WINTERWIND 2020

3-5 Feb 2020 Åre (Sweden)

Onshore Technology Development

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RENEWABLE ENERGY

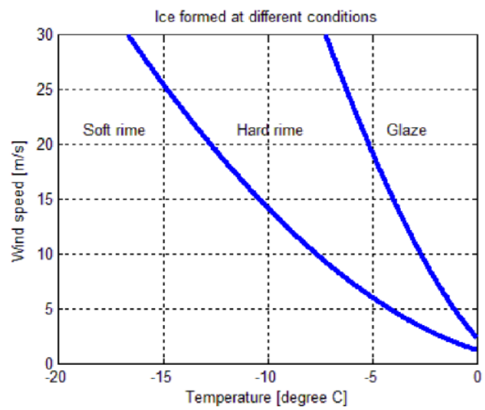
Cold climate sites

- Very attractive for the installation of wind turbines…
  - High annual mean wind speeds
  - High air densities
  - Usually located at remote sparsely populated places (minor noise restrictions)

- …but different drawbacks could arise:
  - Ice accretion on blades causing aerodynamic and mass imbalance
  - Decrease in the Annual Energy Production (AEP)
  - Higher mechanical loads
  - Ice throw risk
  - Decrease in the wind turbine availability (difficult access to the wind farm, harder working conditions...)

Atmospheric icing

- ➢ **Precipitation icing (0ºC to +3ºC)**
  - **Wet snow**
  - **Freezing rain**
- ➢ **In cloud icing (-20ºC to 0ºC)**
  - **Soft rime: low/medium adhesion**
  - **Hard rime: strong adhesion**
  - **Glaze ice: strong adhesion**
- ➢ **Hoar frost (<20ºC)**



Hard rime

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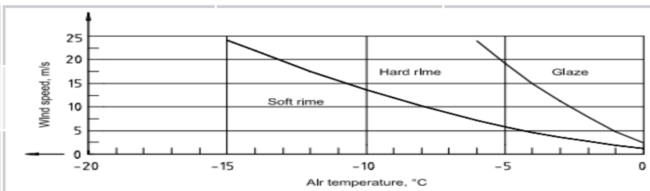
Flowchart

Ice accretion SW

Inputs

Wind speed	Soft rime	Hard rime	Glaze ice
3 m/s			
…			
18 m/s			
MDD	low	medium	high
LWC	low	medium	high



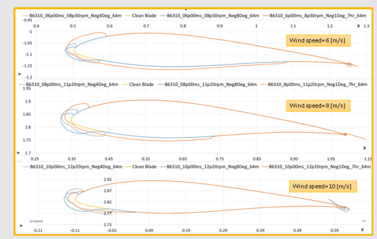
Blade section		
#1	…	#N

Icing time
t_1
…
t_M

Outputs

Iced polars

Added mass



Aeroelastic simulations

Blade charact.
Iced polars
Added mass

Icing and wind conditions at site
α, ρ, TI, V, k,..

Specific control strategies for cold climate sites

Load cases
Fatigue
Ultimate

Output

Scenario	Solution	AEP losses	ΔLoads	Cost	Profit in 20 years
#0 (Ref)	Nothing	L_0%	0%	0 k€	0 k€
#1	Control strategy #1	L_1%	-M_1%	C_1 k€	P_1 k€
…	…	…	…	…	…
#N	Active sol. + Control	L_N%	-M_N%	C_N k€	P_N k€

Ice Accretion conditions

- **Ambient conditions**

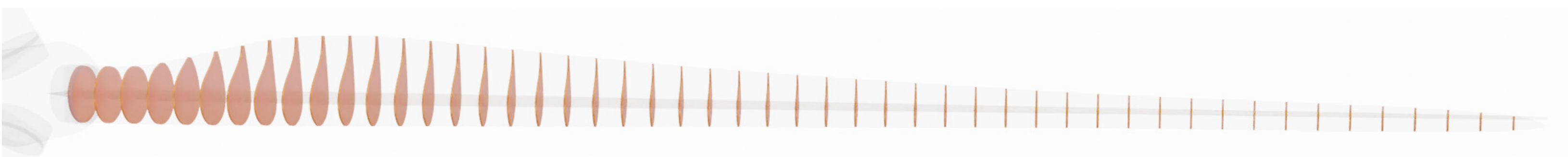
  Ice formation conditions selected from literature and previous studies:

