Ice protection systems and retrofits: Performance and experiences

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Background and objectives

• Evaluation of the performance of IPS and Retrofits
  – No standard evaluation method industry
  – Various results available using non-equivalent methods
• Help industry in comparing IPS and Retrofit technologies
• Identify improvements required to help technology providers
• Task 19 working towards standardization of IPS performance evaluation -> New guidelines coming in 2020!
The approach

1. Literature review of publically available IPS/Retrofit performance studies
   • 11 distinct studies
   • From 2011 to 2019

2. Open industry survey
   • 19 respondents
   • From 9 countries
### Reporting performance studies

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Reference turbine</th>
<th>Performance metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology</td>
<td>Stop turbine reference for Performance Analysis</td>
<td>Result</td>
</tr>
<tr>
<td>Operational strategy (Anti-icing / De-icing)</td>
<td>IEA Ice class</td>
<td>Analysis period</td>
</tr>
<tr>
<td>New IPS/ Retrofit</td>
<td>Number of sites for performance studies</td>
<td>Evaluated by third-party</td>
</tr>
<tr>
<td>Method of performance evaluation</td>
<td>Number of turbines for performance studies</td>
<td>Energy consumption</td>
</tr>
</tbody>
</table>
Method of performance evaluation

A1: Power Performance
A2: Side-by-Side
A3: Turbine Self-Comparison

B: Ice Protection Technology Performance

This performance study review excludes B
91% of studies use side-by-side approach (A2), with an operating wind turbine without IPS as a reference.
Site comparison

<table>
<thead>
<tr>
<th>IEA Class</th>
<th>Met. icing</th>
<th>Inst. icing</th>
<th>Production losses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% of year</td>
<td>% of year</td>
<td>% of annual production</td>
</tr>
<tr>
<td>5</td>
<td>&gt; 10</td>
<td>&gt; 20</td>
<td>&gt; 20</td>
</tr>
<tr>
<td>4</td>
<td>5-10</td>
<td>10-30</td>
<td>10-25</td>
</tr>
<tr>
<td>3</td>
<td>3-5</td>
<td>6-15</td>
<td>3-12</td>
</tr>
<tr>
<td>2</td>
<td>0.5-3</td>
<td>1-9</td>
<td>0.5-5</td>
</tr>
<tr>
<td>1</td>
<td>0-0.5</td>
<td>&lt; 1.5</td>
<td>0-0.5</td>
</tr>
</tbody>
</table>

Only two studies provided information useful for site comparison!
Scope of study

- Number of sites: Generally 1, up to 4
- Number of turbines: From 2 to 20
- Duration of study: Few months to 2 winters
Performance metrics

- Power Curve
- Energy Loss Reduction
- Energy Gain
- AEP Gain
Most popular approaches are Energy Gain and Energy Loss Reduction: Are they the same?

Longer analysis periods required to compute AEP Gain
Comparing performance

- Technology
- Performance evaluation method
- Reference turbine used
- Performance metric
- Comparable sites
Performance range

**Energy Gain [%]**
- Not Specified
- Icephobic Coating
- Hot Air

**Energy Loss Reduction [%]**
- Hot Air
- Electrothermal

**AEP Gain [%]**
- Hot Air
- Electrothermal
Industry survey

19 answers from 9 different countries
Small sample, results to be analyzed accordingly

In your organization, which Ice protection technology (IPT) are used?

- Electrothermal (heating mats): 7 (36.8%)
- Hot air: 5 (26.3%)
- Icephobic coating: 1 (5.3%)
- None: 8 (42.1%)
Industry survey

Are you considering the purchase of IPS equipped turbines or retrofits in the near future (< 3 years)?

- Yes: 42.1%
- No: 15.8%
- I don’t know: 42.1%
- I don’t know: 15.8%

Are you satisfied with the performance of the IPS you are using?

- Yes: 42.1%
- No: 15.8%
- I don’t know: 42.1%
- I am not using an IPS: 15.8%
Why are you not satisfied regarding IPS performance?

“Robustness is missing”

“Causing long standstill losses in low winds”

“Does not de-ice full blade which still gives losses.”

