Vindmøller. Opskalering, Koncepter

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Vindmøller

Opskalering, koncepter

Dansk Elektroteknisk selskab

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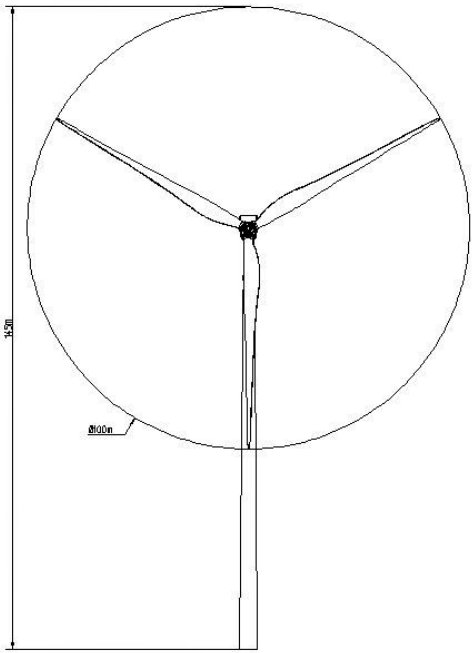
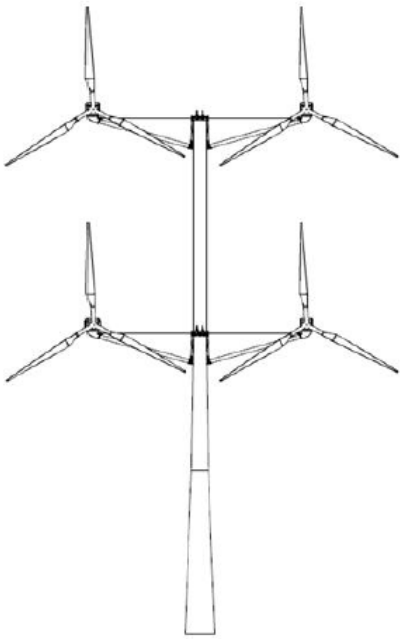
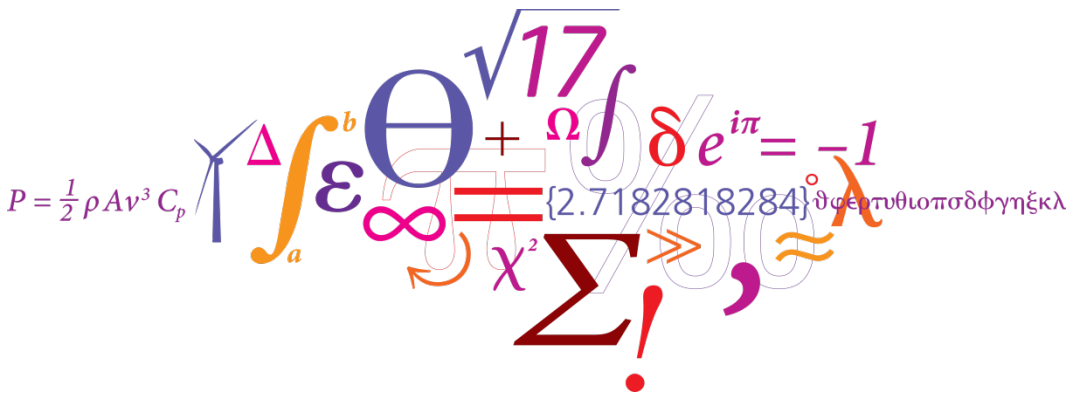
Senior Forsker

