Quantification of energy losses caused by blade icing and the development of an Icing Loss Climatology

Using SCADA data from Scandinavian wind farms

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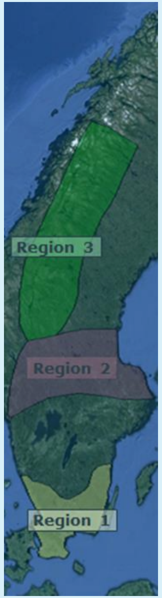
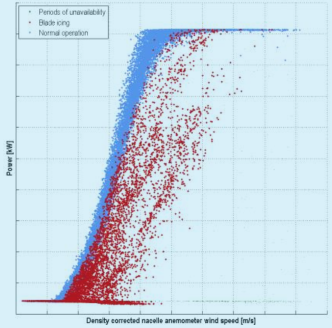
Winterwind 2015

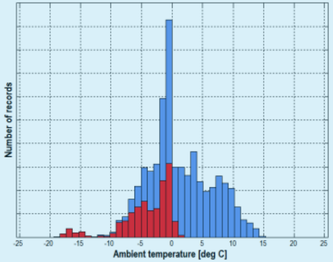
SAFER, SMARTER, GREENER

Winterwind 2014

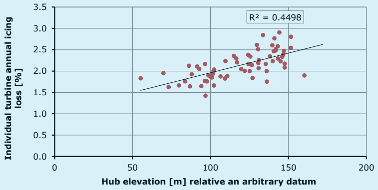
What we did

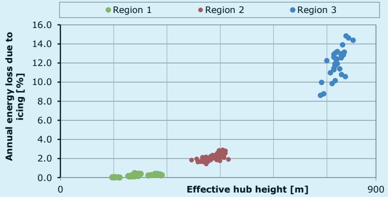


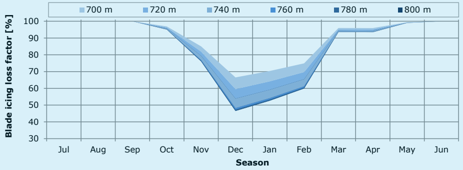




What we found







Conclusions we drew

- SCADA data are great for quantifying energy loss caused by blade icing
- Losses in Scandinavia vary greatly, from close to 0% to more than 10% of annual energy production.
- Evidence of correlation between elevation and icing loss. Linear over small elevation range. Polynomial over large range?
- Potential scope for developing empirical relationship between icing losses and elevation

Contents

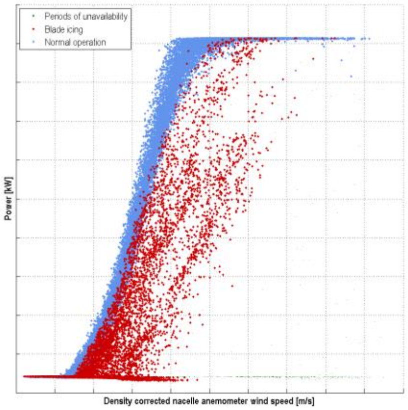
- Review of operational data considered
- Re-cap on loss calculation method
- Specific investigations undertaken
  - Influence of control strategy
  - Inter-annual variability
  - Importance of elevation – update from Winterwind 2014
- Conclusions

