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Methods for Detection of Icing Losses in Scada Data

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Understanding Icing

- Extreme difference between WTG suppliers operational methodology
Other research

- Icing research have mainly been carried out in the Nordic countries and to some extent in the Alpine countries.

- Main topics related to wind power in icing conditions are
  ✔ Analysis of production losses due to icing in wind farm operational data. AEP
  ✔ Forecasting of production losses/icing events. NEXT DAY
  ✔ Ice throw risk assessment. RISK
  ✔ Prevention of production losses in icing conditions. ACTION

- A few of the main studies and actors in this field are mentioned below:
  ✔ WECO (Wind Energy Production in Cold Climate)
  ✔ First big research project on icing of wind turbines (1996-98). Research on e.g. production losses and ice throw risk. Carried out mainly by FMI, founded partially by the European Commission.
Background

- Icing detection in Scada data challenging as error codes are not sufficient for this task
- Different turbines operate in clearly different ways in icing conditions
- In this study, the icing behaviour of two parks with different turbines was analysed
- The goal was to describe and filter icing-affected data in a mathematical way

Site conditions:
- Elevation ~ 100 m
- Hub height ~ 140 m
- Temperature: -45°C – +35°C
  (Actual during last years -18°C – +31°C)
Icing of the Two Wind Turbines

- The Site is located in Western Finland, 15-20 km from the coast.
- Two wind parks with two different turbine types.
- The Finnish Icing Atlas (2011) predicts significant losses due to icing, about 6% at hub height altitude.
- Three different operation modes during icing conditions could be seen:
  - Wind Farm I turbines did often shut down during icing conditions -> Big icing losses
  - Wind Farm II turbines were usually operating during icing conditions -> Small icing losses
- A new software installed to the Wind Farm I turbines greatly reduced the icing losses.
Turbine Behaviour during Icing

1. Decrease in Production
   - Ice causing degradation of aerodynamic properties
   - Very small losses difficult to identify due to uncertainty in the wind speed measurements

2. Turbines Stopped
   - Turbines are completely stopped when production losses or vibrations are detected
   - Cause major production losses.
   - Behaviour that should not be accepted.
Turbine Behaviour during Icing

3. Startup Delayed
- After a low wind speed period
- Ice built up -> production loss until ice have been shaken off

4. Icing after Maintenance Stop
- Similar as delayed startup, but caused by a maintenance stop
- Ice built up -> production loss until ice have been shaken off
Defining the Ice Detection Code

- Icing losses are usually not detected by the Scada system (no error code is returned).
- Theoretical power was compared to actual power, losses of more than 15% was marked (more detailed criterias close to cut-in and peak power wind speeds). A power curve for winter air densities were used.
- Periods with losses were manually checked together with the error codes. It was found that more or less all production losses during the winter without an error code was due to icing.
- A rather simple approach could thus be implemented, where each loss > 15 % were marked as an icing loss if no error code were returned, and the average temperature during the last 24h period was below 4 degrees.
- The icing losses were further categorized as either production decrease, stop, delayed startup or icing after maintenance.
Results

- The total icing loss for Wind Farm I during the measured year was calculated to be 8.0 %
- The total icing loss for Wind Farm II during the measured year was calculated to be 1.0 %
- The big difference is due to the large amount of shut downs of Wind Farm I.
- Our neural network model suggested that the long-term losses are 1.4x higher than during the measured winter (2014-15). Still, the Finnish Windatlas estimate of 6 % seems to be clearly too high for wind parks operating without excessive icing shut downs.
- Wind Farm I has since clearly decreased the losses due to shut downs (slide 12).
Long term normalization of icing losses: Neural Network Model

1. Input:

- Wind farm icing occasions estimated from Scada data
- EMD-ConWx mesoscale weather data (most important parameters: current, last 24H minimum and maximum temperature and wind speed)

2. Training of the network.

- 50% of the 2014-15 data was used during training
- Prediction was done on the remaining 2014-15 data. Network parameters were fine-tuned, additional care taken related to overfitting risks.