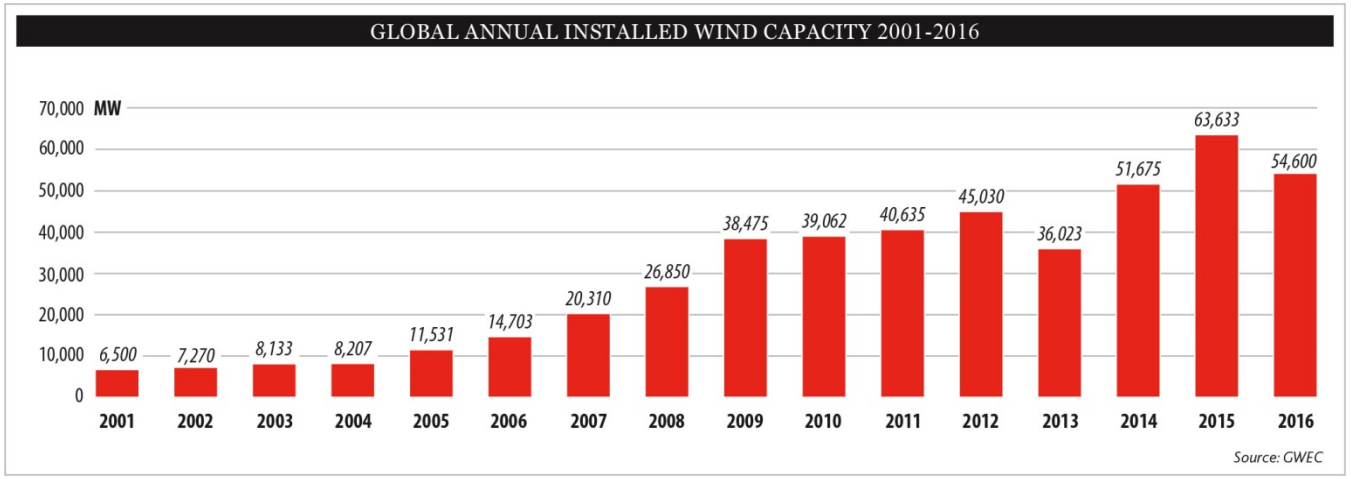


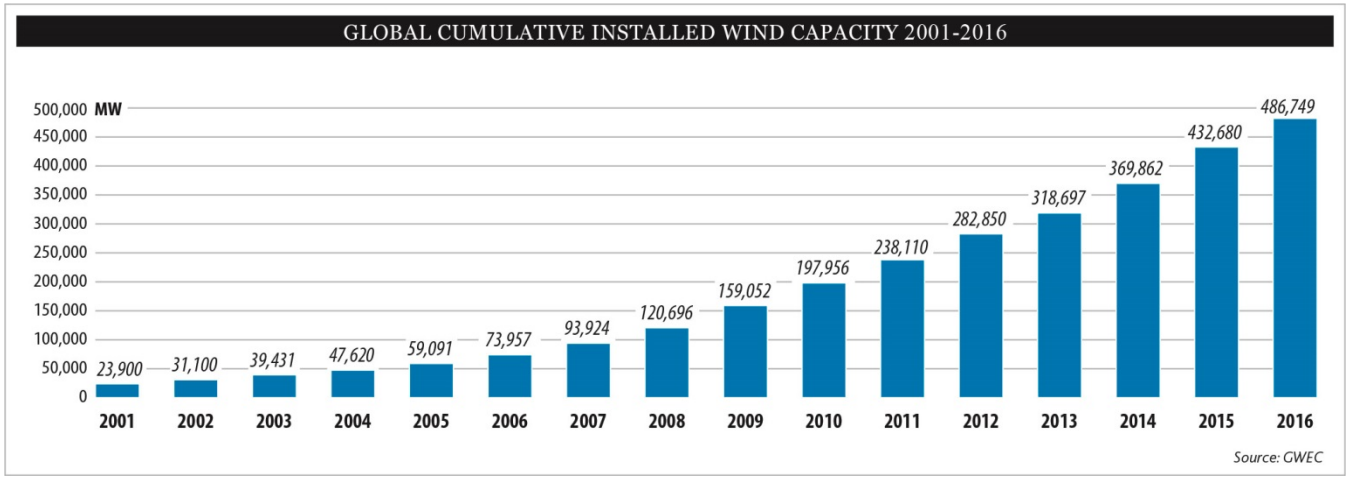




DTU Wind Energy
Department of Wind Energy

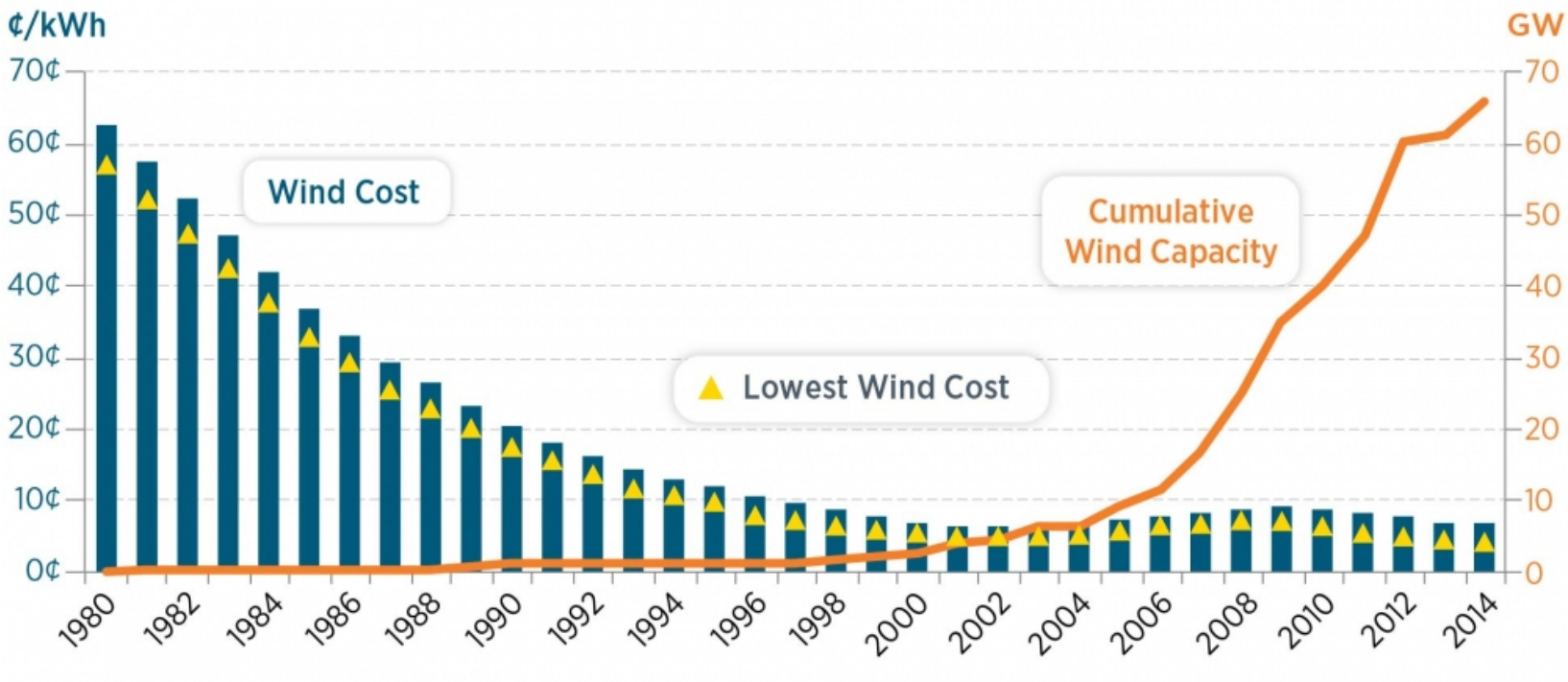
Lidt hovedtal fra branchen



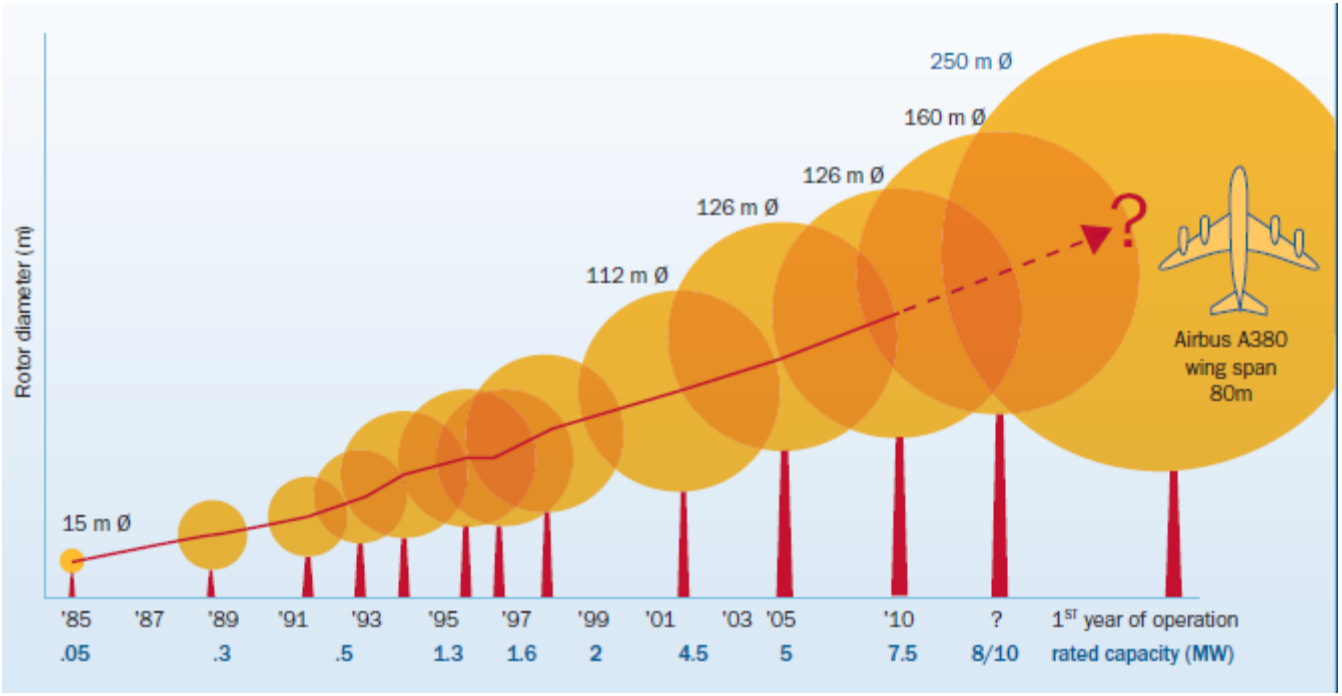


