Wind turbine blade heating

Can it pay even more?

René Cattin
Icing in Switzerland

Wind map of Switzerland

Currently installed: 40 MW
Potential: 400–600 MW (maybe more?)

6-7.5 m/s
Icing in Switzerland

Wind map of Switzerland

Icing map of Switzerland

→ Almost all Swiss sites under icing conditions
St. Brais

Wind map of Switzerland

St. Brais
1’100 m asl

2 Enercon E-82
Hub height 78 m
Enercon blade heating
The Project

The research project (2009 to 2011)

1) Monitoring of a 2-MW-wind turbine in the Jura arc (2/3 of the planned Swiss wind parks) concerning icing, turbulence and wind shear

2) Evaluation and validation of different systems for ice detection and de-icing
   → Enercon ice detection via power curve
   → Moog/Insensys ice detection system
   → Ice detection via temperature and relative humidity
   → Goodrich ice detector prototype

→ Performance of Enercon blade heating system

→ Verification via camera images
The Project

The research project
(2009 to 2011)

3) Evaluation of the production loss due to icing and of the gained energy based on use of ice detection and de-icing systems

→ WEA1: blade heating off, ice detection on
→ WEA2: blade heating on, ice detection on

How much additional production on WEA2 compared to used energy for blade heating?

→ Calculation of scenarios for the whole winter time

→ Heating during operation versus heating during standstill
The Project

The research project
(2009 to 2011)

4) Evaluation of the additional loads caused by icing
   → Moog/Insensys system

5) Evaluation of the noise emissions of a wind turbine under icing conditions
   → noise measurement campaigns
The Project

The research project
(2009 to 2011)

4) Evaluation of the additional loads caused by icing → Insensys system

5) Evaluation of the noise emissions of a wind turbine under icing conditions → noise measurement campaigns

Collaboration between
→ Federal Office of Energy
→ Meteotest
→ ADEV Windkraft AG (Operator)
→ Enercon
→ Moog/Insensys
Instrumentation

Instrumentation: Camera system

→ The eye is / cameras are still the **best ice detectors**

Commercial Mobotix Webcams mounted at nacelle

Developed and tested at the **Guetsch site** (Andermatt, Switzerland)

→ [www.meteotest.ch/cost727/index.html](http://www.meteotest.ch/cost727/index.html)

**Video motion detection** for capturing the moving blades
Instrumentation

Blade camera

Sensor camera
Instrumentation

Sensor camera: image taken every 30 minutes
Instrumentation

Sensor camera: image taken every 30 minutes

→ Very high availability of sensor camera
Instrumentation

Blade camera: image taken by motion detection
Instrumentation

Blade camera: problems
Instrumentation

Latest images displayed on website (protected by password)
All images archived
Instrumentation

Wind speed
Wind direction
Temperature (2x)
Relative humidity (2x)
Incoming longwave radiation
Goodrich ice detector (prototype)
Instrumentation

Operational data: wind speed / wind direction

Wind flow disturbed by ice?
Instrumentation

Operational data: power production

![Chart showing operational data for power production](chart.png)
Icing on Structures

Cloud icing (rime icing, glaze icing)
Precipitation icing (freezing rain, wet snow)
Icing on Structures

Wind turbine:
- Reduced production
- Additional loads
- Imbalance
- Fatigue
- Increased noise
- Ice Throw
Icing on Structures

Meteorological and instrumental icing
Icing at St. Brais

Meteorological and instrumental icing 2009/10

meteorological icing

Icing at St. Brais

Meteorological and instrumental icing 2009/10

- Meteorological icing
- Instrumental icing

Icing at St. Brais

Meteorological and instrumental icing 2009/10

Meteorological icing: 276h / 11.5 d (longest event: 63h / 2.6d)
Instrumental Icing: 997h / 41.5 d (longest event: 241h / 10 d)

→ Factor 3.6!
Icing at St. Brais

Meteorological and instrumental icing 2010/11

meteorological icing

Icing at St. Brais

Meteorological and instrumental icing 2010/11

- Meteorological icing
- Instrumental icing

Timeline:
- 01 Okt 2010
- 06 Nov 2010
- 12 Dez 2010
- 18 Jan 2011
- 23 Feb 2011
- 31 März 2011
Icing at St. Brais

