Business from technology

Method for Estimating Wind Turbine Production Losses Due to Icing

Winterwind 2012 – International Wind Energy Conference

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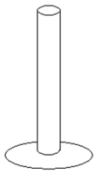
Production loss estimation

Overview of the process

Cylinder icing model

$$\frac{dM}{dt} = \alpha_1 \alpha_2 \alpha_3 w \vec{V} A$$



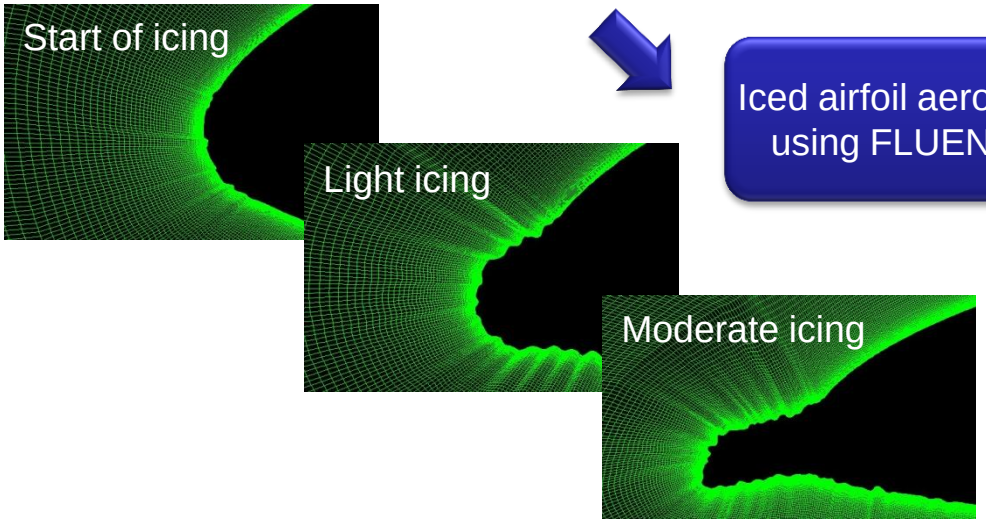
Numerical weather prediction (NWP) model with icing model acc. ISO12494 standard

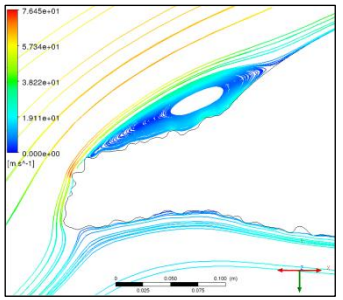
Energy production with losses due to icing

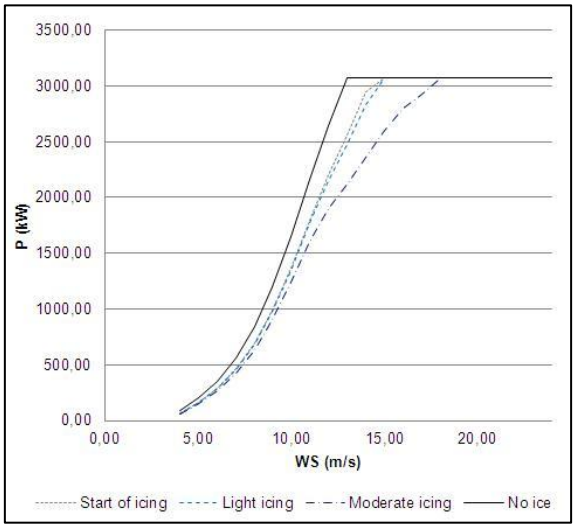
Ice accretion on operating wind turbine blade using TURBICE

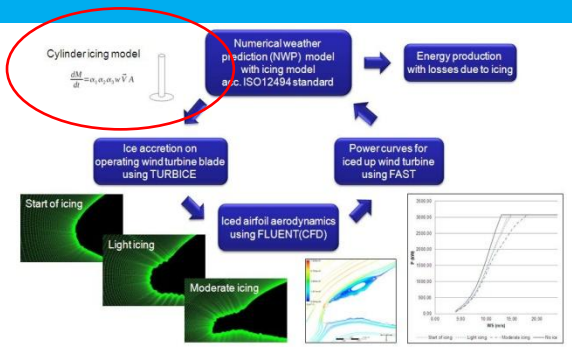
Power curves for iced up wind turbine using FAST