  Temp [K] + Water content [g/m^3] + Droplet size [μm] + Ice type + Ice density [kg/m^3] + Time

  Corresponding to GLAZE, HARD RIME & SOFT RIME

- **Blade discretization**

  Profiles representative of all blade sections are selected for 2D analysis



- **Wind & Airfoil conditions**

  Wind conditions selected representative of field conditions

  Local wind speed and angle of attack for each windspeed as function of:

  Radial position

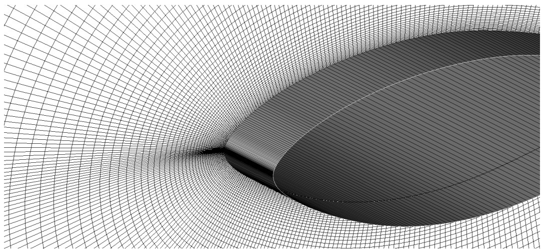
  Rotational speed

  Pitch

  Local twist ….

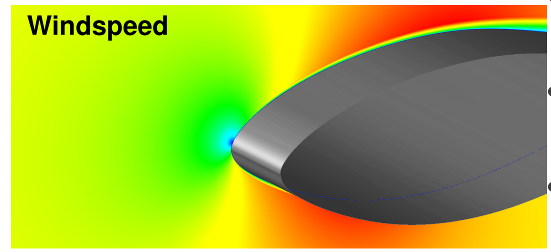
Calculation of Airfoil transformation:

1. 2D mesh



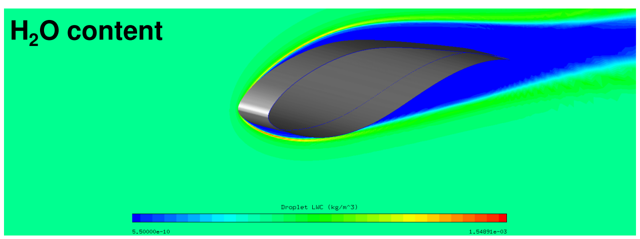
- Strict quality parameters
- Boundary Layer refinement
- Local surface orthogonality
- High resolution at LE & TE

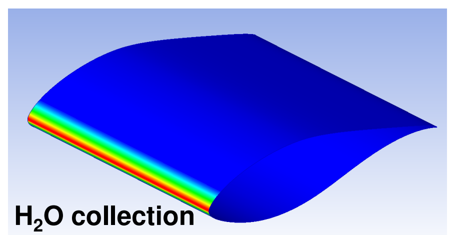
2. Local Flow



- Steady state simulation
- kOmegaSST turbulence model
- Moderate Turbulence intensity

3. Drop impingent

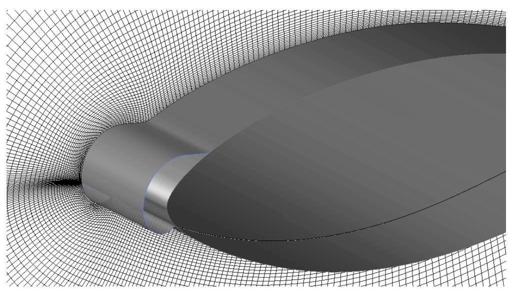




- Droplet carried by current
- Inertial vs viscous effects
- Water collection on surface
- Adhesion, deflection and rebound based on angle and velocity

4. Surface deformation

- Icing conditions + water collection = Ice accretion / time
- Moderate timesteps
- Local surface displacements
- New profile