Meteorological and instrumental icing 2010/11

Meteorological icing: 246h / 10.3 d (longest event: 25h / 1 d)
Instrumental Icing: 853h / 35.5 d (longest event: 239h / 10 d)

→ Factor 3.4!
Icing at St. Brais

Comparison with Guetsch (2‘300m asl)

meteorological icing

Icing at St. Brais

Comparison with Guetsch (2'300m asl)

- meteorological icing
- instrumental icing

01 Sep 2009 - 30 Apr 2010
Comparison with Guetsch (2'300m asl)

Meteorological icing: 130h / 5.4 d
Instrumental Icing: 674h / 28 d (longest event: 103h / 4.3 d)

→ Factor 5.2!
## Icing at St. Brais

### Summary Icing Events

<table>
<thead>
<tr>
<th></th>
<th>Anzahl Ereignisse met. Vereisung</th>
<th>Meteorologische Vereisung</th>
<th>Instrumentelle Vereisung</th>
<th>Faktor</th>
</tr>
</thead>
<tbody>
<tr>
<td>St. Brais 2009/10</td>
<td>12</td>
<td>276h / 11.5 Tage</td>
<td>997h / 41.5 Tage</td>
<td>3.6</td>
</tr>
<tr>
<td>St. Brais 2010/11</td>
<td>26</td>
<td>247h / 10.3 Tage</td>
<td>853h / 35.5 Tage</td>
<td>3.4</td>
</tr>
<tr>
<td>Gütsch 2009/10</td>
<td>24</td>
<td>130h / 5.4 Tage</td>
<td>674h / 28.1 Tage</td>
<td>5.2</td>
</tr>
</tbody>
</table>

→ Icing conditions are very site specific
Blade Heating

Blade heating

**Status** 2009/10 and partly 2010/11:

- turbine is stopped when icing is detected
- blades are heated for 3 h (80 kW)
- turbine is automatically restarted
Blade Heating

Blade heating 2009/10

- meteorological icing
- instrumental icing

Dates:
- 01 Nov 2009
- 01 Dec 2009
- 31 Dec 2009
- 30 Jan 2010
- 01 Mar 2010
- 31 Mar 2010
Blade Heating

Blade heating 2009/10

124 heating cycles (372h/15d downtime, 7.5d per turbine)
30 MWh heating power (80kW per turbine)
Blade Heating

Blade heating 2009/10

→ Blade heating mainly active during meteorological icing
→ Reduces downtime by approximately factor 4
Blade Heating

Example

![Graph showing blade heating and power production over time. The graph includes data for meteorological and instrumental icing.]
Blade Heating

Blade heating
Blade Heating

Case study: No blade heating

Assumptions:
- Wind turbine **without blade heating**
- **Turbine stops** when ice is detected
- **Automatic restart** if temperature was **above 2° C for 6 hours**
Blade Heating

Case study: No blade heating

Meteorological icing: 276h / 11.5d (longest event: 63h / 2.6d)
Downtime without blade heating: 1’349h / 56.2d (longest event: 312h / 13d)

→ Blade heating system increases production significantly

→ Factor 4.8!
Blade Heating

What was the benefit?

- Production loss without blade heating: ~10%
- Additional production thanks to blade heating: ~7%
- Energy needed for blade heating: ~0.4%
- Production loss due to stopped turbine during heating: ~3%
Blade Heating

Experimental proof

→ WEA1: blade heating off, ice detection on
→ WEA2: blade heating on, ice detection on

Experiment carried out in January 2010
Losses of operator compensated through project budget
Blade Heating

Experimental proof

blade heating off
ice detection on

blade heating on
ice detection on
Blade Heating

Experimental proof

<table>
<thead>
<tr>
<th>Start Ereignis</th>
<th>Ende Ereignis</th>
<th>Produktion WEA 2 [kWh]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Produktionsverlust WEA 1</strong></td>
<td></td>
<td>103'493</td>
</tr>
<tr>
<td><strong>Eingesparte Energie durch deaktivierte Blattheizung</strong></td>
<td></td>
<td>-7'020</td>
</tr>
<tr>
<td><strong>Total Produktionsverlust WEA 1</strong></td>
<td></td>
<td>96'473</td>
</tr>
</tbody>
</table>

