Design and CFD Studies of UPWARDS 15 MW Virtual Wind Turbines

Balram Panjwani[1], Victoria Margaux Bloodworth[2], Søren Daugaard Henrichsen[2]

[1]SINTEF, Trondheim, Norway

Siemens Gamesa Renewable Energy, Aalborg, Denmark

EERA DeepWind'2021, Trondheim, Norway

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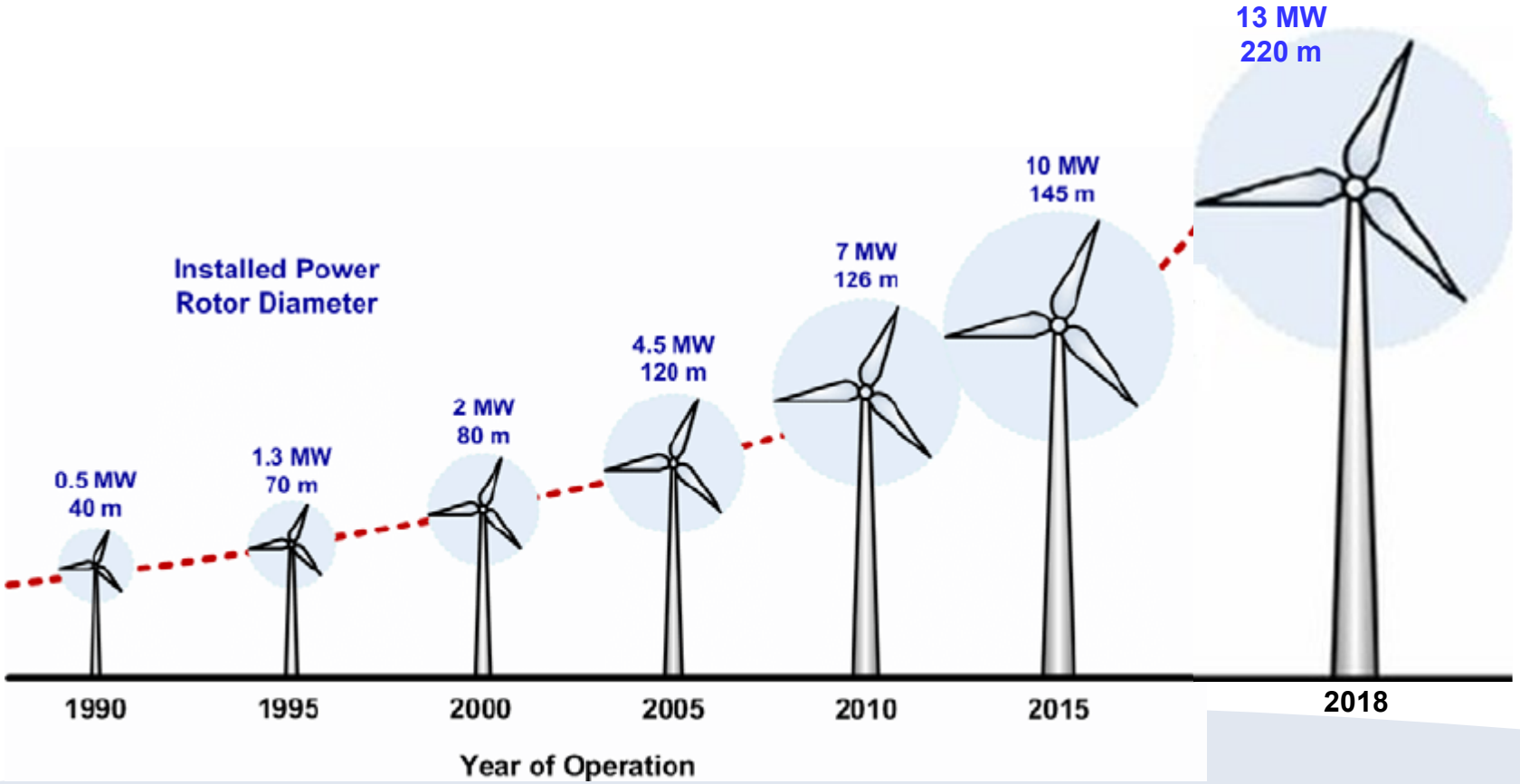
Outline

- In the past 30 years, wind turbines have become from kW to MW in size, and the largest turbines sizes are
  - Vestas V164 with a rated capacity of 8 MW and later upgraded to 9.5 MW,
  - Siemens Gamesa 10 MW wind turbine SG 10.0-193 DD upgraded to SG 11.0-193 DD Flex,
  - GE Haliade-X 13 MW wind turbine.