Udvikling

Den globale vækst af vindenergi tog for alvor fart da prisen kom ned



Udvikling i størrelse



Lidt omkring opskalering

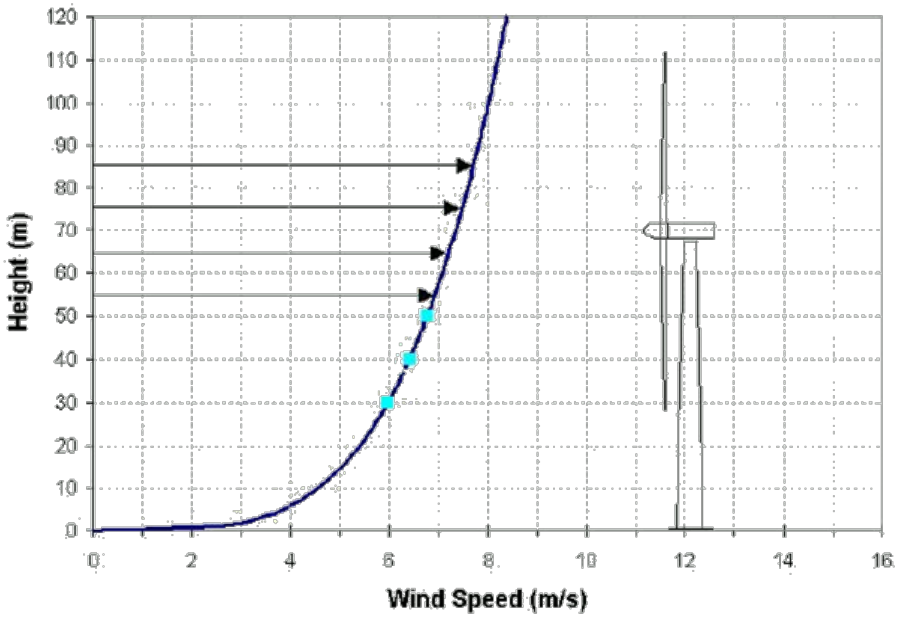
Hvorfor dette konstante ræs mod større størrelse?

