Winterwind 2018

Leveraging insight from operational data to optimize performance in cold climates

Contents

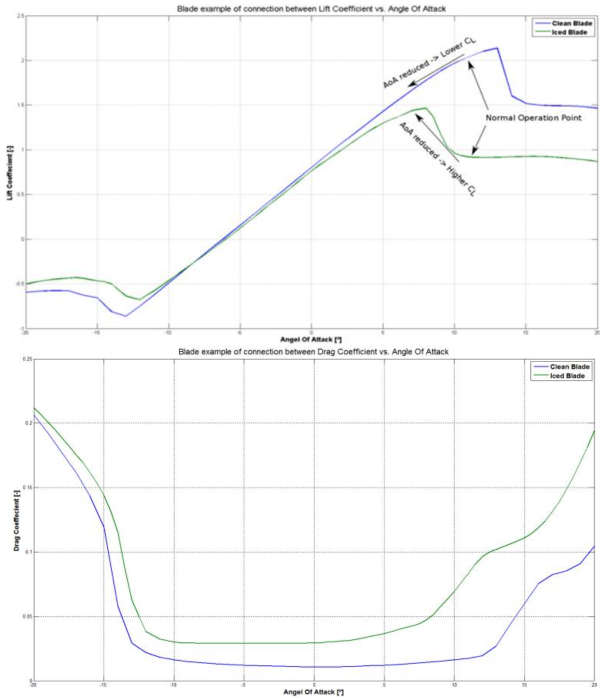
Health and safety under icy conditions for Siemens Gamesa turbines

- The risk of ice throw cannot be entirely eliminated by the current technologies within the area of de-icing and anti-icing, as their purpose is to reduce ice buildup primarily on the leading edge.
- The risk of ice throw can be contained by acknowledged guidelines of safe zones, typically in the order of 250 m to 400 m depending on the turbine type.
- The turbine owner is responsible for taking the appropriate risk mitigation measures to protect the public from being exposed to falling ice in accordance with local legislation.
- The site personnel are typically more exposed to ice-throw than the public. Site personnel must, in the event of icing conditions, always follow the health and safety rules and procedures provided by Siemens Gamesa

The ice problem

The ice problem

- A turbine affected by ice will have its aerodynamic performance altered due to the natural change in profile caused by ice buildup.
- The lift coefficient is reduced and with ”normal control strategy”, the operation point is now in the area of stall.
- In addition to reduced production, operation in stall also introduces risk of vibrations and over speed.
- A standard turbine certificate does not cover this situation and therefore the normal action is to bring the turbine to a stop, with significant production loss as a consequence.



Three different solutions to the ice problem

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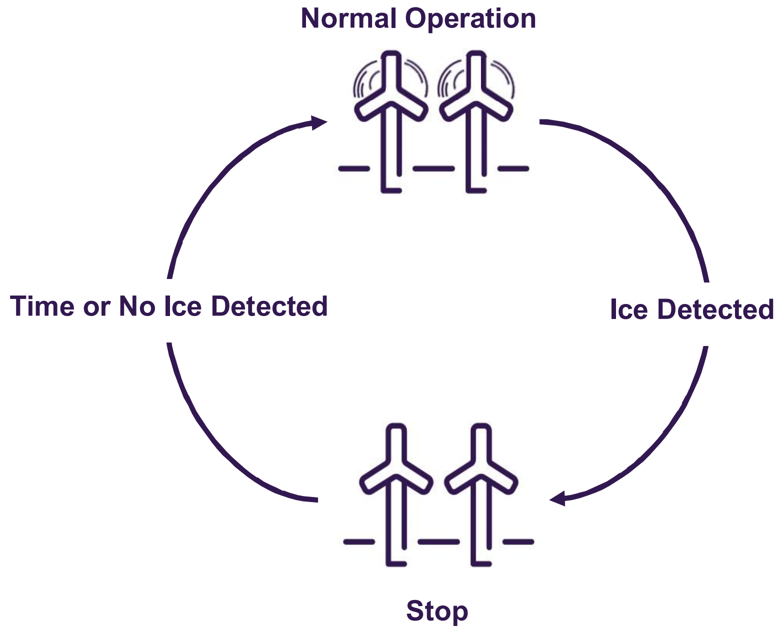
“Ignore the problem” Strategy