- The primary objective of the current study is to
  - Provide detailed design parameters of UPWARDS 15 MW virtual WT
  - Present and discuss CFD simulation (RANS) of virtual wind turbine
  - Provide power performance data of the virtual wind turbine



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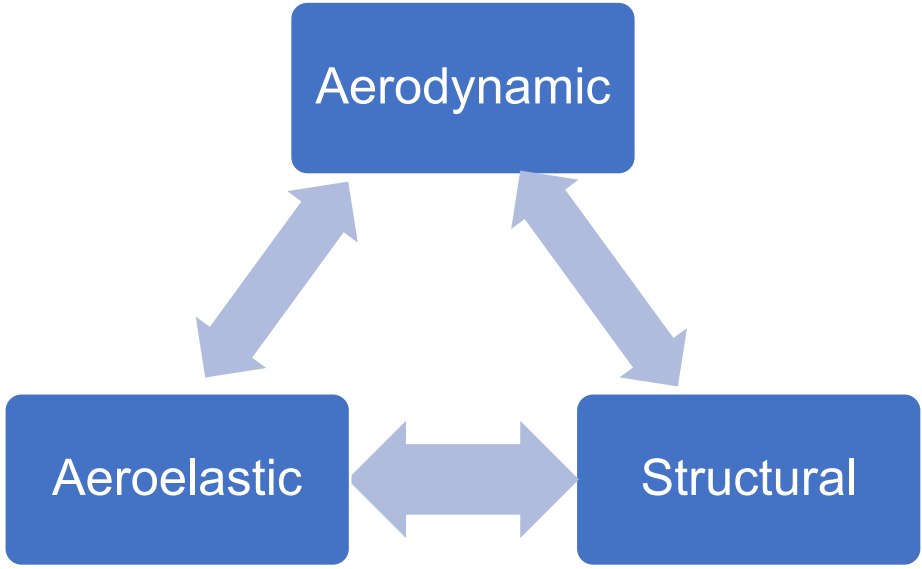
Methodology

- The design of the wind turbine is based on the previous SGWP 10MW wind turbine.

- Siemens internal design software have been used for designing the 15MW wind turbine rotor and following design parameters related to the rotor have been considered.

  - **Power control:** stall, variable pitch, controllable aerodynamic surfaces and yaw control
  - **Rotor position:** upwind or downwind
  - **Yaw control:** yaw driven, free yaw or fixed yaw
  - **Rotor speed:** constant or variable
  - **Tip speed ratio and solidity**
  - **Type of hub:** rigid, teetering, hinged blades or gimballed
  - **Number of blades**

- WT have been optimized considering aerodynamic, aeroelastic and structural properties.



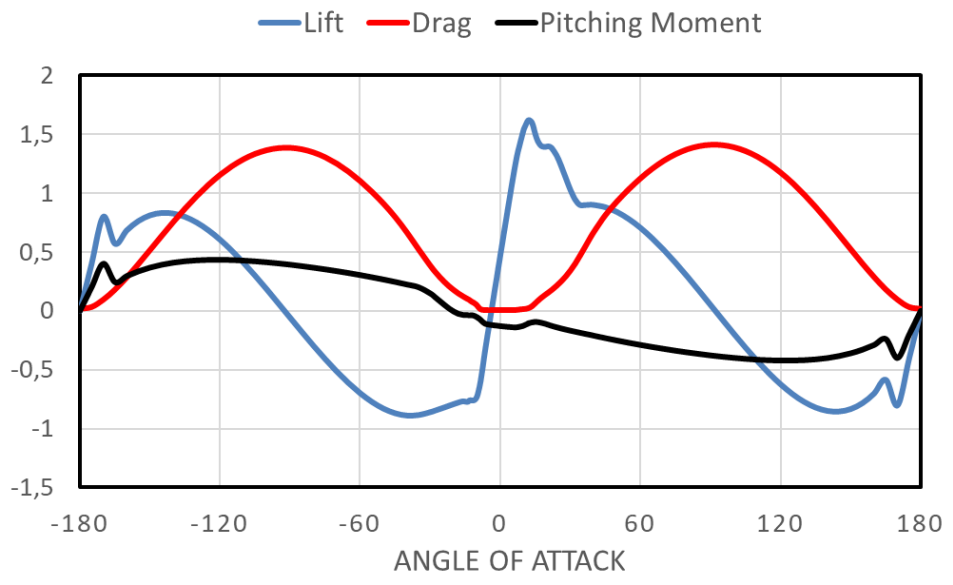
Design specification

Design Criterion	Design Specification
Type of turbine	3- bladed front runner
Direction of rotation	Clockwise (looking downwind)
No. of blades	3
Power Control	Pitch regulated with variable speed
Rated Power	15MW
AEP – Target	80.17 GWh
Capacity Factor	60.70 %
Rotor Diameter	230 m
Hub diameter	6 m
Min. RP.2M	3 RPM
Rated RPM	8.8
Cut-in-Wind Speed	3 m/s
Cut-out wind speed	25 m/s
Rated wind speed	10.77 m/s
Tower Height	130 m
BCD	4.3

