KJELLER VINDTEKNIKK
Part of Norconsult

Workshop: How turbine design may reduce ice fall risks for personnel

Winterwind 2024, Åre

Photo: John Magne Gitmark, Kjeller Vindteknikk

In-cloud icing

In-cloud icing

- Made by sub cooled droplets in the clouds
  - Liquid water normally occurs down to -20 °C.
- Typical situation:
  - Low clouds or fog
  - Temperature below 0 °C.

- Accumulates as vane from the wind direction
- White surface
- High density
- Build-up along the entire blade
- Usually reduce power production

Photo credit: Magnus Baltscheffsky, WeatherTech Scandinavia

In-cloud icing

- Lifting of air
  → condensation

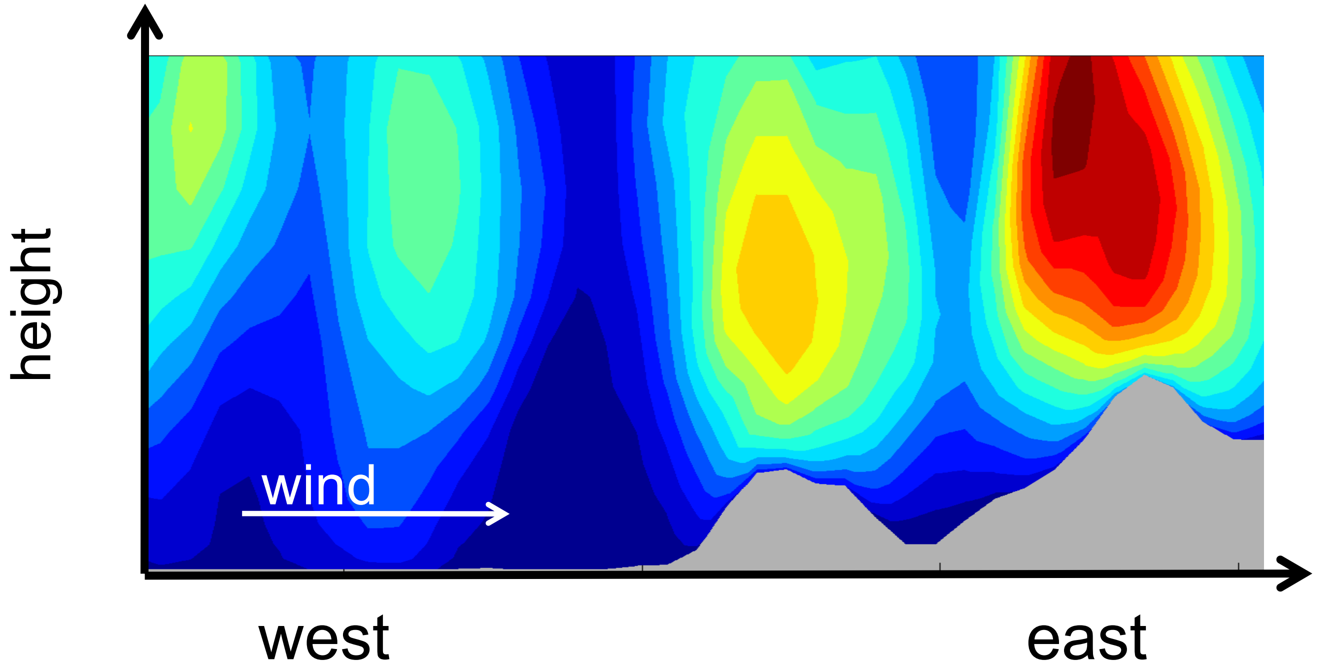

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Photo credit: Magnus Baltscheffsky, WeatherTech Scandinavia

In-cloud icing on blades

- Accumulates on the leading edge
- The build-up rate depends on:
  - Rotation speed (wind velocity)
  - Amount of water in the air
  - The size of the droplets

Types of icing

Wet snow

- Consist of snow crystals and liquid water
- Typically occurs at temperatures just above 0 °C
- Can potentially build up fast

Where to find it:

- On blades when rotating slowly
- On the nacelle (both roof and side)
- On the tower