- Ice builds up on the blades
- Aerodynamic performance decreases
- Power production decreases
- Ice is detected by low power production or by ice detection sensor
- Turbine stops
- Turbine is restarted after a specific period, or when ice is no longer detected

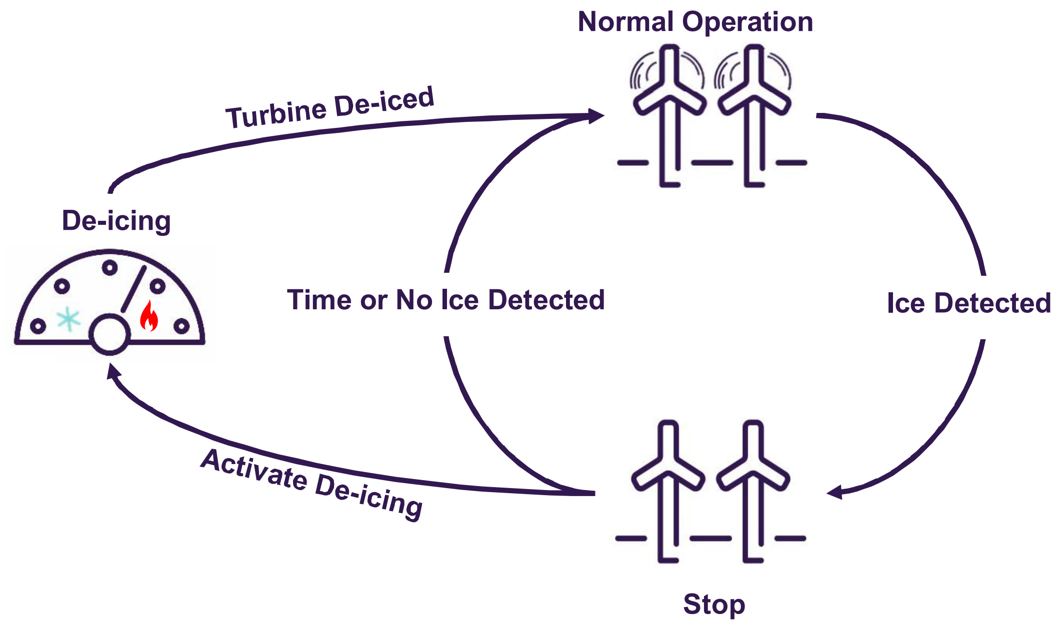


Standard certificate doesn’t include ice on the blade

Significant production loss

“Try to remove the problem” Strategy using de-icing

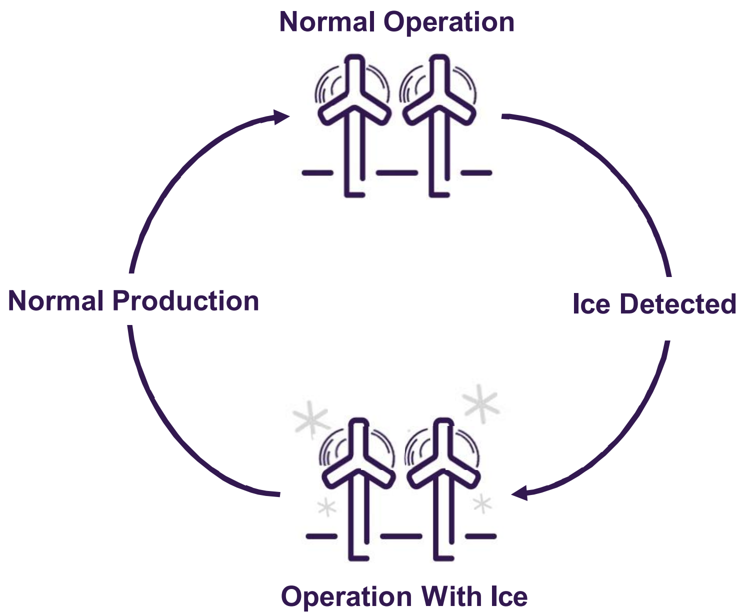
- Ice builds up on the blades
- Aerodynamic performance decreases
- Power production decreases
- Ice is detected by low power production or by ice detection sensor
- Turbine stops and de-icing process is activated
- Turbine is restarted once de-icing is complete