Iced airfoil aerodynamics using FLUENT(CFD)









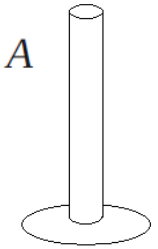
Production loss estimation

Ice model & relation between cylinder and blade

Ice accretion in NWP

- Numerical weather prediction with icing modelling
- Icing modelling according to ISO 12494 – Atmospheric icing of structures
- Ice accretion on stationary cylinder (Ø 0,03m)

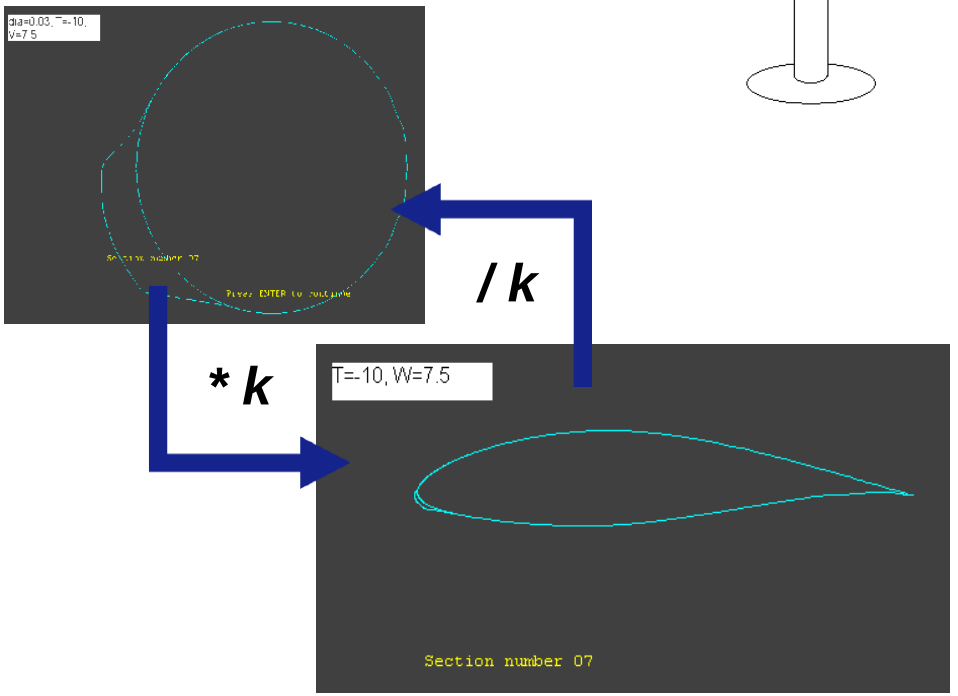
$$\frac{dM}{dt} = \alpha_1 \alpha_2 \alpha_3 w \vec{V} A$$



Accurate ice modelling on cylinder and wind turbine blade

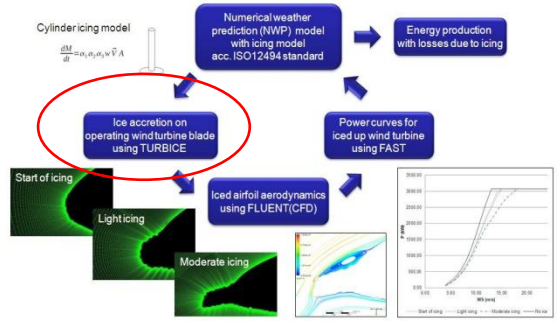
- TURBICE ice accretion calculations for
  - ISO 12494 cylinder
  - Wind turbine blade
- Using representative weather conditions
  - Windspeed = 7 m/s
  - Corresponding rotational speed
  - Temperature = -7 C
  - LWC = 0,2 g/m^3
  - Droplet size = 25 microns

→ Rime ice (glaze ice cases included in the future)