“Don't reduce losses as projected. Only part of the blades are covered. Vortex vanes are not ice protected and creates lots of losses.”

“The performance is lower than expected, especially at low temperature or high wind speed.”

“Heating power is insufficient”
In your experience, do you consider that IPS are reliable?

Which sub-system is affecting the reliability of the IPS you are using?

- Ice detection and control algorithm
- Ice detection triggering heating element
- Control algorithm and power distribution
- Detection, control algorithm, heating elements, power transfer to the elements, mechanical organs of the system
- The default control algorithm is suboptimal
- Heating element
Industry survey

What do you think OEMs and IPS manufacturers should be focusing on to improve the performance of IPS?

“Improve reliability and performance envelope”
“Robustness and durability”
“Smarter or more adaptive, and efficient, de-icing cycles”
“Focus on making the de-icing more efficient time and power wise and to de-ice a larger section of the blade. Find a way to validate if the blade is de-iced enough or not.”
“Focus of de-icing to where it makes most effect. I.e. outer half of blades and including Vortex Generators”
Industry survey

What do you think OEMs and IPS manufacturers should be focusing on to improve the performance of IPS? (continued)

“Detection/anticipation of icing events”
“Smarter (predictive) control algorithms, more heating power, heating during operation.”
“Freely available data of the turbines as well as performance data are necessary to increase the performance of the systems.”
“Reliability, power consumption”
“Cost”
“Reliability of the system during operation and making the system accessible for maintenance.”
Conclusions

• Industry has not come to a standardize evaluation method, this causes dissatisfaction: performance is not meeting expectations -> T19 warranty guidelines to be updated

• Performance of IPS is inconsistent, both in performance studies and end-users opinion

• Robustness and reliability of IPS must be improved

• Other improvements for IPS: Earlier ice detection, adaptive control, increased power and lower costs
Thank you!
## Appendix 1: Summary of Published Studies

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>[5] K. Sachse</td>
<td>Nordex</td>
<td>Electro-thermal</td>
<td>Anti-icing</td>
<td>IPS</td>
<td>A2</td>
<td>Yes</td>
<td>No</td>
<td>1</td>
<td>2</td>
<td>Power Curve</td>
<td>8</td>
<td>2011</td>
</tr>
<tr>
<td>[7] S. Barup</td>
<td>Enercon</td>
<td>Hot air</td>
<td>De-icing</td>
<td>IPS</td>
<td>A2</td>
<td>Yes</td>
<td>No</td>
<td>4</td>
<td>8</td>
<td>AEP Gain</td>
<td>3 to 12</td>
<td>2016-2018</td>
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<tr>
<td>[8] R. Cattin</td>
<td>Enercon</td>
<td>Hot air</td>
<td>De-icing</td>
<td>IPS</td>
<td>A2</td>
<td>Yes</td>
<td>No</td>
<td>3</td>
<td>6</td>
<td>Energy Loss Reduction</td>
<td>14 to 27</td>
<td>01-04 2013</td>
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<tr>
<td>[9] T. Karlsson</td>
<td></td>
<td>IPS</td>
<td></td>
<td>A3 NA3</td>
<td>2 to 4</td>
<td>4</td>
<td>4</td>
<td>Energy Gain</td>
<td>0 to 45</td>
<td>2016-2018</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>[10] M. Yamazaki et al.</td>
<td>NTT-AT</td>
<td>Icephobic coating</td>
<td>Passive</td>
<td>Retrofit</td>
<td>A2</td>
<td>Yes</td>
<td>No</td>
<td>1</td>
<td>3</td>
<td>Energy Gain</td>
<td>7</td>
<td>11-12 2018</td>
</tr>
<tr>
<td>[13] A. Stoki, A. Krenn</td>
<td>Vestas</td>
<td>Hot air</td>
<td>De-icing</td>
<td>IPS</td>
<td>A2</td>
<td>Yes</td>
<td>No</td>
<td>3</td>
<td>2</td>
<td>Energy Loss Reduction</td>
<td>47.5</td>
<td>2017-2018</td>
</tr>
</tbody>
</table>
References


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