Energi produktion for en mølle stiger med arealet

$$P = \frac{1}{2}\rho A C_p U^3$$

- dvs produktion fra en større mølle stiger med D^2

Derudover er der også mere energi at hente højere oppe



Lidt omkring opskalering

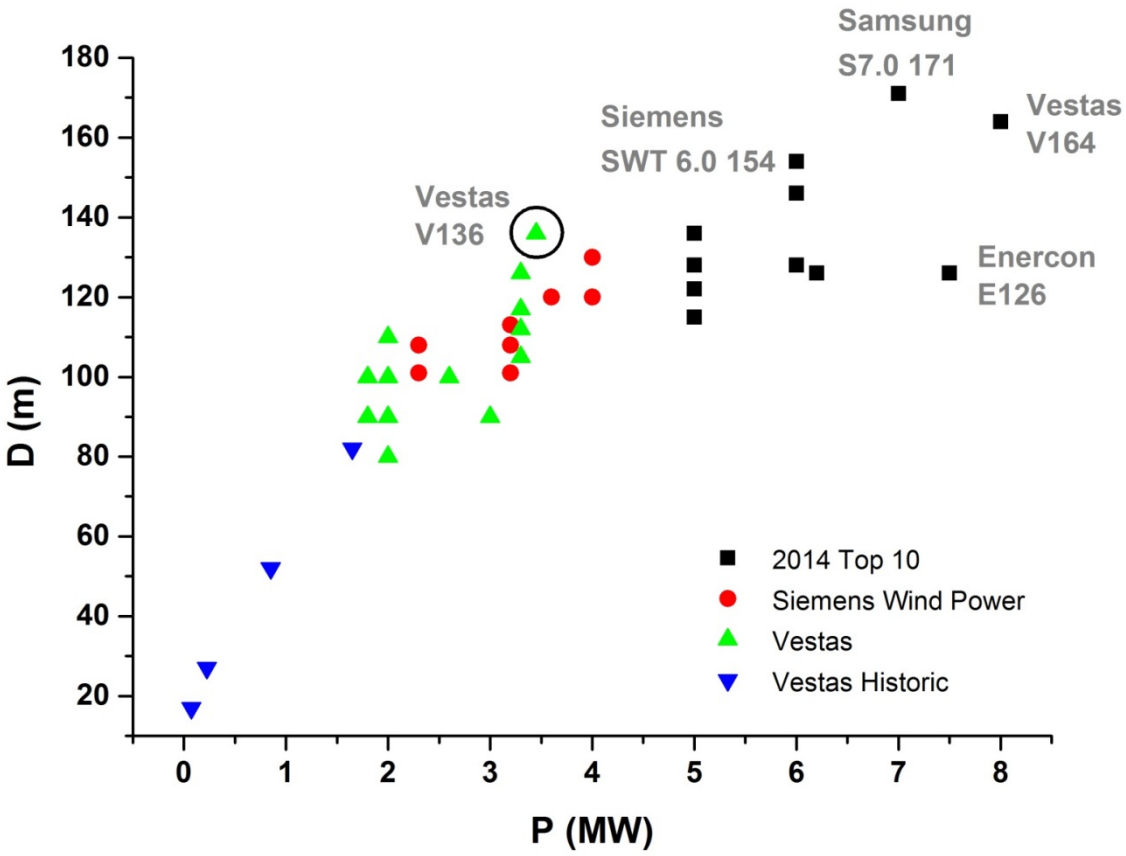
Hvis vi nu taler om at placere møller på en række med afstand xD imellem

Vinden er på tværs af rækken (ingen skygge effekter) og møllens produktion er f.eks 1000kWh/m^2

$$\frac{E}{L} = \frac{E/A \cdot A}{xD} = const\,\frac{D}{x}$$

Kommer vi til konklusionen: Større diameter, mindre afstand

Udfordring gennem de sidste 35 år
Opskalering, længere vinger



Challence:
Beating ”Square-cube law”
(Rotor diameter = D)

Power ~ D^2
Mass ~ D^3
Aero force moment ~ D^3
Mass moment ~ D^4

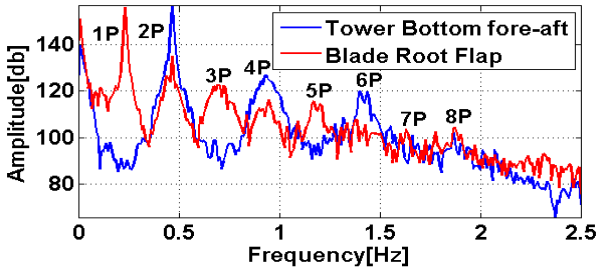
Real blades:
Mass ~ $D^{2.1\text{-}2.3}$

But:
Strenght ~ D^3

Implications of Upscaling

Advantages:

- Increased wind resources
- Increased Reynolds no. (speed and size)
- Rotational sampling of turbulence concentrates energy at 1p
- Filtering of turbulence (lower loads)



Challenges:

- Input and resonance freq. get closer
- The flexibility increases
- Self induced loads and stability issues
- Increased tip speed (Mach no. effects after 90 m/s and erosion)
- Noise increases with size and tip-speed
- Installation and transportation

Wind Turbine Technology 2015

Siemens
7 MW

Vestas
V164, 8 MW

Achieved through:

- ❑ Slender blades with thick airfoils
- ❑ From design for stiffness towards design for strength
- ❑ Upwind coning and prebend
- ❑ Aeroelastic tayloring

Multirotor konceptet

- Vingers størrelse kan ikke opskaleres i det uendelige
- Der er transport og installationshensyn der bliver meget vanskelige for meget store vinger
- Store komponenter kan kun fremstilles få steder (monopol, logistik)

- Det er hensigtsmæssigt at øge produktionen på hver site (her kommer også hensyn til kabelomkostninger og fundamentsomkostninger).

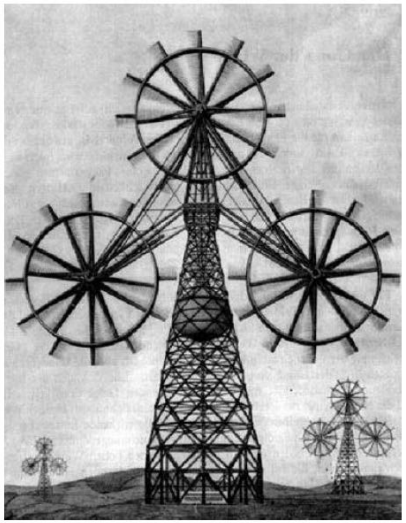
- Dvs når rammerne nås for et konventoinelt design, er det (måske) muligt at fortsætte med et multirotor design
- Derudover kan der være sites med specielle krav

Egenskaber for multi rotor demonstratoren

- 4 V29-225kW naceller
- Tip højde 74m
- Rotoren monteres parvis
- Uafhængig krøjning
- Moderne refurbished configuration
- Variabelt rpm

- Viden øges mht
  - Den strukturelle dynamik
  - Aerodynamikken
  - Laster
  - Kontrol
  - Wake effekter

Idéen er sådan set ikke ny



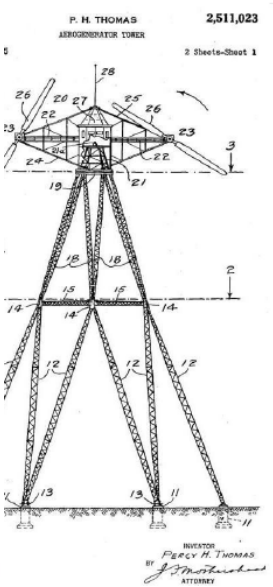


Figure 2.3. 3-Rotor turbine concept by Hermann Honnef, 1930 [9]

Lagerwey 1980-90's

Innowind project (Peter Jamieson), ongoing

Hvad er DTU's rolle?