5. Repeat

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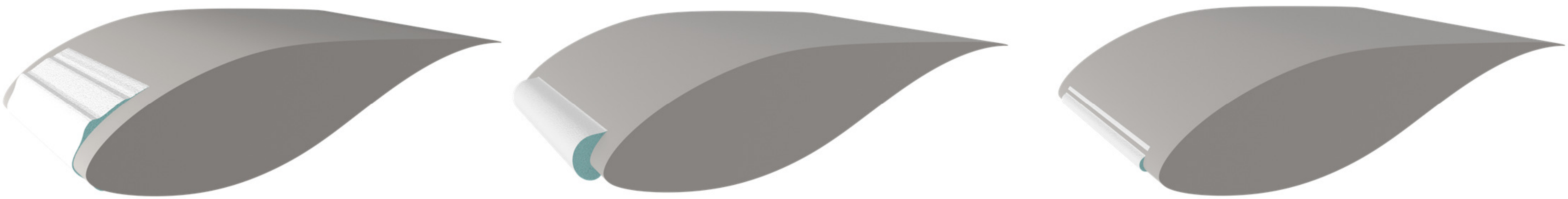
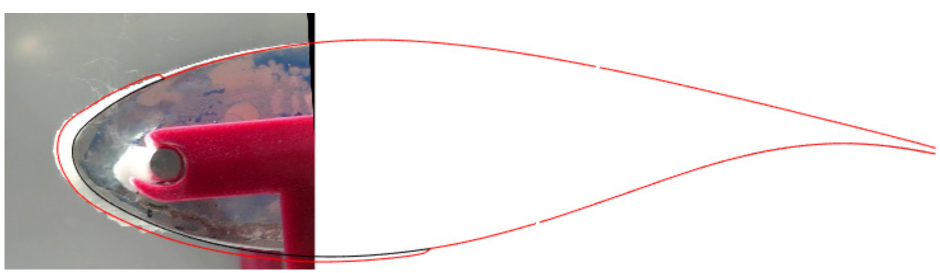
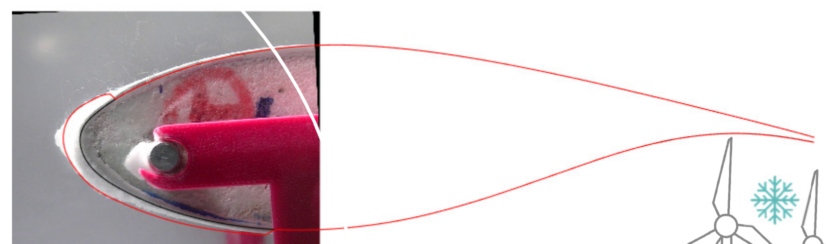
- **Iced Airfoils Results:** Shape = f(Profile, Icing conditions, Windspeed, time)



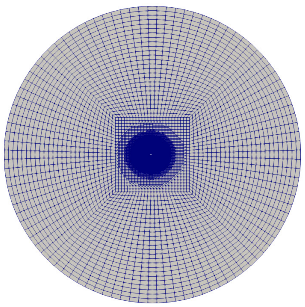
GLAZE HARD RIME SOFT RIME

- **Methodology compared with wind tunnel tests**

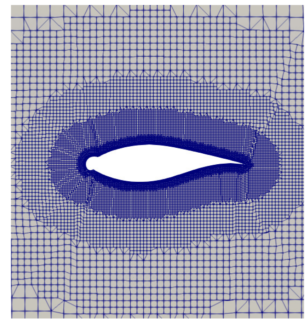


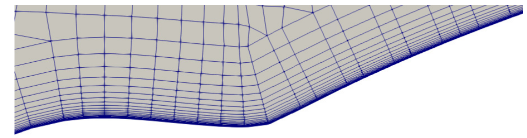


➢ Iced Airfoil Performance Evaluation

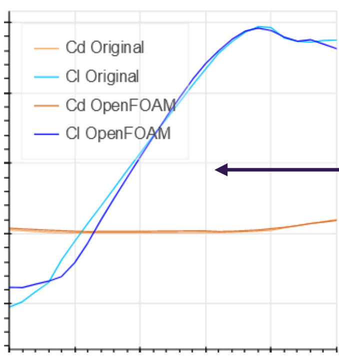


- 2D simulation cases
- Omnidirectional Mesh
- Hybrid Mesh
- Careful boundary layer refinement
- y+ criterion ~ 1
- Turbulence model: kOmegaSST with Langtry-Menter correction