Production loss estimation

Iced wind turbine rotor blades

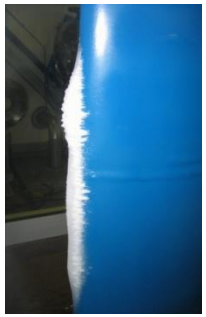


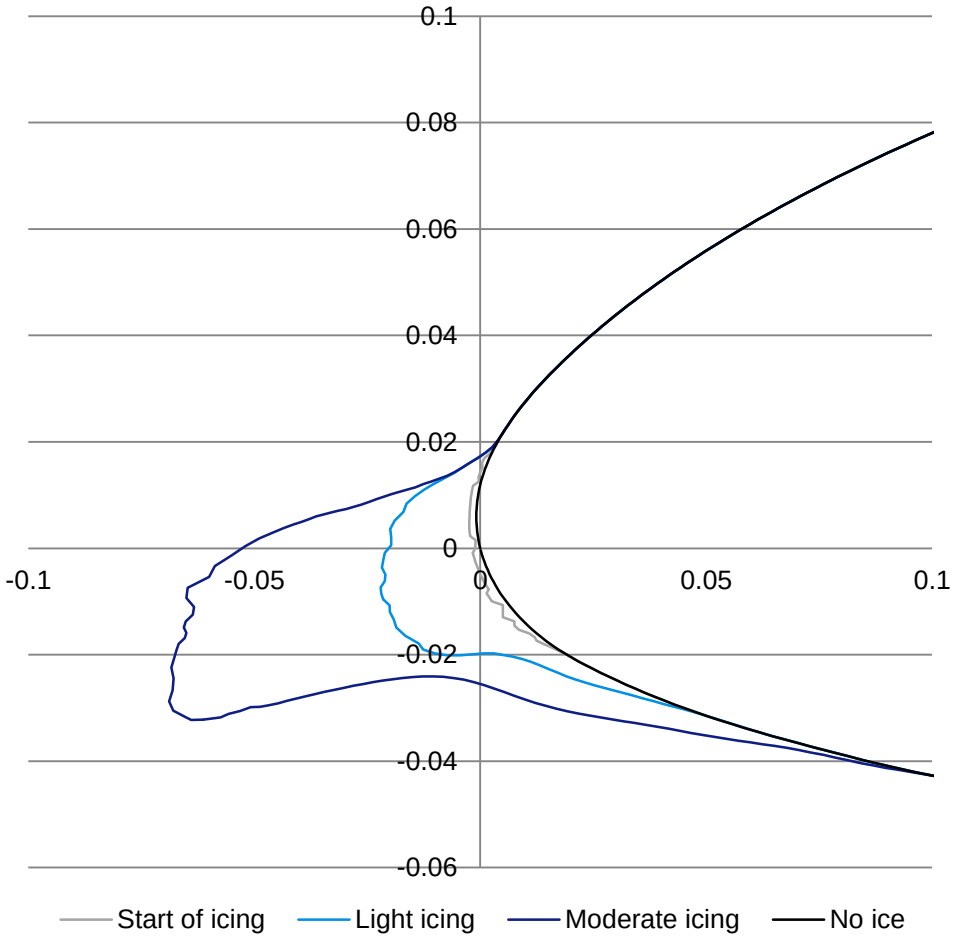
Ice accretion on blade using TURBICE

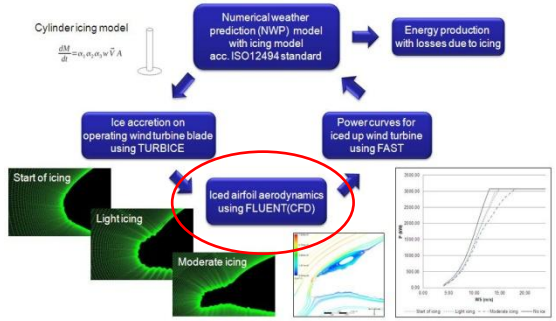
- Outer 3rd part of the blade is considered iced
- Different icing times – Different ice mass/shape
  - No ice
  - Start of icing–roughness
  - Light icing (some hours of icing) –roughness and larger mass of accreted ice
  - Moderate icing (long lasted icing) – roughness and horn type ice shape

Wind tunnel verifications and field observations

- Ice accretion experiments in VTT icing wind tunnel
- Observations from Olos wind farm, Finland