- Udover at stille siten til rådighed
- Programmet HAWC2, hvor lasterne er simuleret på forhånd er udviklet af DTU
- Vi bruger LIDAR's til at scanne vindfeltet
- Vi er med til at undersøge forskellige områder

Lidt billeder fra installationen


Vestas

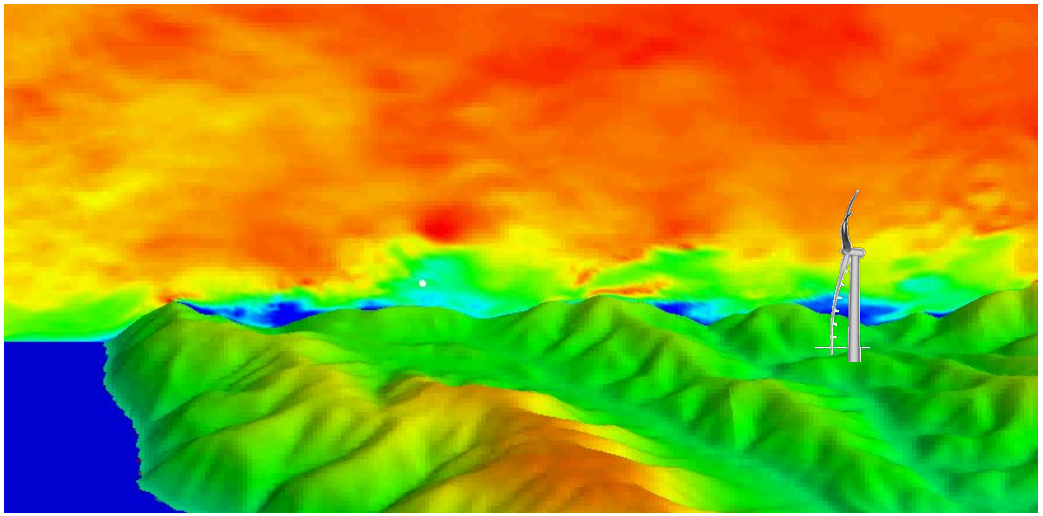

Vestas
Vestas


Vestas

HAWC2 overview

Purpose: Enable accurate load simulations for research purposes

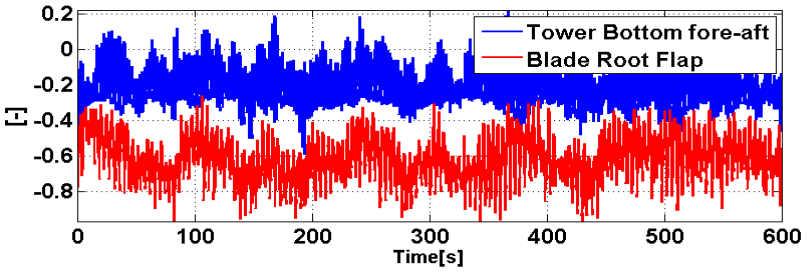
- However it should also be robust and suited for industrial application!

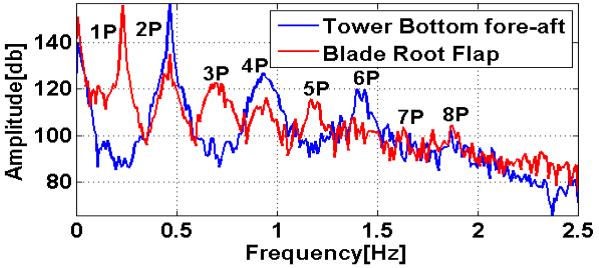


It is all about the response.