Costly and complex

”Accept and live with the problem” strategy using OWI (Operation With Ice)

- Ice builds up on the blades
- Aerodynamic performance decreases
- Power production decreases
- Ice is detected by low power production or by ice detection sensor
- Turbine changes control strategy to avoid stops and keep operational
- Turbine leveraging on operational data and adapt to the most optimum controller setting



Low cost
No additional hardware

Operation With Ice controller feature

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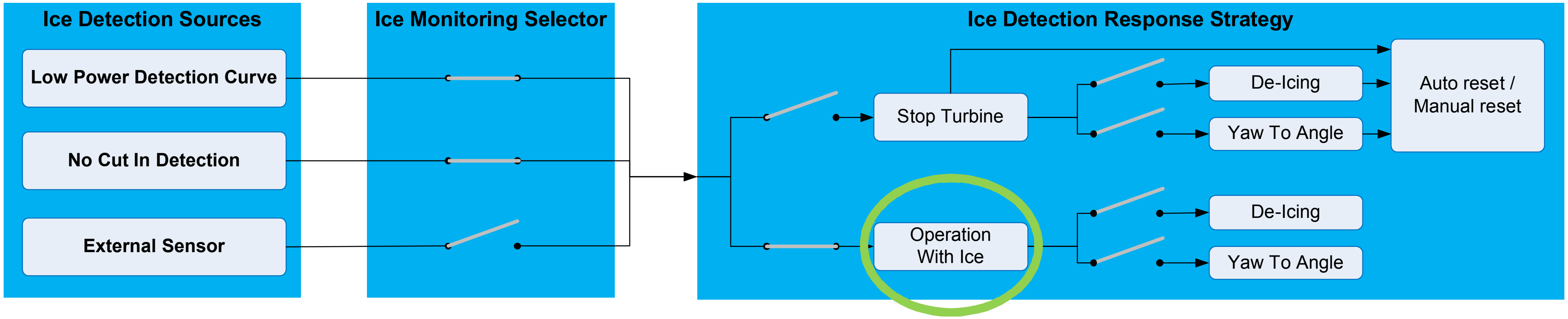
Flexible configuration for cold climate strategy

- Siemens Gamesa's ice detection and response system offers a functionality that extends the range of operation during ice conditions.
- The configurable options determine how ice is detected and the associated action taken to e.g. comply with building permits
- Default configuration maximizes the power production



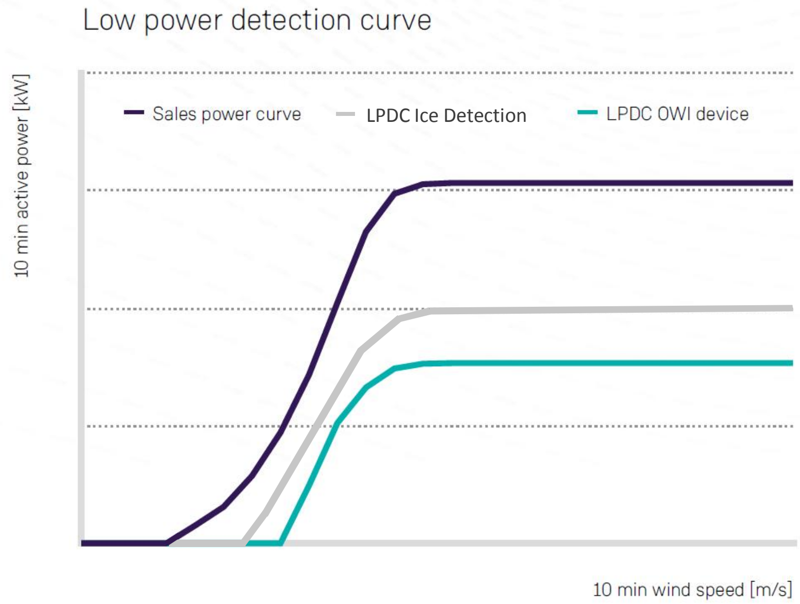
Standard ice detection method

Low Power Detection Curve (LPDC) Ice Detection

- Ice buildup on the blades reduces power production and degrades the power curve.
- Operation With Ice is activated once the measured power falls below the level of the Low Power Detection Curve (LPDC).
- If installed, the de-icing system is triggered by heavier ice buildup once the power falls below the OWI De-Icing power curve.

