Wind Turbine Stall/Separation Mitigation and Alleviation Using Overset Elements

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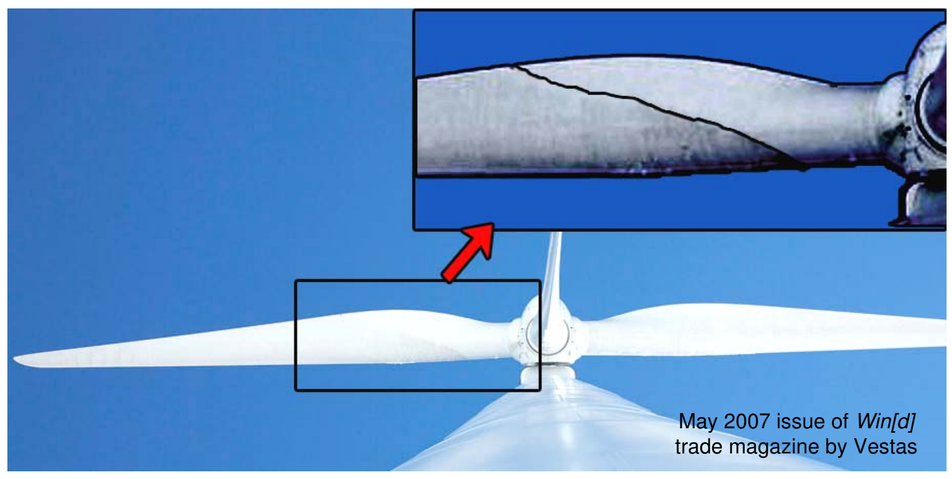
Current Industry Standard

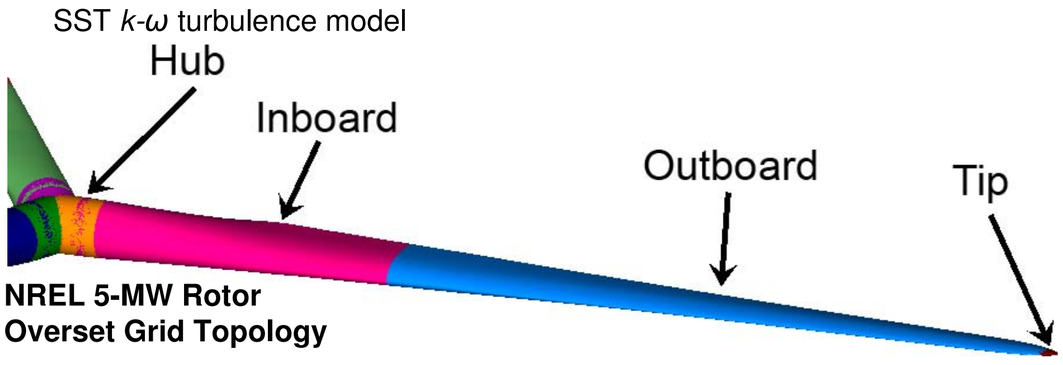
Blade Element Momentum (BEM)
- Idealized 2-D aerodynamic flow
  - Post-stall often based on empirical models
- Actual 3-D flow behavior missed
  - No spanwise interaction
  - No rotational effects
  - Ad hoc correction models used
- Larger rotors, structurally require thick inboard sectional shapes inherently more prone to stall
- BEM does not properly model inboard flow development of rotors
- This leads to overly optimistic blade designs
  - Inboard stall is not predicted
  - Power is overpredicted