- Photo credit: TrønderEnergi – Frøya wind farm

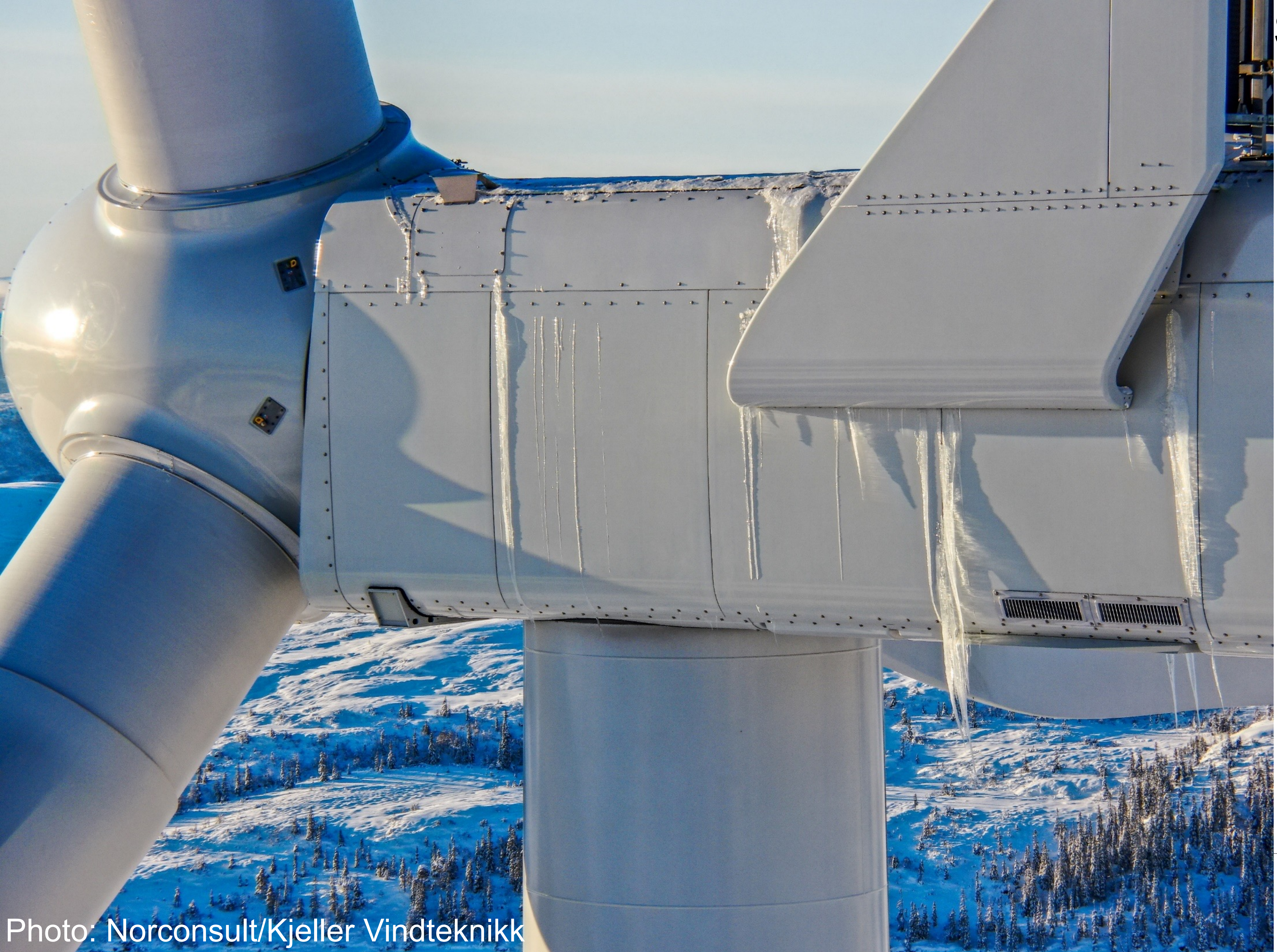
Types of icing

Dry snow

- Snow with a low content of liquid water.
- Typically occur at temperatures below 0 °C.
- Does not stick to the blades.
- May accumulate on the nacelle but will often blow away.
- Melting of snow on the nacelle:
  - Large ice blocks that can fall down.
  - Icicles.