No Cut-in Ice Detection

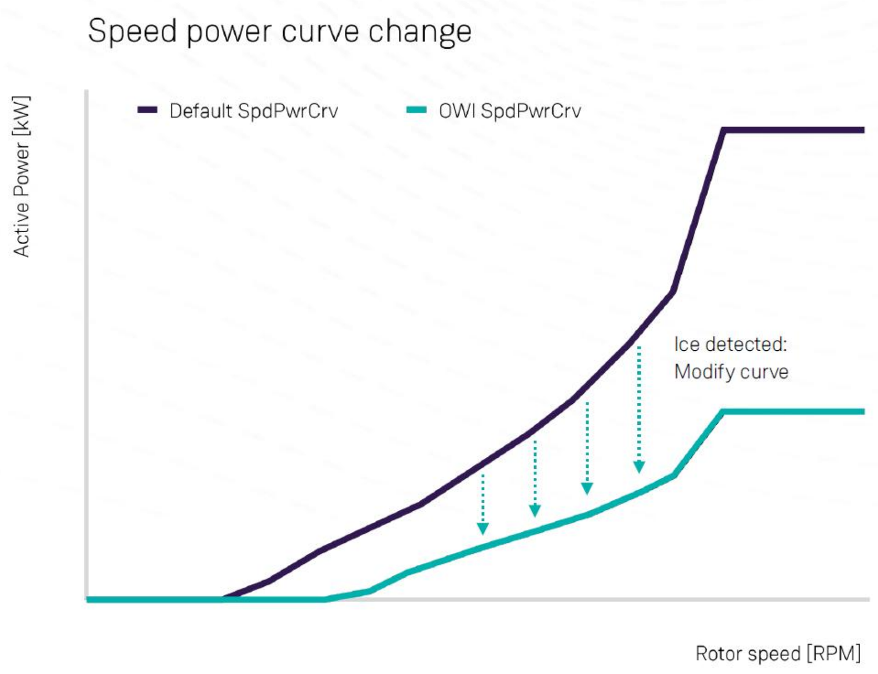
- Indications are that there is sufficient wind for the turbine to produce power, but the rotor speed is not high enough for the turbine to cut-in
- It is reasonable to assume that this is caused by ice buildup.



Illustrative comparison of the standard, LPDC, OWI De-Icing power curves

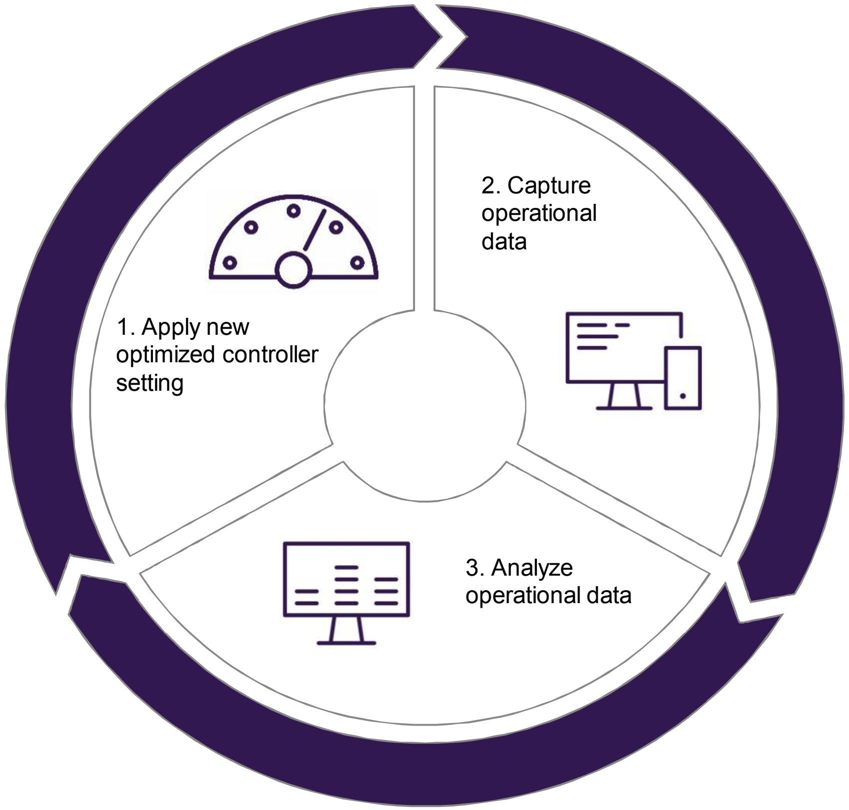
Step 1: Get the rotor speed back to normal speed