Resulting in inboard flow separation

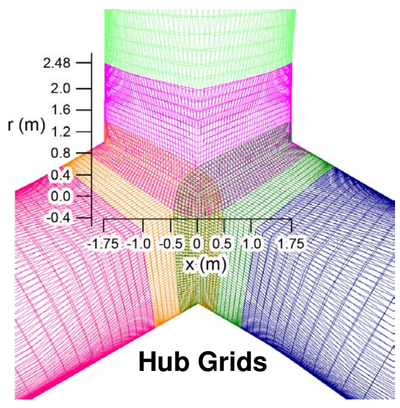


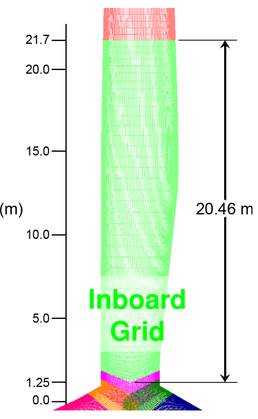
Proposed Methodology

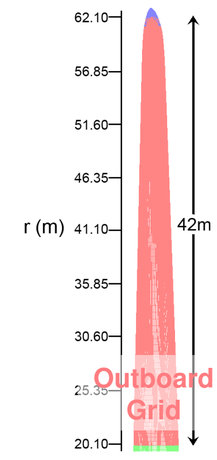
OVERFLOW-2
- Fully viscous 3-D URANS
- SST k-ω turbulence model