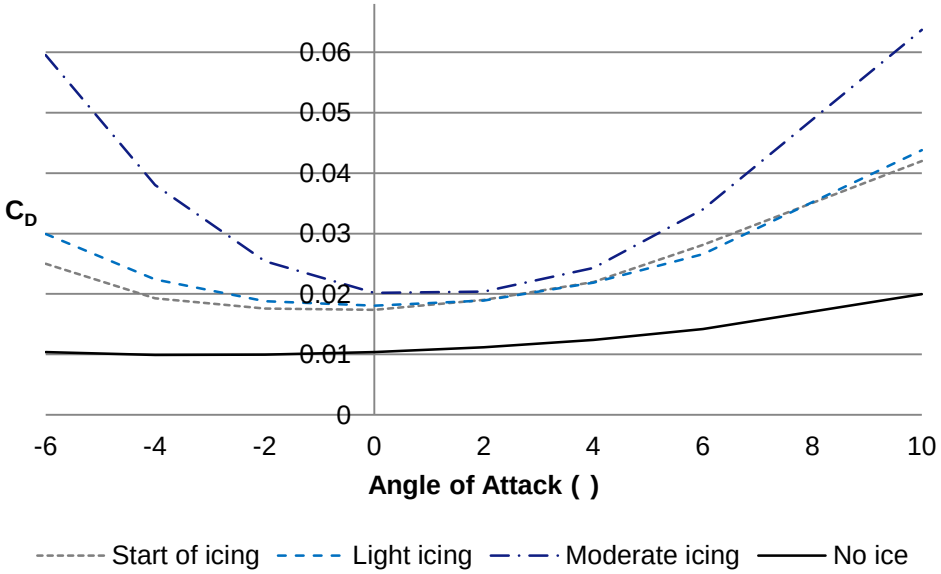


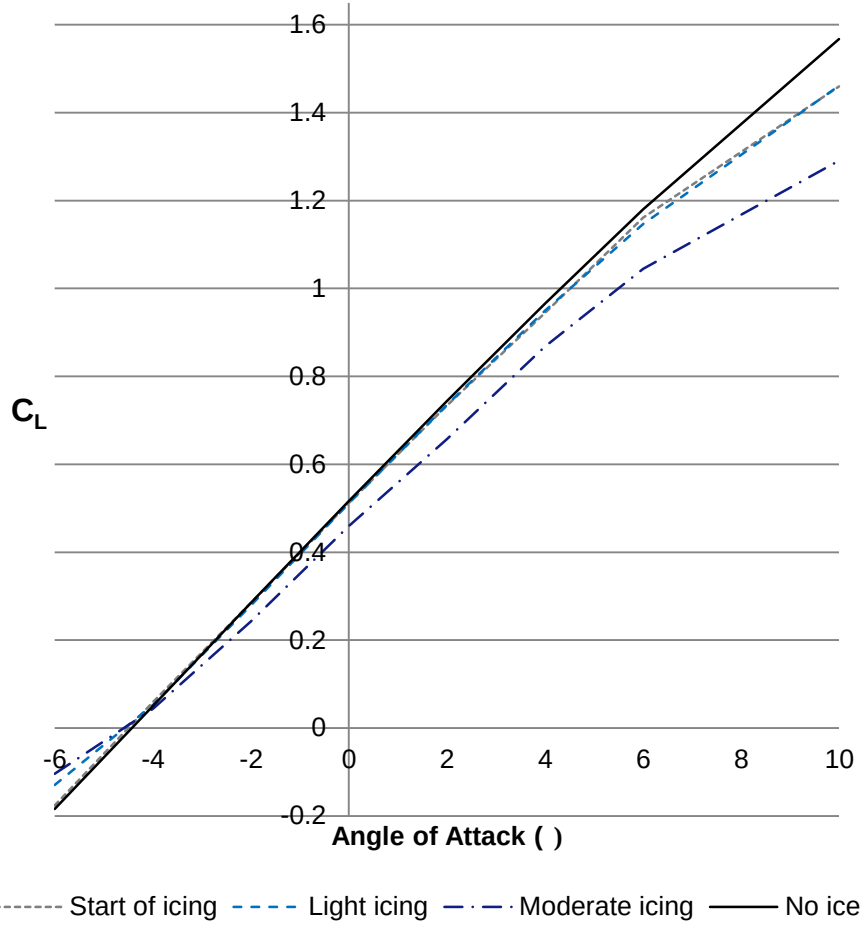
Production loss estimation

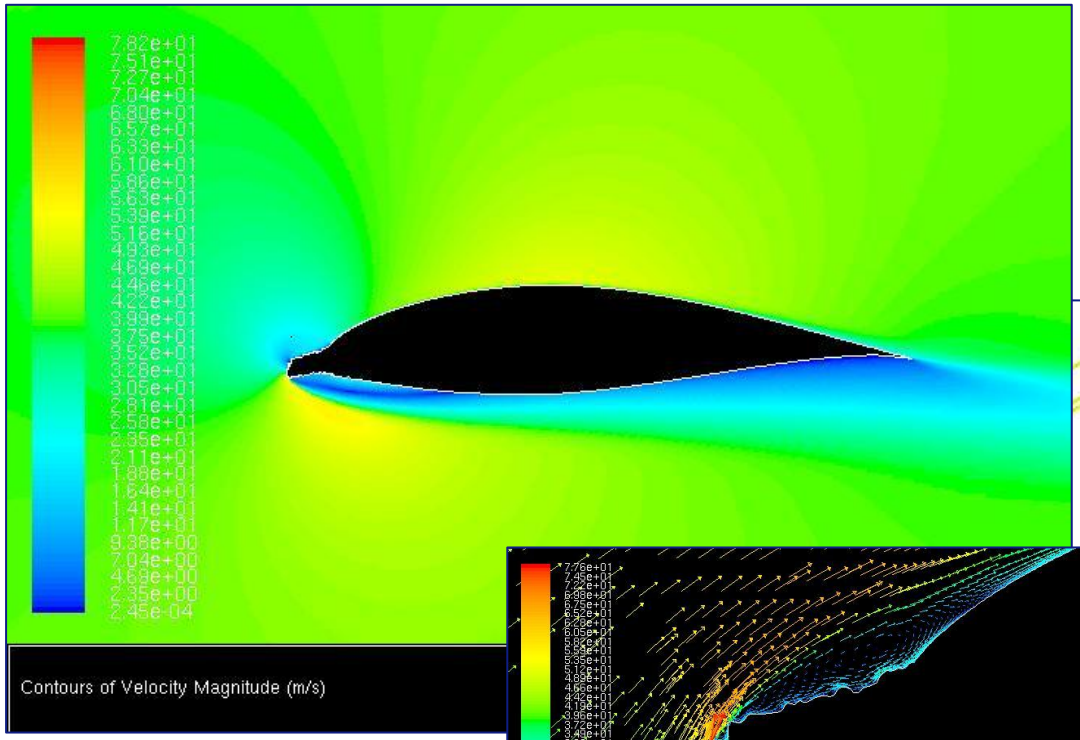
Iced airfoil aerodynamics

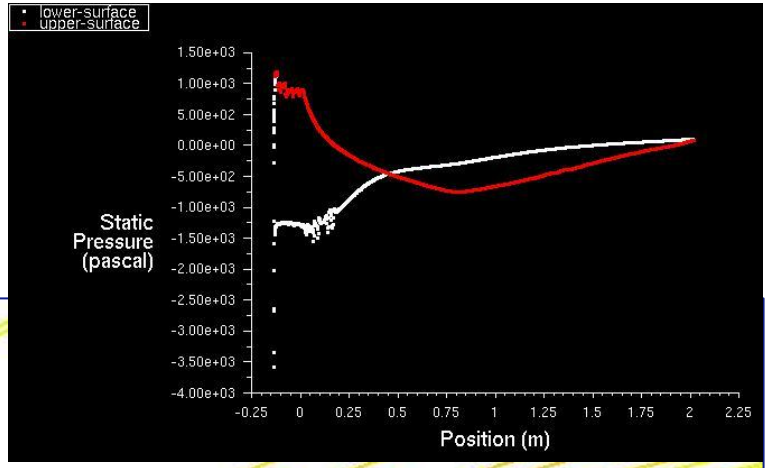
CFD simulation and force coefficients