<table>
<thead>
<tr>
<th>Wind park</th>
<th>Sample</th>
<th>Icing occasions</th>
<th>Total icing occasions identified</th>
<th>Icing estimated vs actual icing</th>
<th>Icing correctly identified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Park 1</td>
<td>1</td>
<td>184</td>
<td>148</td>
<td>80%</td>
<td>96</td>
</tr>
<tr>
<td>Park 1</td>
<td>2</td>
<td>176</td>
<td>190</td>
<td>108%</td>
<td>112</td>
</tr>
<tr>
<td>Park 1</td>
<td>3</td>
<td>195</td>
<td>173</td>
<td>89%</td>
<td>112</td>
</tr>
<tr>
<td>Park 2</td>
<td>1</td>
<td>73</td>
<td>76</td>
<td>104%</td>
<td>53</td>
</tr>
<tr>
<td>Park 2</td>
<td>2</td>
<td>71</td>
<td>76</td>
<td>107%</td>
<td>49</td>
</tr>
<tr>
<td>Park 2</td>
<td>3</td>
<td>74</td>
<td>70</td>
<td>95%</td>
<td>40</td>
</tr>
</tbody>
</table>

Figure 2: Prediction results, wind park 1.
Figure 3: Prediction results, wind park 2.
Long term normalization of icing losses: Neural Network Model

   - The trained network is run with 10-year mesoscale weather data, estimating the number of icing occasions for each year.

   - The average production loss during icing conditions in the 2014-15 measurement period is applied.

- A trained network can be used for icing estimation at another wind farm only under the assumption that the wind farms operate in similar ways during icing conditions.

<table>
<thead>
<tr>
<th>Winter</th>
<th>Production Loss Farm 1</th>
<th>Production Loss Farm 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014-15</td>
<td>1.0 %</td>
<td>3.1 %</td>
</tr>
<tr>
<td>2013-14</td>
<td>1.0 %</td>
<td>3.1 %</td>
</tr>
<tr>
<td>2012-13</td>
<td>2.2 %</td>
<td>5.3 %</td>
</tr>
<tr>
<td>2011-12</td>
<td>1.0 %</td>
<td>3.1 %</td>
</tr>
<tr>
<td>2010-11</td>
<td>2.2 %</td>
<td>6.5 %</td>
</tr>
<tr>
<td>2009-10</td>
<td>2.0 %</td>
<td>6.3 %</td>
</tr>
<tr>
<td>2008-09</td>
<td>1.6 %</td>
<td>4.2 %</td>
</tr>
<tr>
<td>2007-08</td>
<td>1.1 %</td>
<td>3.5 %</td>
</tr>
<tr>
<td>2006-07</td>
<td>1.4 %</td>
<td>4.0 %</td>
</tr>
<tr>
<td>2005-06</td>
<td>2.0 %</td>
<td>5.1 %</td>
</tr>
</tbody>
</table>
Improving the Performance in Icing Conditions

- A new software in Wind Farm I have according the initial tests reduced the production losses due to ice with 60%.
- When production losses are detected by the software, it actively changes the pitch angle in order for the turbine to reach the highest possible production. By continuing operation at this stage, it is likely that the ice will be shaken of at some point. The turbines will after a while go back to normal operation.
- The ice loss estimate of Wind Farm I is now much closer to the level of Wind Farm II.
  -> Do not accept big production losses due to turbine shut down.
- The evaluated windfarms do not use deicing technology. In harsh icing conditions it is recommended to install de-icing systems. In the coastal regions of Finland, these systems are usually not needed, as production losses are small (assuming the turbines operate without icing shut downs).
- With de-icing systems it can be valuable to run an icing-forecast model, so that e.g. heating of the blades can be turned on before the icing conditions start.
Improving the Performance in Icing Conditions

Old software (high ice loss)

New software (low ice loss)
Conclusion

• Turbine specific behaviours during icing conditions – bad behaviour can be improved!

• Icing losses can be fairly easily detected from Scada data. By estimating the theoretical power level, the yearly production loss could be calculated. Long-term icing losses can be calculated using long-term weather data in e.g. a neural network model.

• Future Goals: Icing forecasting

• Main Conclusion: Confirm that your supplier seriously understand icing issues….