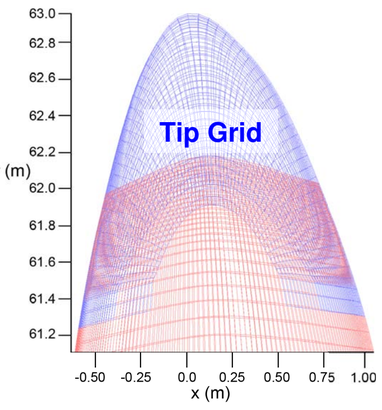


NREL 5-MW Rotor Overset Grid Topology









NREL 5-MW Rotor Overset Surface Grids

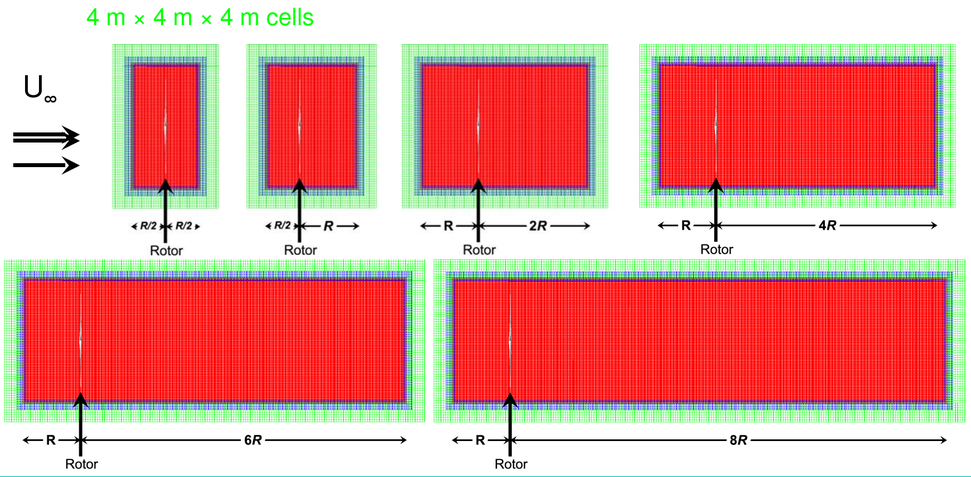
Wake Grid Independence Studies

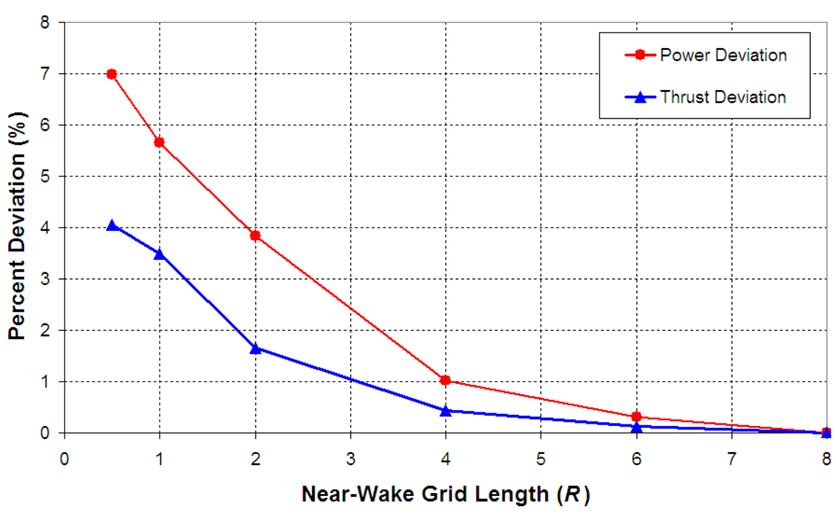
Near-Wake Grid Size Study

Off-body Cartesian BRICKS

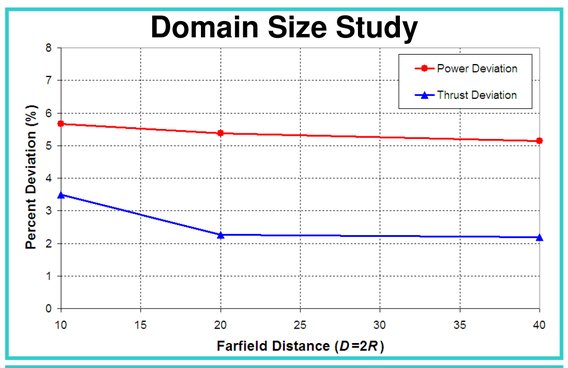
Varying size of 1st level BRICK/finest off-body grid size (ZBRKMAX)
- Downstream distance varied between 0.5 to 8 rotor radii (R = 63 m)

Cell sizes fixed for this study:
- 1 m × 1 m × 1 m cells
- 2 m × 2 m × 2 m cells
- 4 m × 4 m × 4 m cells