- In low wind conditions, the rotor speed is controlled by a lookup table, where the generator power demand is a function of the generator speed (Speed Power Curve).
- The lookup table ensures a constant tip speed ratio under normal conditions, but with icy conditions this table setting results in reduced rotor speed
- OWI brings the rotor speed back to normal speed to avoid blade stall and turbine cut out.



Step 2: Optimize pitch angle to avoid stall

- The minimum pitch angle is increased to move the Angle Of Attack (AOA) away from the stall area
- Turbine leverages operational data and adapts to the most optimal setting
- It continues to optimize until the optimum angle matches the default setting



Same or reduced risk of ice throw, compared to de-icing solutions

- The de-icing system does not provide an ice-free turbine/blade scenario.
- Only the leading edge is de-iced, and the remaining part of the blade isn't cleaned. There's even a greater chance of large chunks of ice building up on the blade while the turbine is stopped for de-icing during ~60 minutes.
- OWI attempts to keep the turbine running, meaning it is less likely for ice to build up in large chunks compared to a rotor standing still.

Operation With Ice can be combined with Noise Restricted Operation at noise sensitive sites

- Operation With Ice reduces stall and thereby noise emissions as well.
- Operation With Ice is compatible with Noise Restricted Operation and will respect a low speed set point from the noise control feature.

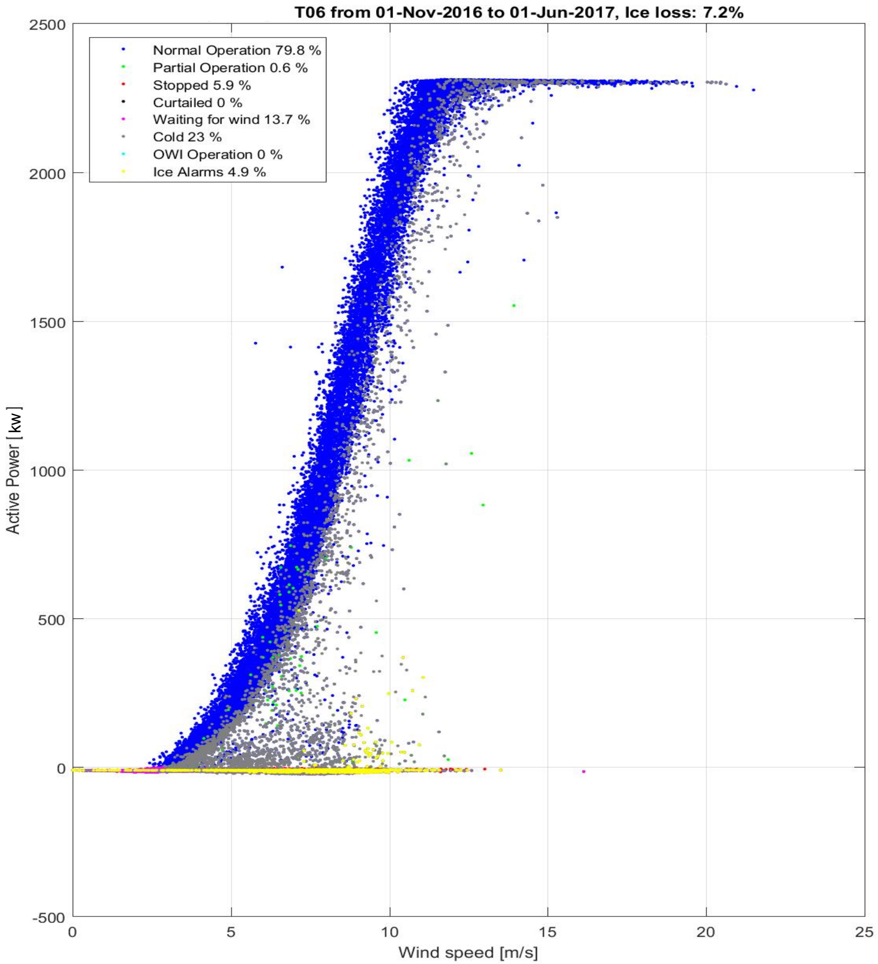
Field experience with Operation With Ice