Design Criterion	Design Specification
Shaft Hub Flange horizontal relative to tower top [SHFtoTThor][m]	-4.829
Shaft Hub Flange vertical relative to tower top [SHFtoTTver][m]	-5.212
Shaft Hub Flange to Rotor Center [SHFtoRC][m]	-3.250
Rotor Center to BladeFlange_horizontal [RCtoBFhor][m]	-0.158
Rotor Center to BladeFlange_vertical [RCtoBFver][m]	3.636
Blade length [Bll][m]	112.0
Blade pre-bending [BlpreB][m]	2.860
Tower Diameter at Blade tip [TowD][m]	7.50
Horizontal distance from tower top center to blade root [TTtoBroot][m]	-8.68
Horizontal distance from tower top center to undef blade tip [UndefHorDist][m]	-25.31
Vertical distance from towertop to blade tip	109.95

Properties of 15 virtual WT

- Blade Structural
- Blade Aerodynamic
- Hub and Nacelle
- Drive train and tower
- Baseline Control System



Aerodynamic coefficients of the DU 08-W-210, at Re = 8 million

Blade Aerodynamic properties

Design Criterion	Design Specification
Aero baseline	NACA64-618; DU 08-W-210; DU91-W2-250; DU97-W-300; DU-A 400-050; Cylinder
Blade length	112.0 m
Chord length	5.82 m
Blade twist. From Max. to min. Value	20
Blade surface area	906m^2
Airfoils – family	Mixture of NACA and DU profiles
Maximum chord length position	22
Tip chord	0.52
Maximum Blade pre bending (x-axis offset)	2.86m
Max. Self-pitch/Blade Sweep (y-axis offset) – Based on a straight beam	0

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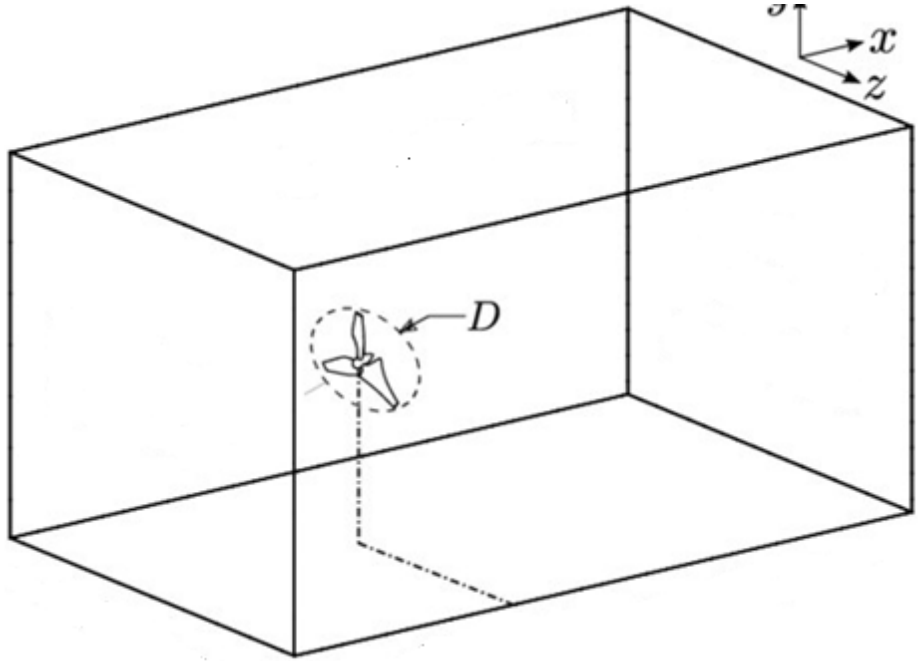
CFD simulation of 15 MW wind turbine

- CFD simulations of WT using OpenFoam were performed
- Wind turbine model using Actuator surface model developed during the UPWARDS project was utilized[1]
- Simulation were performed for a single turbine



Computational domain

[1]Balram Panjwani, "Effect of wind direction on wind park performance using Actuator Surface Modelling (ASM) approach", EERA DeepWind2020 conference, Trondheim January 15th-17th, 2020