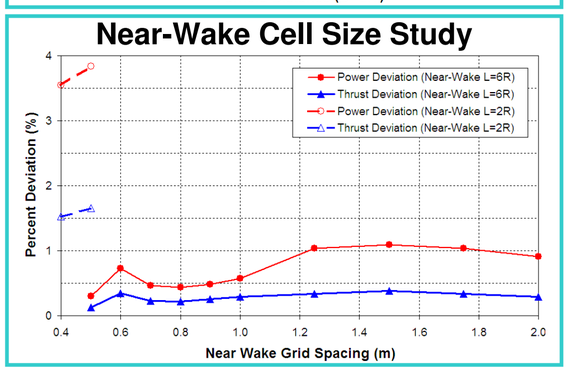




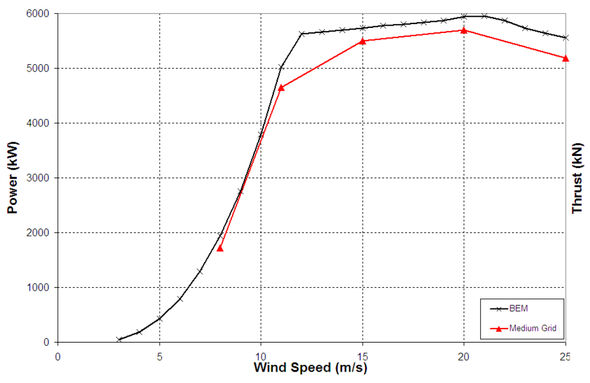
Domain Size Study

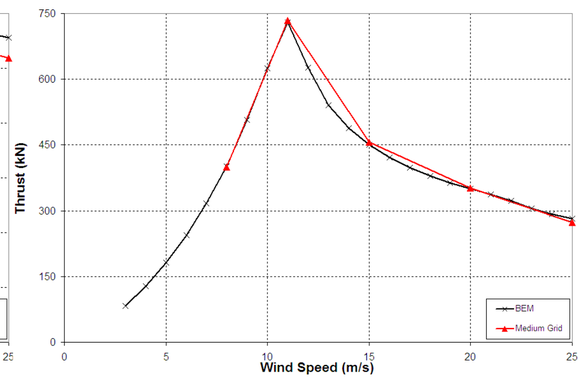


Near-Wake Cell Size Study

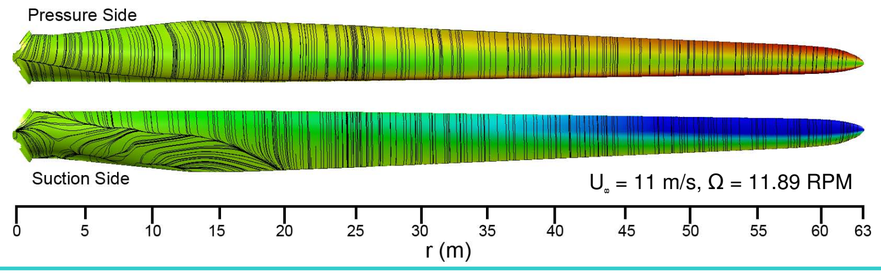


Baseline Rotor Results

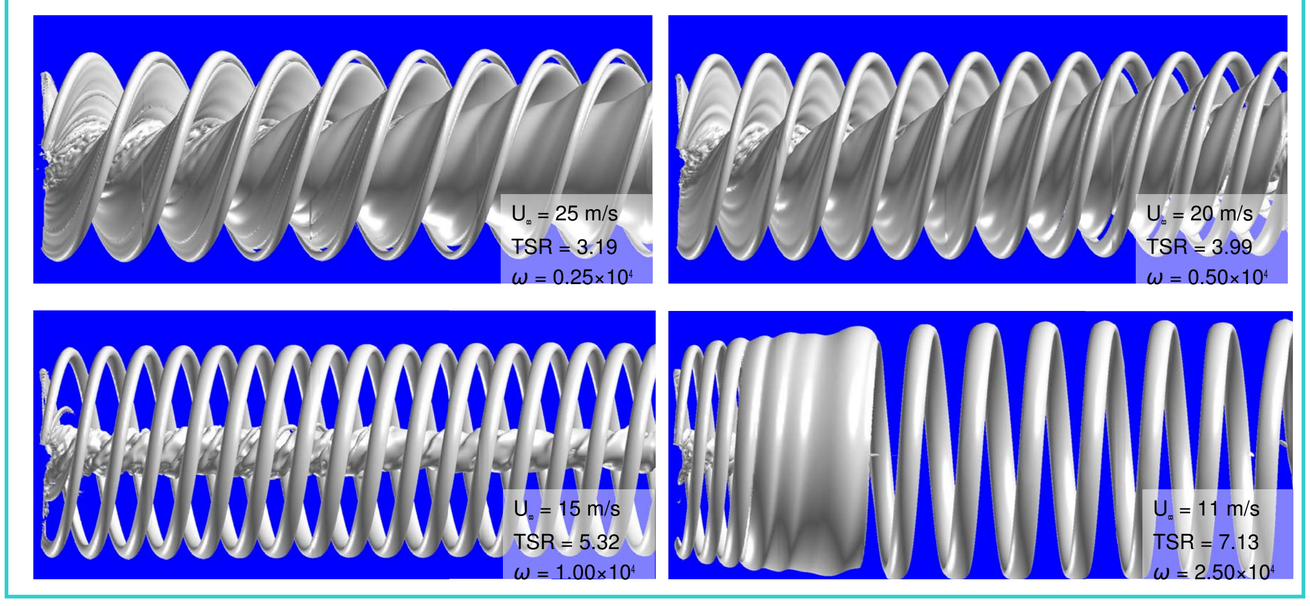




Surface Streaklines Over Surface Pressure Contours



Iso-Vorticity Contours of Baseline Rotor Wake as Various Wind Speeds



Overset Inboard Fence Modification

Fence Geometry

Ring fence con stant height
- Both sides of airfoil
- $h_{fence} = 5\%c_{max}$
- $h_{fence} \approx 0.23$ m
- $r_{fence} = 13.7$ m
- $r_{fence} = 21.7\%R$
- 201×47×81 points