We need to be able to simulate in order to

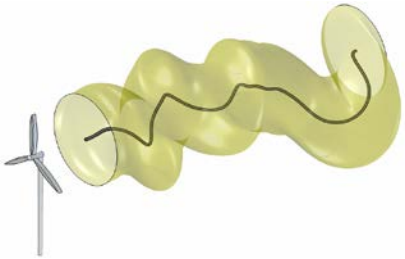
- Understand
- Improve
- Evaluate

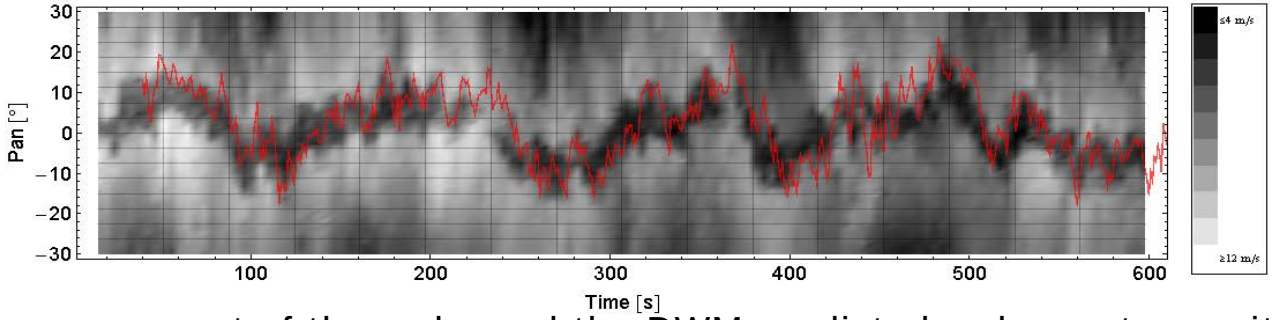




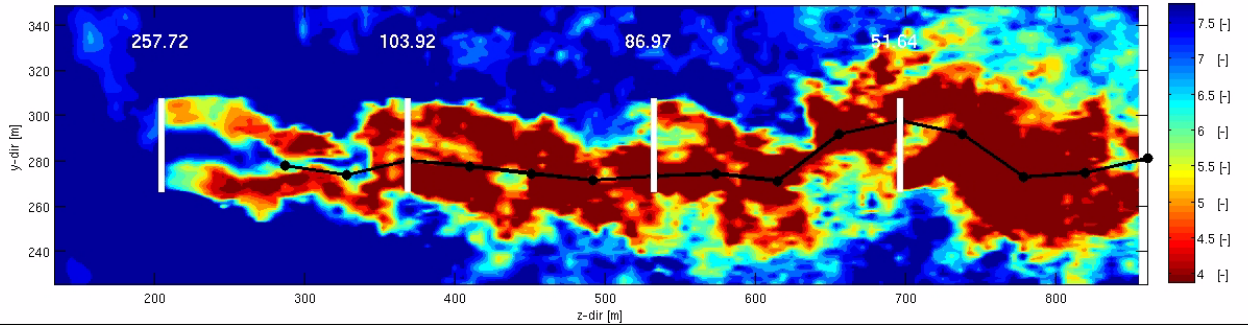
Similar load variations for a 2B turbine

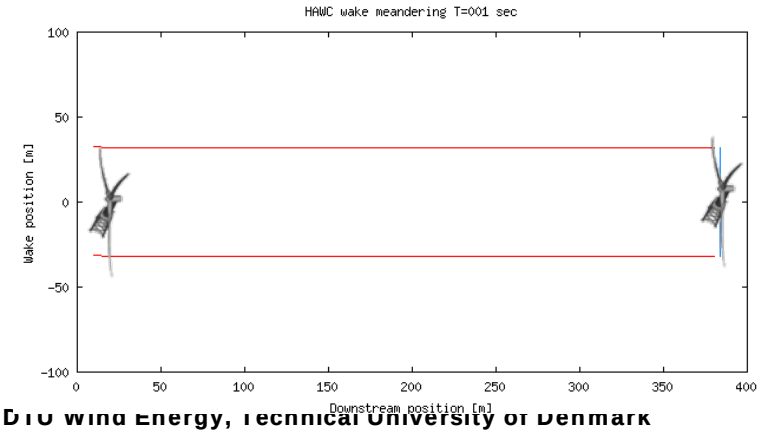
Dynamic Wake Modelling
– important for loads and power