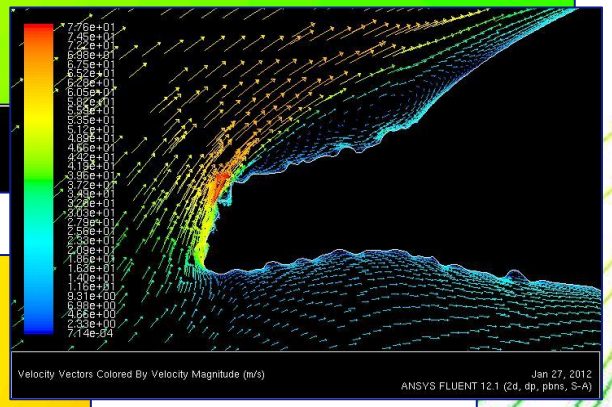
- ANSYS FLUENT
- Spalart-Allmaras turbulence model
- Lift coefficient from CFD analysis
- Drag coefficient affected by large and small scale surface roughness
  - Large scale surface roughness – CFD analysis
  - Small scale surface roughness – theoretical modification

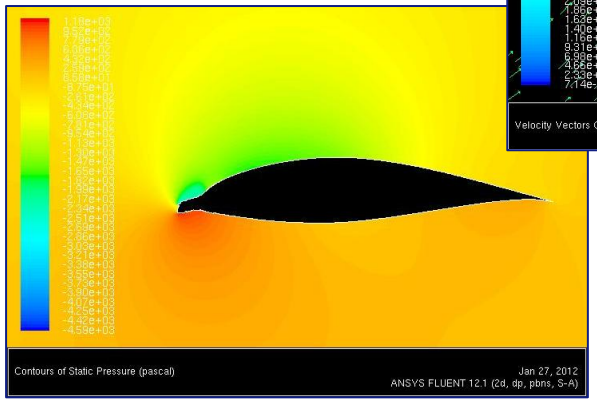


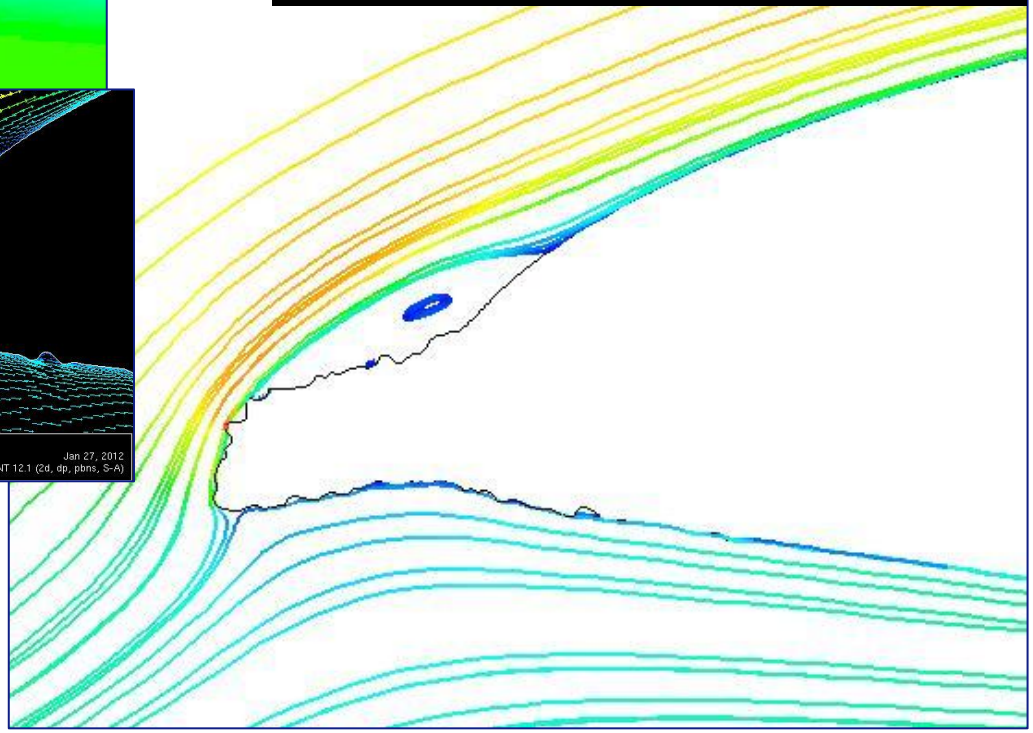


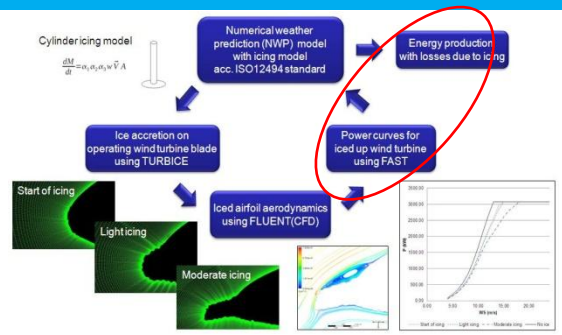

Contours of Velocity Magnitude (m/s)