Effect on Blade Loading

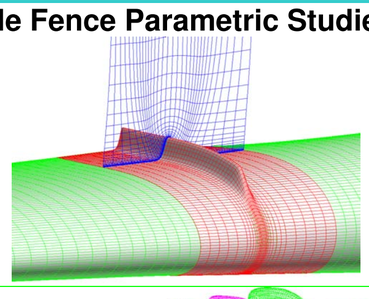
Surface Streakline Comparison Between Clean and Fenced Blades

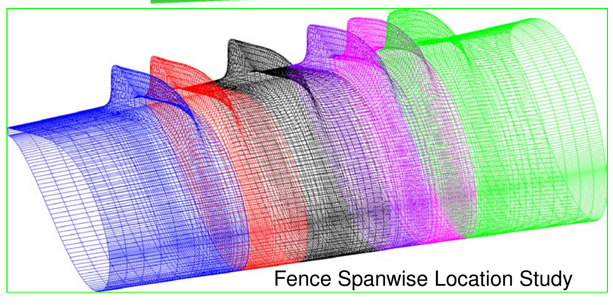
Effect on Rotor Power

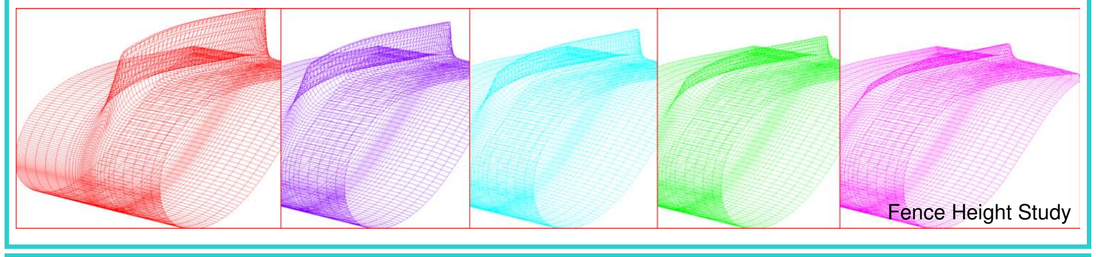
Solver Mode	U_∞	RPM	$P_{baseline}$ (kW)	P_{fenced} (kW)	ΔP (kW)	% Gain
Steady	8	9.16	1718	1733	15.3	**0.889%**
Time-Acc	8	9.16	1719	1735	15.3	**0.888%**
Steady	11	11.89	4650	4679	28.9	**0.622%**
Time-Acc	11	11.89	4654	4681	27.1	**0.583%**

Upcoming Work

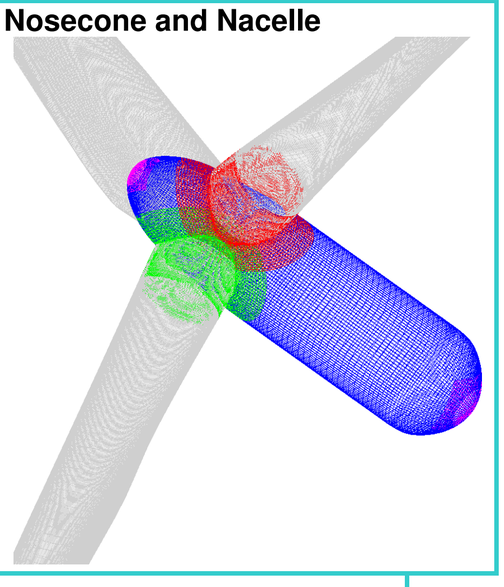
Suction Side Fence Parametric Studies







Nosecone and Nacelle



In addition to inboard twist, camber and VG studies.