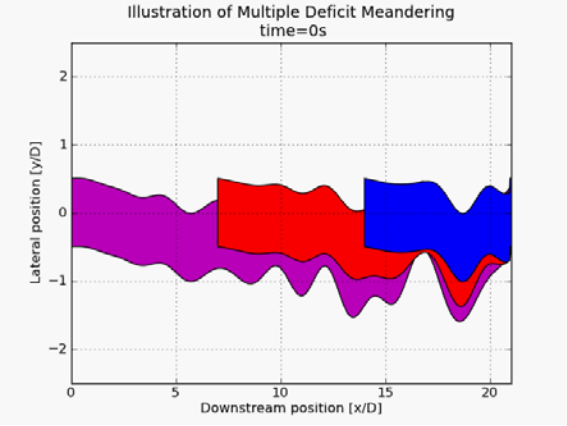




Lidar measurement of the wake and the DWM predicted wake center position



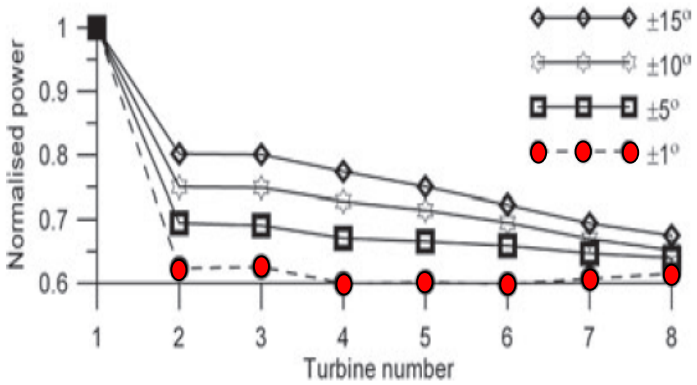




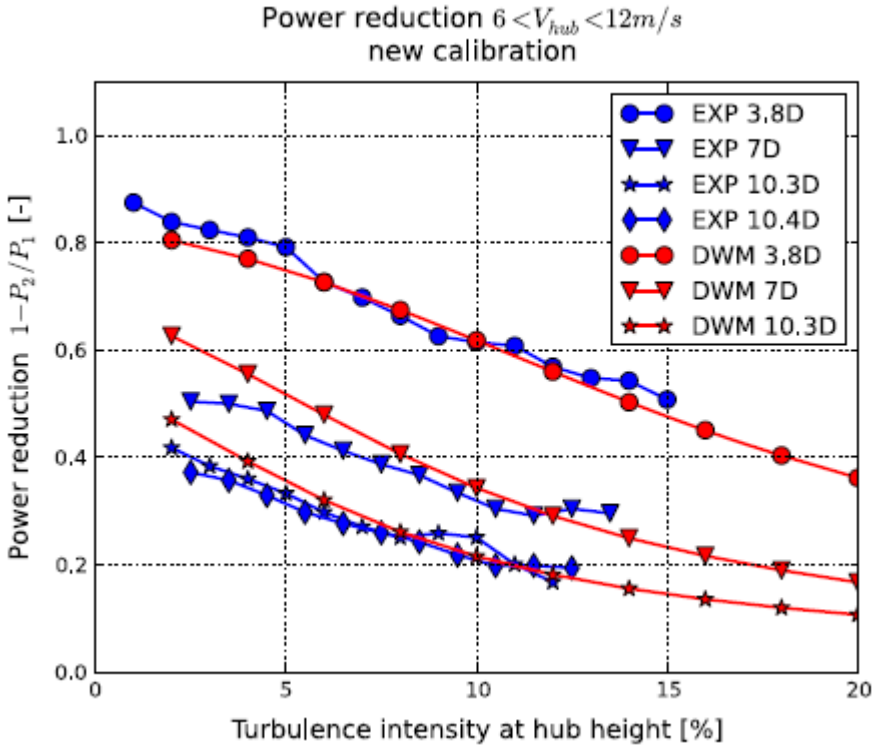
DWM

Previous observations

- Previous studies indicate that a flow equilibrium seem to occur so the extracted energy equals the restoring flow from turbulent mixing.
- The power production of turbine #n in a row is almost the same as for turbine #2.

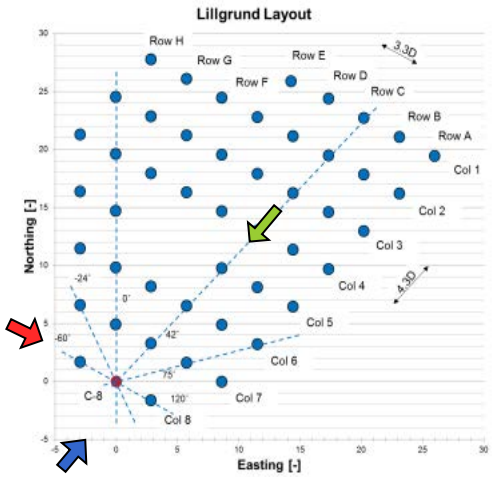


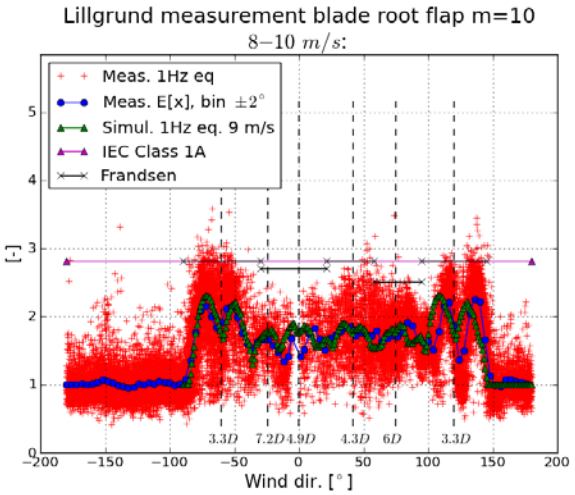
Barthelmie et al. (2009) *Modelling and Measuring Flow and Wind Turbine Wake in Large Wind Farms Offshore.Wind Energ.* 2009; **12**:431–444

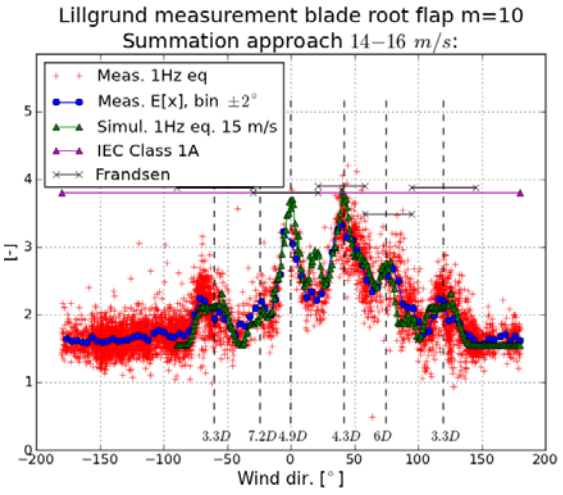


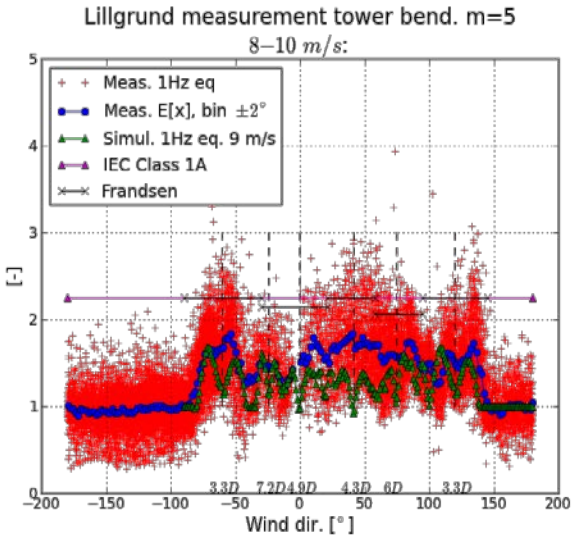
An example from real life: Results from Lillgrund

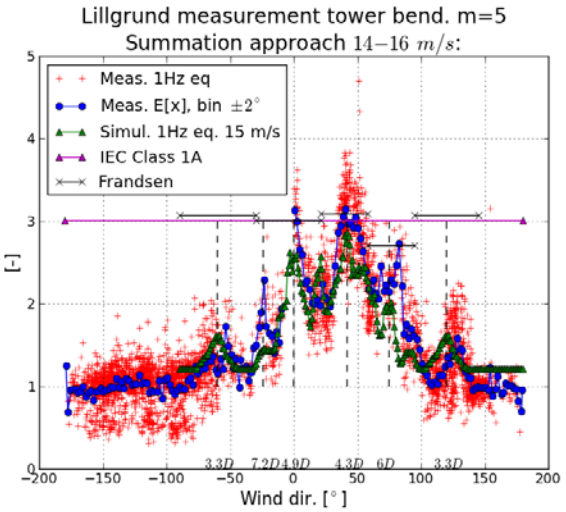
3-7D spacing, single and multiple wake situations











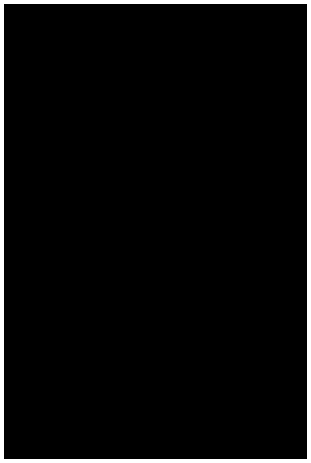
Very good general agreement

SURPRISINGLY high loads in the multi-wake high wind regime!

