Operational Strategies in Cold and Harsh Climates

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Operational Characteristics and Specifications
**Operational Characteristics**

<table>
<thead>
<tr>
<th></th>
<th>Min Survival Temp</th>
<th>Min Operational Temp</th>
<th>Max Operational Temp</th>
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</thead>
<tbody>
<tr>
<td>Standard</td>
<td>-20°C</td>
<td>-15°C</td>
<td>40°C</td>
</tr>
<tr>
<td>Cold Weather Option</td>
<td>-40°C</td>
<td>-30°C</td>
<td>40°C</td>
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- Electrical heaters protect the electrical component that needs to be protected from condensation and freezing due to the cold temperature environment.

- All bearings contain cold weather suitable grease in order to ensure proper lubrication even under severe low temperatures.

- A Special Gearbox lubrication system assembly is installed for faster start-up after grid loss

- Additionally, turbine control algorithms have been implemented to assure that temperature-sensitive components have achieved operational temperature prior to start-up.
Control System
Ice Collection on Blades

Ice collection patterns vary by event, elevation and region.

1. *Soft rime* on LE … Temperature around 3 °C and lower H2O content; accounts for ~15-40% loss in power performance

2. *Hard rime on LE and PS* … starts a few degrees below freezing then drastically drops; low H2O content; accounts for 15-40% loss in power performance

3. *Clear glazed ice* on LE and PS … Temperature near freezing with high H2O content i.e. rain/snow/freezing drizzle or mist; accounts for 70-90% loss in power performance

As little as ¼” of ice on LE is sufficient to significantly change performance
What is WIOM?

WIOM, or Winter Ice Operation Mode, is a controls based solution that pitches the blades to mitigate ice induced stall.

Ice accumulating on the blades causes poor aerodynamics and forces the blades into stall. To avoid stall, the blades should pitch to feather which will allow flow to reattach, but normal pitch control is a function of power output:

WIOM allows the blades to pitch based on Tip Speed Ratio (TSR = \omega R/V) instead of just power alone. Basically, if the wind speed is high but generator RPM is still low, the blades will start to pitch to feather to track a higher TSR/Generator RPM.
Icing climate packages
De-Icing Summary

- De-icing when turbine shutdown
- Simultaneous de-icing 3 blades
- Auto de-icing on/off
- Remote or manual turbine restart
- Can be coupled with ice detection system
De-Icing Triggers

1. GE controls logic*
2. Manual turbine shutdown because of icing
3. Bosch ice detection system

* Two options: (1) ice accretion beyond WIOM's capability, (2) proprietary ice detection algorithm
** De-icing duration set within GE controls if Bosch ice detection system not available