→ ~ 20% of production in this month
Blade Heating

Heating during operation

Status of WEA1 since January 18 2011:

→ **heating starts** when icing is detected
→ turbine **keeps producing**
→ **heating stops** under given conditions (unknown)
Blade Heating

Heating during operation

- power
- power curve
- blade heating
- ice detected

meteorological icing
instrumental icing

power production WEA1 [kW]

2000
1500
1000
500
0

20 Jan 2011
21 Jan 2011
22 Jan 2011
23 Jan 2011
Blade Heating

Heating during operation

- power
- power curve
- blade heating
- ice detected

Graph showing power production WEA1 [kW] from 20 Jan 2011 to 23 Jan 2011 with meteorological icing and instrumental icing indicated.
Blade Heating

Heating during operation

4 case studies (no more data available)

WEA1 = reference (heating during operation)
→ production according wind speed/power curve

WEA2 = same production as WEA1
stop for heating according to status data WEA 2
Blade Heating

Case 1: Heating during operation

Energy production: 44 MWh
Energy for heating: 1.2 MWh
Case 1: Heating during operation

Balance:

Heating_{WEA1} = \sim 3 \times \text{Heating}_{WEA2}

P_{\text{additional}} - \Delta_{\text{heating}} = +6.3 \text{ MWh} (+\sim 11\%)

Energy production: 53 MWh (+9 MWh)
Energy for heating: 3.9 MWh (+2.7 MWh)
Blade Heating

Case 2: Heating during operation

Energy production: 12.5 MWh
Energy for heating: 1.2 MWh
Heating during operation

Balance:

\[
\text{Heating}_{\text{WEA}1} = \sim 2 \times \text{Heating}_{\text{WEA}2}
\]

\[
P_{\text{additional}} - \Delta_{\text{heating}} = + 5.5 \text{ MWh (+ ~ 28%)}
\]

Energy production: 19.6 MWh (+6.9 MWh)
Energy for heating: 2.6 MWh (+1.4 MWh)
Blade Heating

Case 3: Heating during operation

Energy production: 5.7 MWh
Energy for heating: 0 MWh
Case 3: Heating during operation

Balance:

\[ \text{Heating}_{\text{WEA1}} = \sim 0^* \text{ Heating}_{\text{WEA2}} \]
\[ P_{\text{additional}} - \Delta_{\text{heating}} = -0.7 \text{ MWh} (-\sim 11\%) \]

Energy production: 5.7 MWh (+0 MWh)
Energy for heating: 0.7 MWh (+0.7 MWh)
Case 4: Heating during operation

Energy production: 50 MWh
Energy for heating: 0.7 MWh

Blade Heating
Case 4: Heating during operation

Balance:

\[ \text{Heating}_{\text{WEA1}} = \sim 4.2 \times \text{Heating}_{\text{WEA2}} \]

\[ P_{\text{additional}} - \Delta_{\text{heating}} = +0.7 \text{ MWh} (+\sim 1.3\%) \]

Energy production: 53 MWh (+3 MWh)
Energy for heating: 3 MWh (+2.3 MWh)

→ Positive energy balance in 3 out of 4 cases
→ Benefit dependant on efficiency of heating control
→ Blade is mostly ice-free
→ Heating control has room for optimisation (via relative humidity?)
Summary

Summary I

- Icing has **significant impact** on power production at St. Brais
- Instrumental icing periods ~ **4 times longer** than meteorological icing
- Icing conditions are very **site specific** (**site classification needed during site assessment**)
Summary II

- Blade heating mainly active during the periods of meteorological icing.
- Without blade heating production losses of approximately 10%.
- Blade heating during stand still allowed ~7% more production.
- Energy needed for blade heating: ~0.4% of annual production.
- Production loss of ~3% remains because wind turbine stops for heating.
- Blade heating needs several cycles to melt away the ice.
- Leading edge ice is ice free, flaps are not (heating during stand still).
- No „ice free signal“ → automatic restart is a risk.
- Heating during operation furthers reduces the production loss (another 5-15% of the remaining 3%?).
- Efficient heating: Blades remain mostly ice free.
- Heating control can be optimized (benefit dependant on heating control).
- Ice throw risk lower when heating during operation?
Thank you

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for your attention!