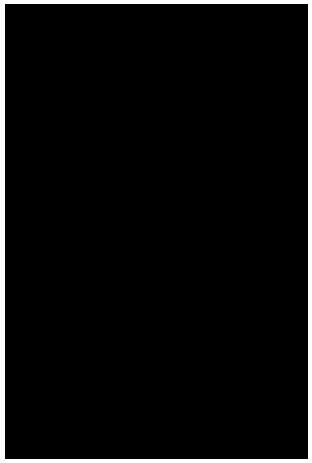
Larsen TJ, Larsen GC, Aagaard Madsen H, Petersen SM. 2015. Wake effects above rated wind speed. An overlooked contributor to high loads in wind farms. In Scientific Proceedings. EWEA Annual Conference and Exhibition 2015 . European Wind Energy Association (EWEA). pp. 95-99.

Closed-loop aero-servo-elastic modes

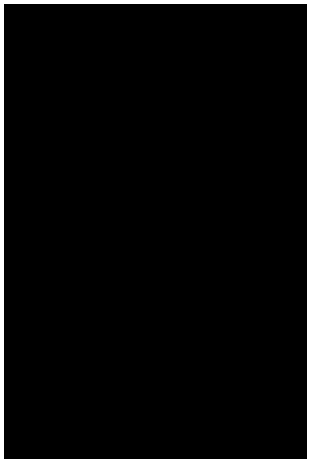
Speed regulator mode



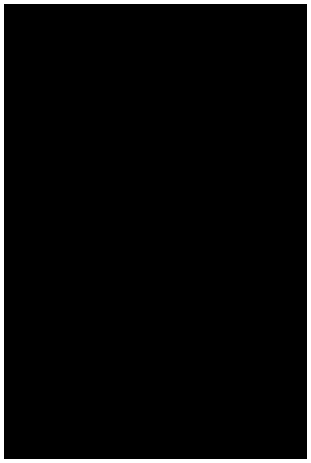
1st side-side twr



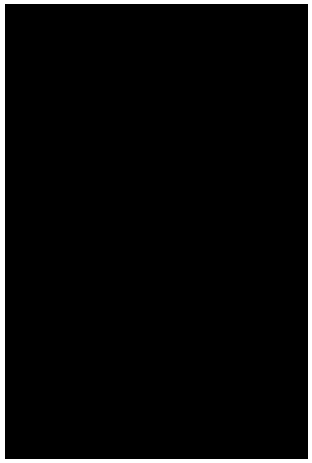
1st fore-aft twr



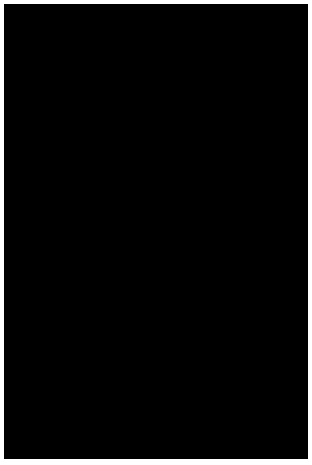
1st BW flap



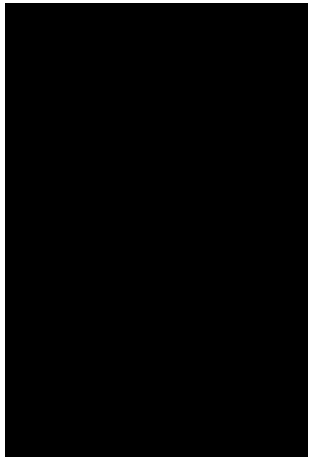
1 sym. flap



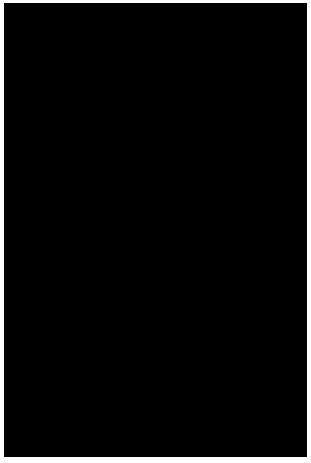
1st side-side twr in open-loop



1st FW flap



1st BW edge



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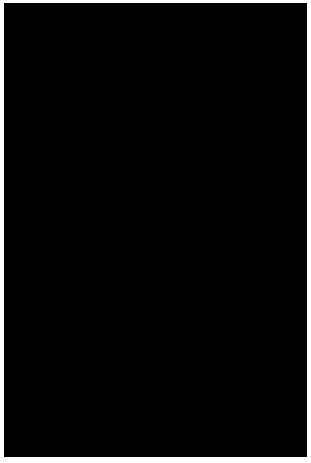
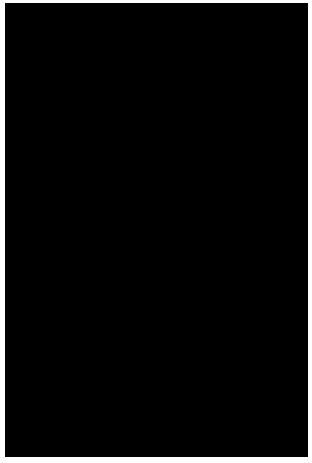


1st drivetrain



Different concepts investigated with HAWC2