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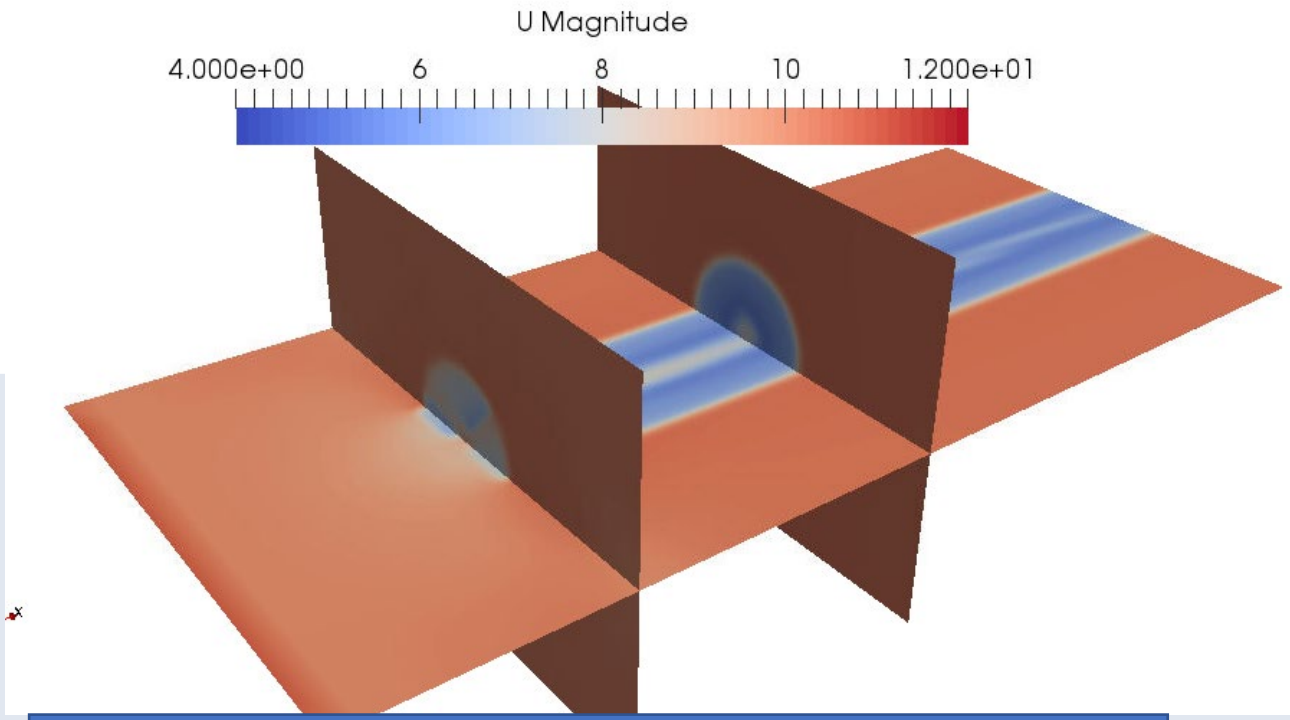
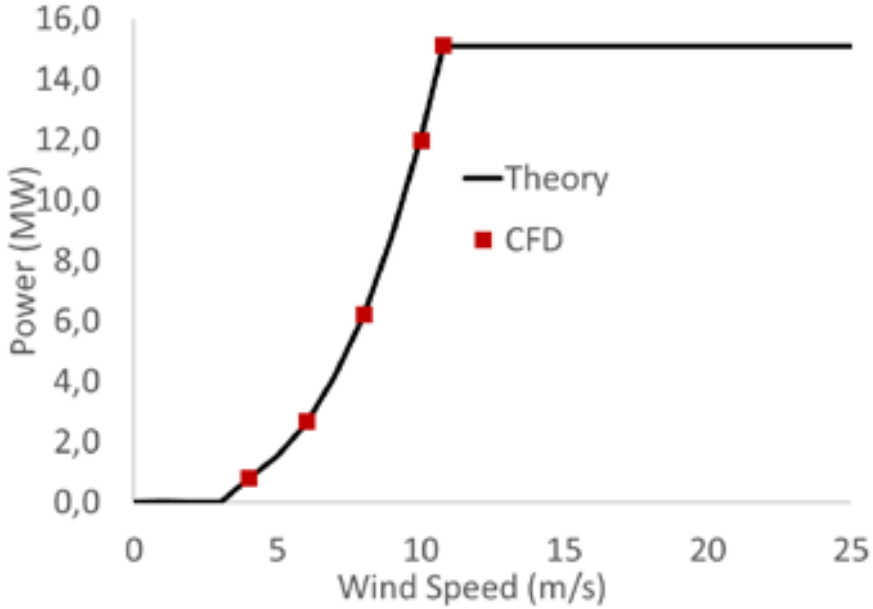
Results: CFD simulation of 15 MW wind turbine

- The power coefficient for this turbine is around 0.465
- The power obtained from theory and CFD are quite similar.



Velocity Contour plot



Power curve of UPWARDS 15 MW Wind turbine

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