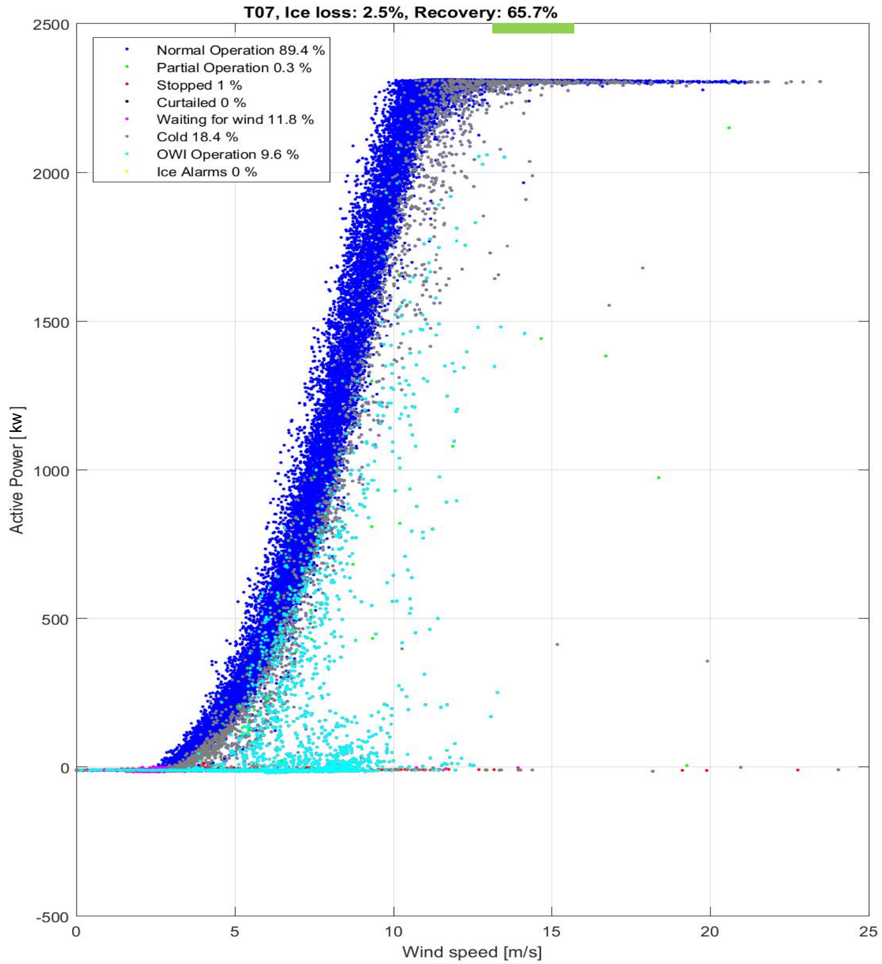
The Relative Ice Loss Recovery (RILR) can be calculated from SCADA data

1. Select a pair of turbines with same conditions, where one is operating with a cold weather feature, and the other one is not.
2. Create "warm power curves" for both turbines based on operational data with no icy conditions.
3. Compensate nacelle wind speed for stopped operation based on wind speed at the peer turbine.
4. Calculate ice loss based on difference between actual power and the "warm power curve".
5. Calculate relative ice loss recovery by comparing the cumulated ice loss of the turbine with and without cold climate feature.