Photo credit: Storheia wind farm – Norwegian Research Council R&D project: “Wind energy in cold climate”

Storheia, Norway



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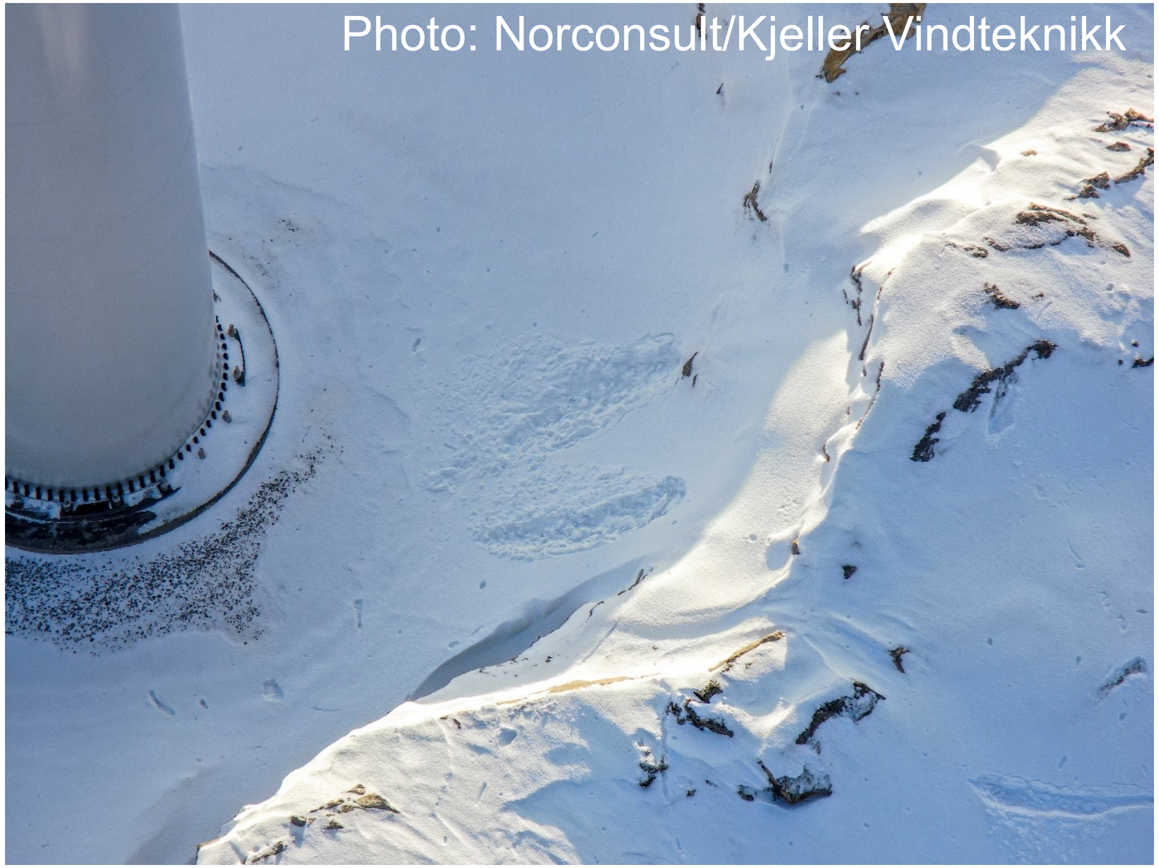
Storheia, Norway 2nd of February 2021



- Tonstad, Norway

In groups:

- Together, sort out 3 - 4 ideas

  Possible criteria:
  - Best
  - Funniest
  - Most ambitious
  - Spectacular

- Prepare for presenting in plenum

  To be presented:
  1. The problem
  2. The idea
  3. How the problem is reduced/solved

10 min

Our ideas:

Effect ↑

1 Hydrofobic coating on blades + nacelle (3) **2 Built-in icofobic coating on leading edge (1)** **3 Drone spraying warm water (2)** **4 Cloud seeding (1)** Move turbines to warm climate during winter **5 Warm pool on top of nacelle with heating from turbine (4)** Drone with flame thrower **6 Retrofit nacelle to minimize ice buildup (3)** Lasergun to shoot down ice	**7 Roof over staircase + car (2)** **8 Operate turbine with varying, higher rotor speed to throw off ice (5)** More clear regulations, define responsibility Standardizations on international level **11 More sensors, cameras with automatic detection (5)** **12 Use AI with all available data to improve forecasts (6)**
Build a train track with a train with fire to depleat moisture Salt on blades	Info campaignes to the public, signs **13 Detect ice, stop (4)** **14 App on telephone to warn about risk (geofensing) (6)**

Achievability →

Round 2 (slide 1/2):

Effect

1 Hydrofobic coating on blades + nacelle (group 3)
- Down: Wear and tear on blade.
- Environmental, a lot of things to be solved
- Up: Not as much wear and tare at nacelle.
- Build-up on the nacelle in larger chunks than on blades.