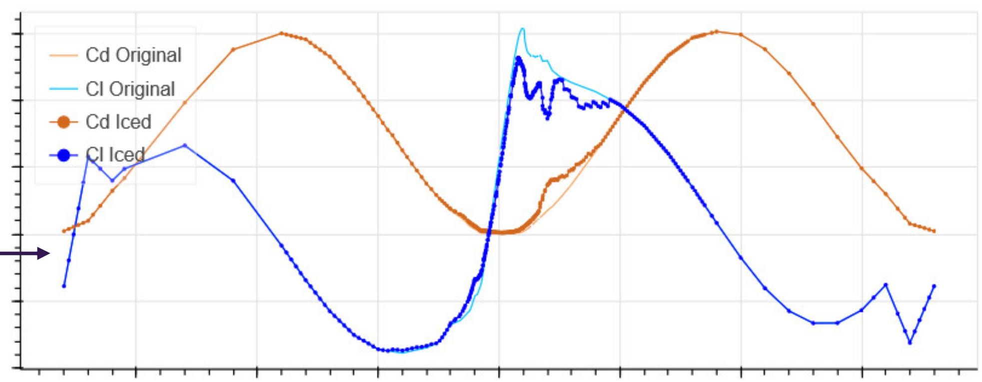
➢ Clean polar comparison



Good accordance between original polar and simulation of clear airfoils
Particularly on **stall angle**.

Iced polars calculated from:
Original + Deltas of simulation (Clean vs Iced)

➢ Iced polars from simulations



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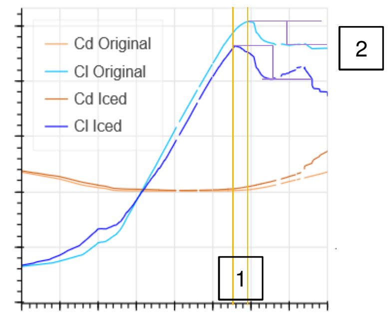
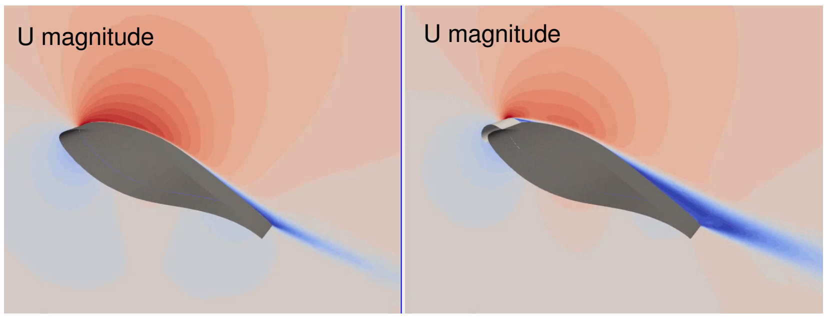
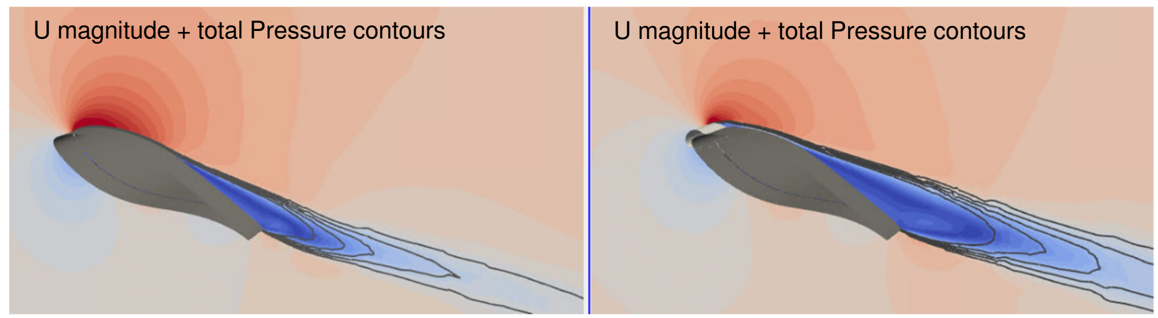
Aerodynamic effects of ice accretion