lower-surface
upper-surface
Static Pressure (pascal)
1.50e+03
1.00e+03
5.00e+02
0.00e+00
-5.00e+02
-1.00e+03
-1.50e+03
-2.00e+03
-2.50e+03
-3.00e+03
-3.50e+03
-4.00e+03
-0.25
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
Position (m)


Velocity Vectors Colored By Velocity Magnitude (m/s)
Jan 27, 2012
ANSYS FLUENT 12.1 (2d, dp, pbns, S-A)


Contours of Static Pressure (pascal)
Jan 27, 2012
ANSYS FLUENT 12.1 (2d, dp, pbns, S-A)





Production loss estimation

Annual energy production

Power curves

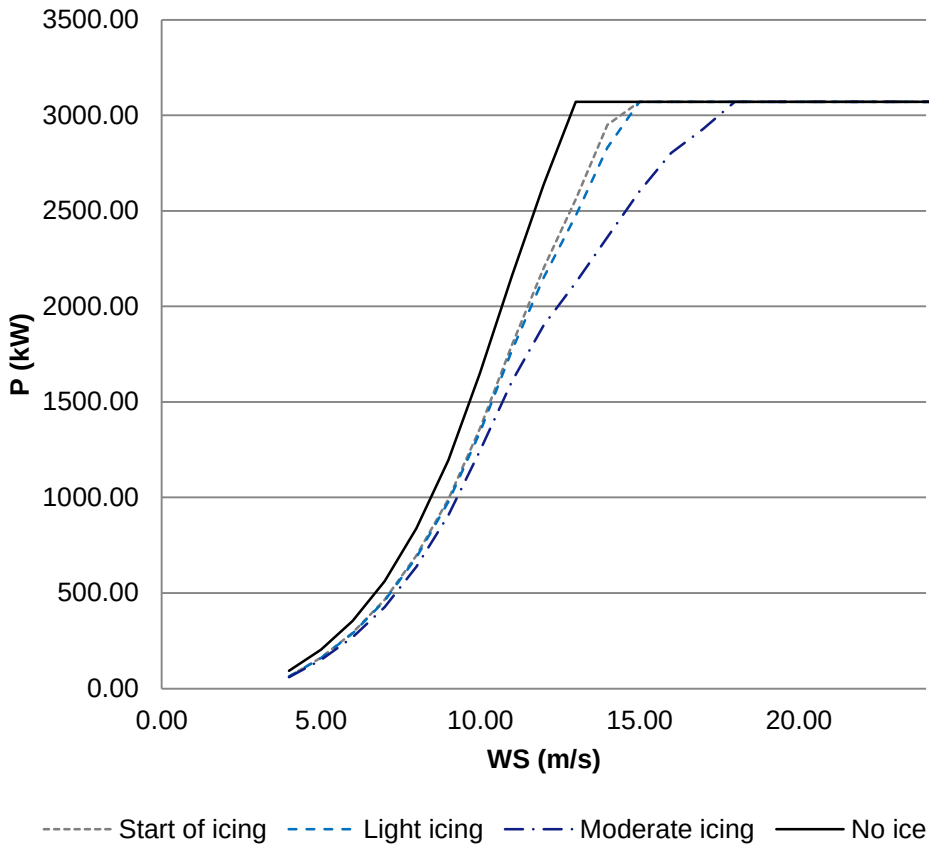
- FAST simulations to generate power curves
- Multi-MW turbines
- C_L and C_D from aerodynamics analysis (CFD + theoretics)

→ Already initial icing (roughness at the leading edge) affects the power curve

Energy production losses

- Can be calculated using weather time series and the corresponding power curve for each icing condition

- *Energy production without icing – Energy production with icing = Lost energy due to icing*



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