2 Built-in icofobic coating on leading edge (group 1)
- Foil on blade can be dirty, loose effectiveness, loss reduction.
- Should not mess with structure.
- Wear and tare, fall off/down.
- Limitations: Can also remove ice to a certain degree.
- Spraying foam → pollution?
- Opportunity: Less icing, less ice loss.
- With coating opportunity for retro fit. Foil better retrofit.

3 Drone spraying warm water (group 2)
- Up: Less icing.
- Combined with heat on nacelle,
- gravity working for you.
- Down: Available water, not on site.
- Like peeing in pants.
- Water on blades = heavy.
- Big risk

4 Cloud seeding (group 1)
5 Warm pool on top of nacelle with heating from turbine (group 4)
6 Retrofit nacelle to minimize ice buildup (group 3)

7 Roof over staircase + car (group 2)
- Up: Being implemented on several sites.
- Can be done in mesh. Mesh design most realistic.
- Must be larger than car.
- Down: Need strong metal shielding
- Comment from KVT: can it be combined with both mesh and less strong shield?

8 Operate with varying, higher speed to throw off ice (group 5)
- Down: Risk throwing off ice. Safety still issue get rid of ice.
- Not possible to approach turbines
- Up: may control when the risk occur

11 More sensors, cameras with automatic detection (group 5)
12 Use AI with all available data to improve forecasts (group 6)

13 Detect ice, stop (group 4)
14 App on telephone to warn about risk (geofensing) (group 6)

Achievability

Round 2 (slide 2/2):

1 Hydrofobic coating on blades + nacelle (group 3)
2 Built-in icofobic coating on leading edge (group 1)
3 Drone spraying warm water (group 2)

4 Cloud seeding (group 1)
- Resistance environment etc.
- Regulation. Local acceptance.
- Expensive.
- Comment from KVT: Does there exist environmentally friendly aerosols?

5 Warm pool on top of nacelle with heating from turbine (group 4)
- Thermodynamic to avoid nacelle ice build-up
- Up: Use excess heat.
- Water distribution solution to avoid throws after build-up.
- Drain the water by being in control (drain tube through the nacelle).
- Keep drops small.
- Make the top of the nacelle black in winter time (white in summer)
- Down: Power consumption. Will create drops.

6 Retrofit nacelle to minimize ice buildup (group 3)
- Down: Too expensive.
- Will still be some build-up.

7 Roof over staircase + car (group 2)
8 Operate turbine with varying, higher rotor speed to throw off ice (group 5)

11 More sensors, cameras with automatic detection (group 5)
- Up: Information in advance.
- Can avoid risk situations
- Comment from KVT: does not reduce or control the ice fall but reduces the uncertainty of wrong judgement.

12 Use AI with all available data to improve forecasts (group 6)
- Up: Cost saving, manageable risk
- automatically collects data for forecasting
- Down: Need relevant data and train the model/code.
- Risk assessment can not be too conservative, or staff will work anyway. Limited by available data.

13 Detect ice, stop (group 4)
- Research, risk compensation. More energy production.
- Need lot of data, based on turbine design.
- Different customers, regions, requirements

14 App on telephone to warn about risk (geofensing) (group 6)
- Up: App with AI.
- Easy way for people to be more aware
- Down: Takes time/money
- must be advanced enough.
- Does not change amount of ice.

Effect

Achievability

Other ideas collected from post-its

- Floppy movements of turbine blades
- Super heating mode
- AI to fix problems
- Combination of camera, met. measurements and control room
- Increase research to get a better knowledge of de-icing systems
- Combine SCADA and met. data.
- Sonic boom blaster
- Other sources to melt ice
- Better water drainage design
- Model and falling risk index (ref. avalanche risk index)
- More robust coating
- “Net” catching ice from the tower
- Develop international standards
- 150 m long flame thrower
- Drone with de-icing to deploy before the storm
- Create shields to reduce surface
- Smarter nacelle design and retrofit
- Site specific forecasting
- Remote inspection and starts
- Heat the whole turbine
- Foldable/portable safety tunnel
- Drone 3D scan to map ice buildup
- Remove with mechanical vibrations
- Heating on nacelle/tower
- Constant heating on
- Stop and start the turbines
- More modular turbines
- Solid roof on vehicles
- Develop regulation on a European level
- Stronger turbine, less maintenance
- Enable blade load data
- Redesign cooling systems and hot spots
- Maintain the leading edge to less sticky
- Missiles or laser to blast off ice
- New coating on nacelle and tower
- Heat camera, radar, microphone
- Snow machine/snow cannon
- Put mats on lakes to reduce water content in the air
- Better heating control (time vs. effect)
- Dehumidifier
- Continue emitting carbon in the air

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