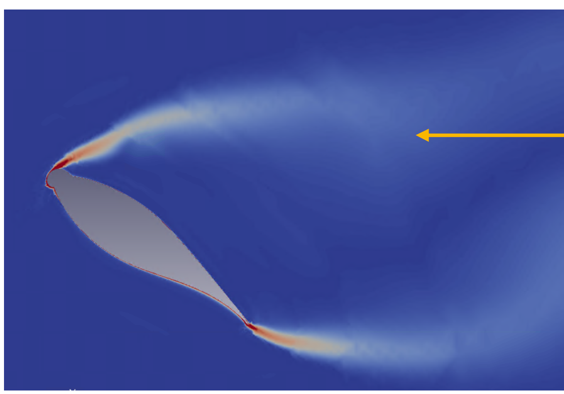
➢ Stall angle decrease



➢ Steeper stall

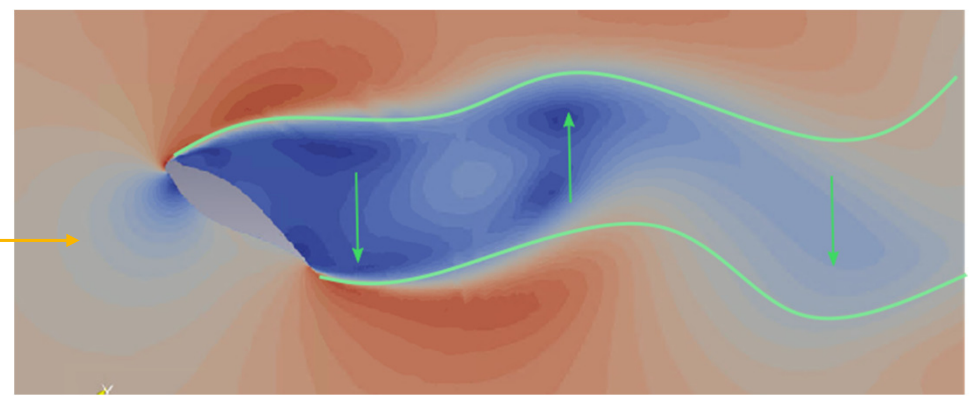


➢ Unsteady aerodynamic effects at lower angles



Vorticity shedding from LE & TE

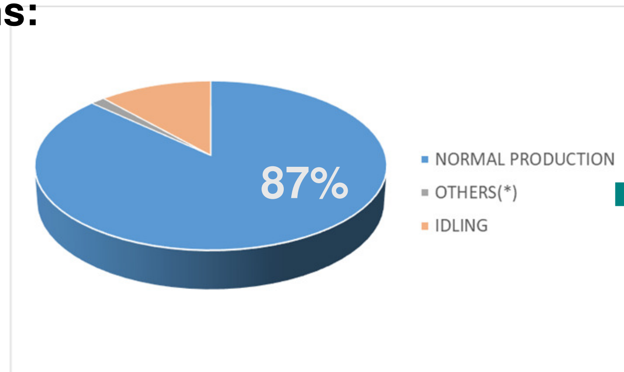
Swaying wake which leads to swaying aerodynamic forces



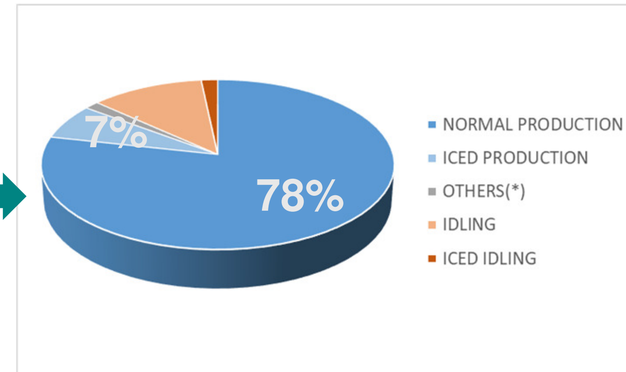
Ambient conditions considered for simulations:

- **Number of Fatigue Simulations:**
  - Baseline (no ice)
  - Glaze Ice
  - Soft Rime
  - Hard Rime
- **Iced Model Changes:**
  - Change in airfoil definition
  - Blade mass Increase (very low increase)
  - No mass imbalance changes due to low mass increase
- **Simulations details:**
  - IEC Ed3 Standard
  - SGXXX TXX
  - Class IIIA

