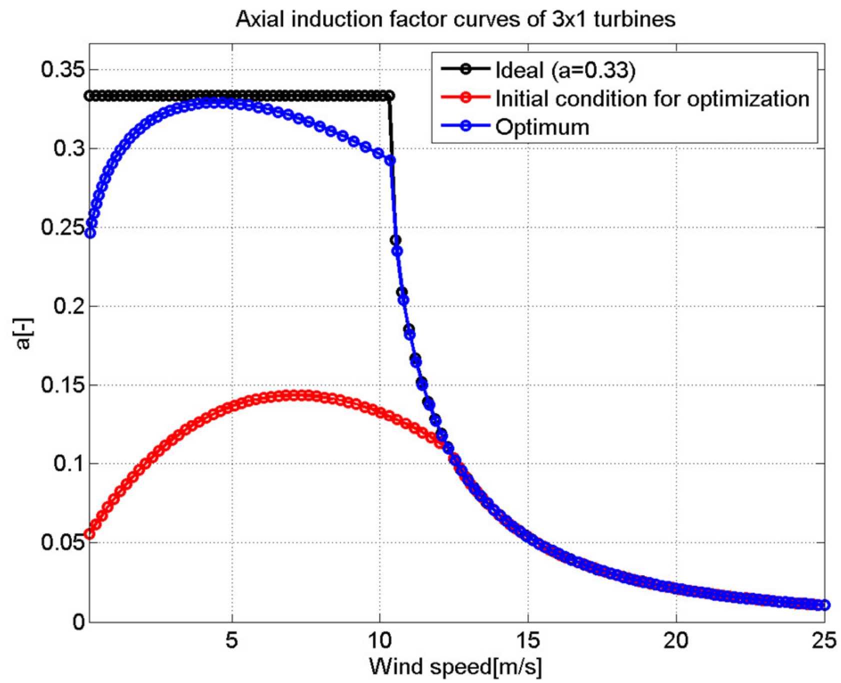
1) J.G. Schepers et al: EERA-DTOC: How aerodynamic and electrical aspects come together in wind farm design EERA-Deepwind Conference, January 2014, Trondheim

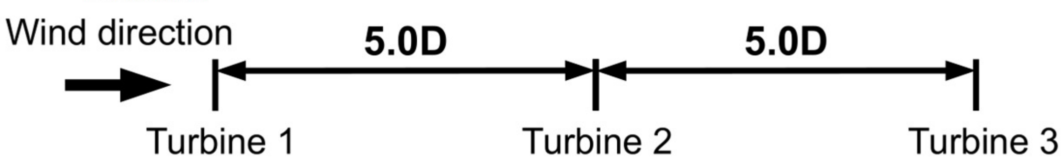
What's Next?: Rotor Optimization for Farm Operation

Reduction in overall AEP is 0.13%
Large reduction in Ct in rated speed.

3 point Bezier approx. of Ct (a) curves







Provided by Ramon Koole

The present work has been partially supported by the FP7 European project INNWIND.EU (project no. 308974).

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Thank you!