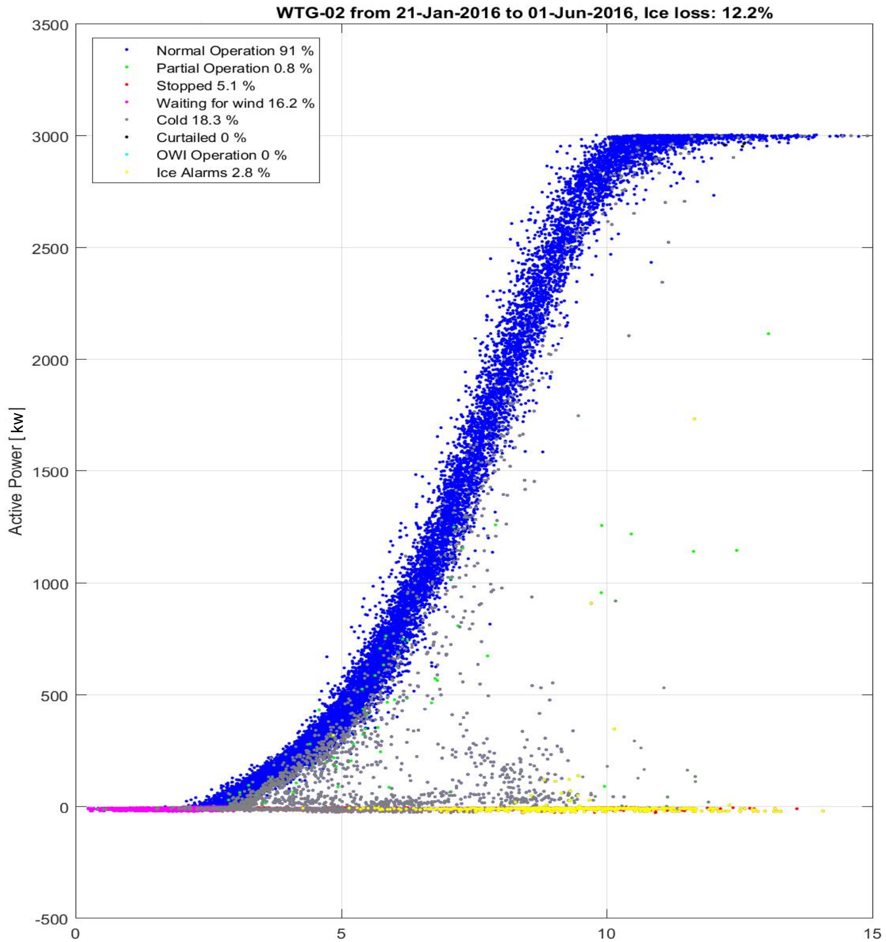
$$RILR = \frac{E^{B}_{iceloss,\%} - E^{A}_{iceloss,\%}}{E^{B}_{iceloss,\%}}$$