NO ICE SIMULATION - ANNUAL TIME

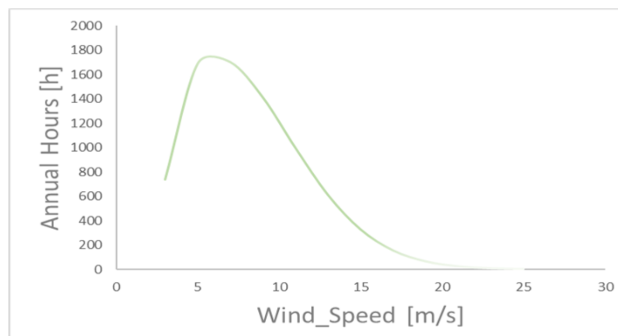


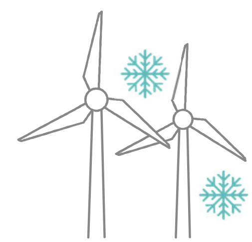
ICED SIMULATION - ANNUAL TIME



(*) – START UP, STOP AND PRODUCTION WITH FAILURE LOADCASES

CLASS IIIA - HOURS DISTRIBUTION





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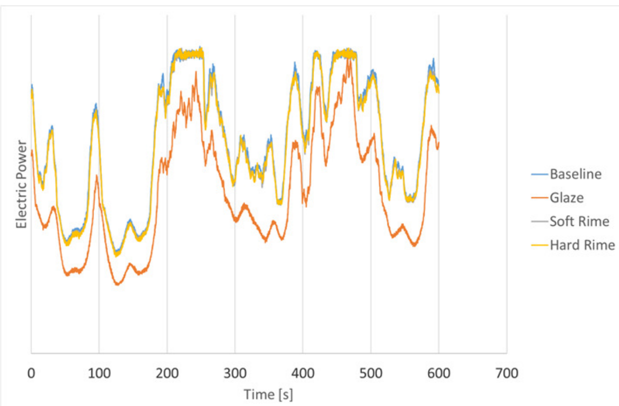
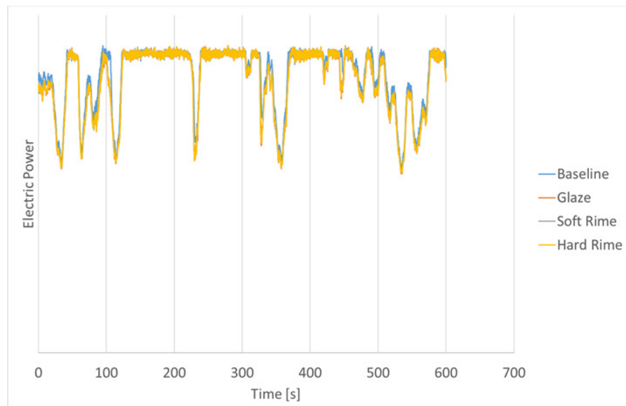
AEP and FATIGE SIMULATION RESULTS FOR ICED CONDITION

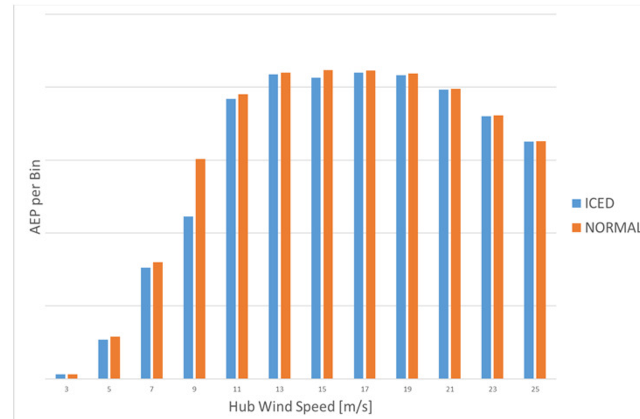
POWER PRODUCTION – 9m/s



POWER PRODUCTION – 11m/s

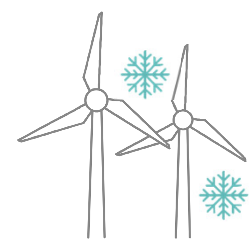


GLAZE ICE - AEP LOST



GLAZE ICED MODEL				
ELEMENT	m	Mx (kNm)	My (kNm)	Mz (kNm)
BLADE ROOT	8			
SHAFT	8			
	10			
TOWER TOP	4			
TOWER BOTTOM	4			

HARD RIME ICED MODEL				
ELEMENT	m	Mx (kNm)	My (kNm)	Mz (kNm)
BLADE ROOT	8			
SHAFT	8			
	10			
TOWER TOP	4			
TOWER BOTTOM	4			



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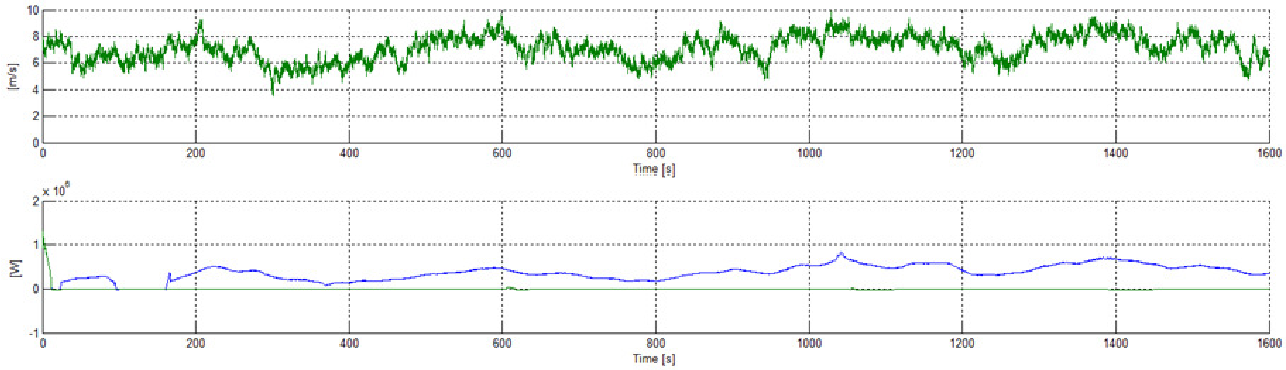
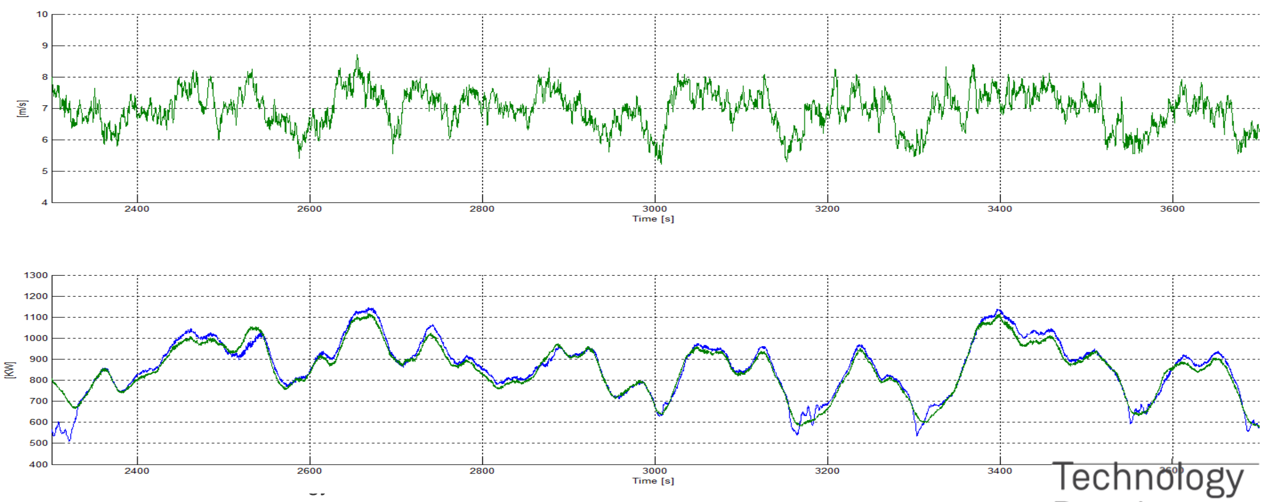
➢ OWI strategy increases the produced power by avoiding WT stop



No OWI

OWI

➢ OWI strategy increases the produced power with iced airfoils.



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Questions?

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Thanks Team!!

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