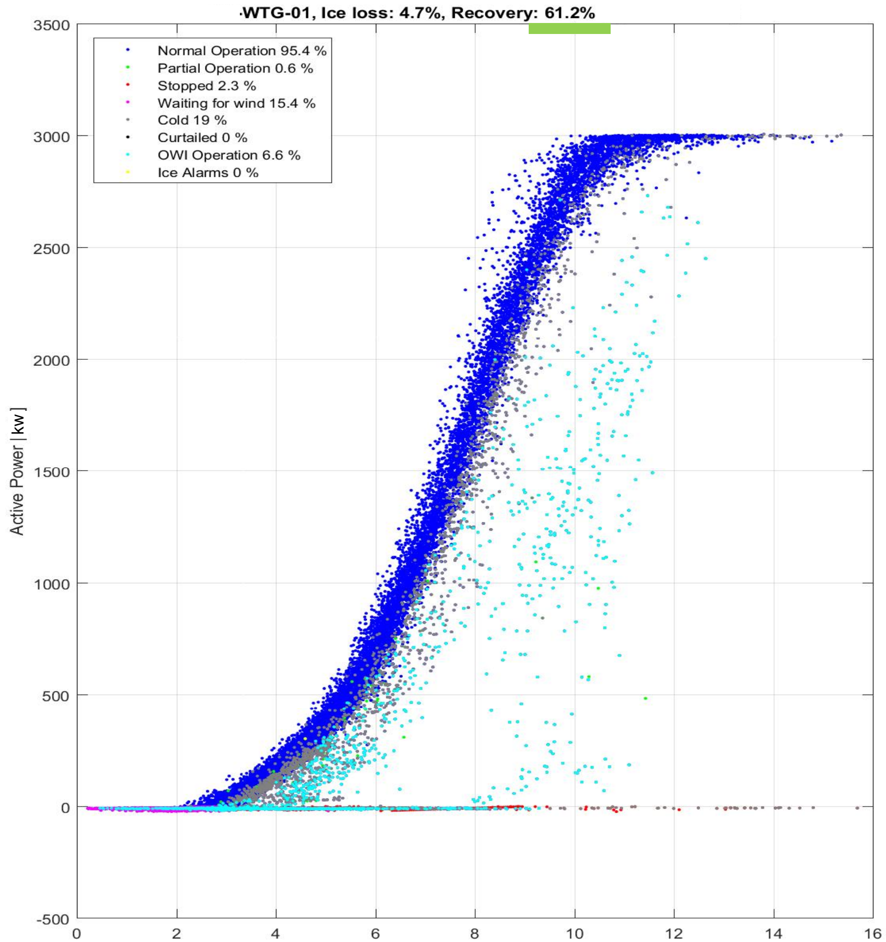
RILR calculation example, SWT-2.3-101





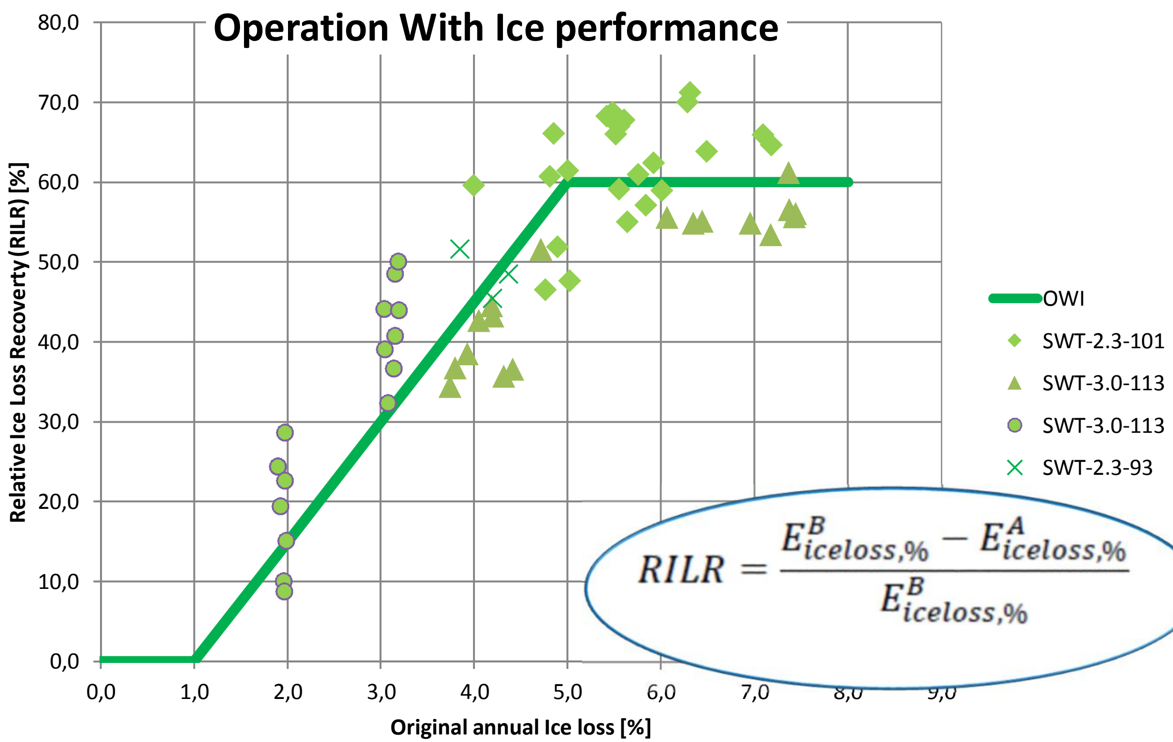
RILR calculation example, SWT-3.0-113





The Relative Ice Loss Recovery (RILR) can be calculated from SCADA data

- Operation With Ice is now running at +300 turbines
- Has been validated over the last two winter seasons
- Average relative ice loss recovery at 60% annual ice loss > 5%



$$RILR = \frac{E^{B}_{iceloss,\%} - E^{A}_{iceloss,\%}}{E^{B}_{iceloss,\%}}$$

Thank you!

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