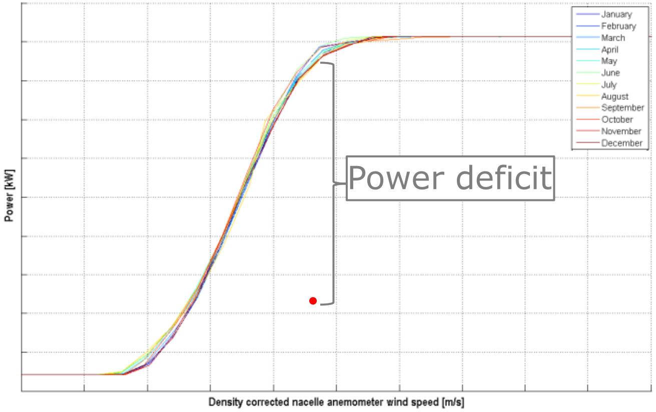
Data included

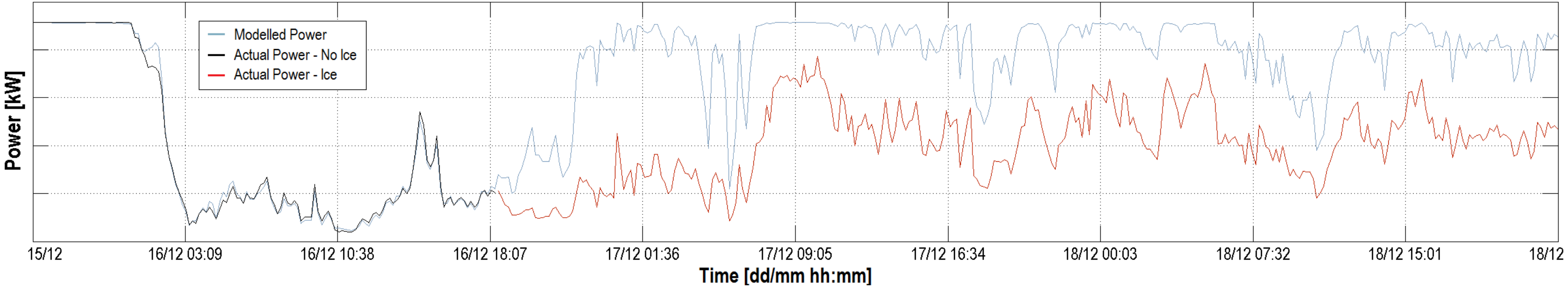
- Data from 350 wind turbines (+200)
- 18 Wind Farms (+8)
- Reasonable geographical coverage
  - 10+ projects in Sweden
  - <5 Projects in Norway
  - <5 Projects in Finland
- Excludes projects where icing loss is managed manually
- Includes projects where:
  - Turbines that shut down when controller detects icing
  - Turbines that remain operational during blade icing events

Energy loss quantification

- Define 'Base-line' power curves based on data for Normal operation only;
- The energy loss is defined by the Actual less the Expected production;
- An energy loss value is calculated for each each 10-minute record.
- Results in a database of Actual Power, Expected Power and an icing event log, for each turbine and each 10-minute record.

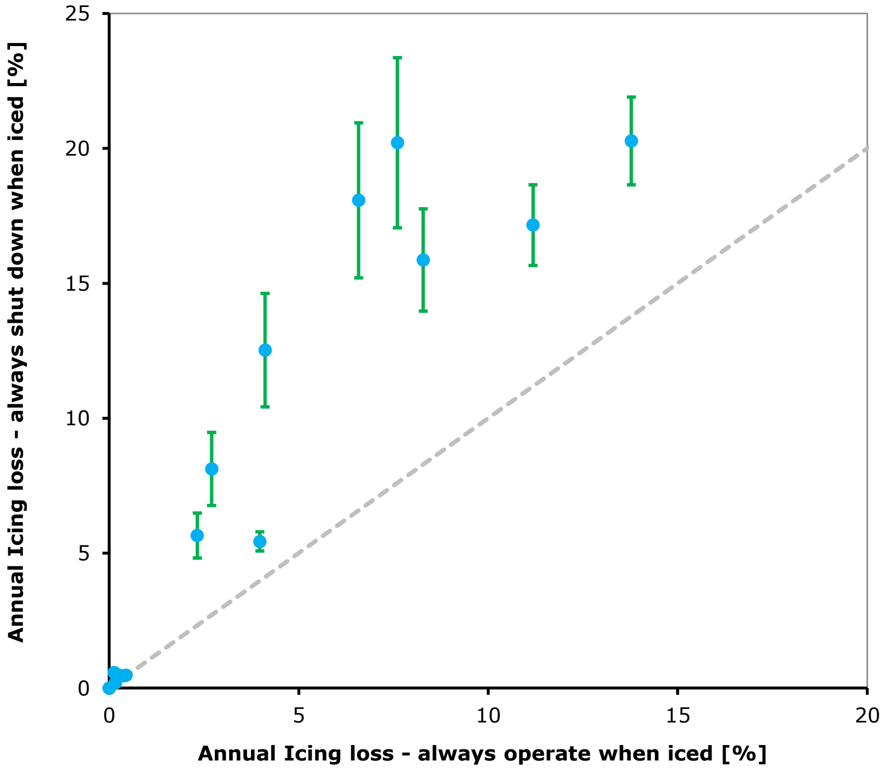






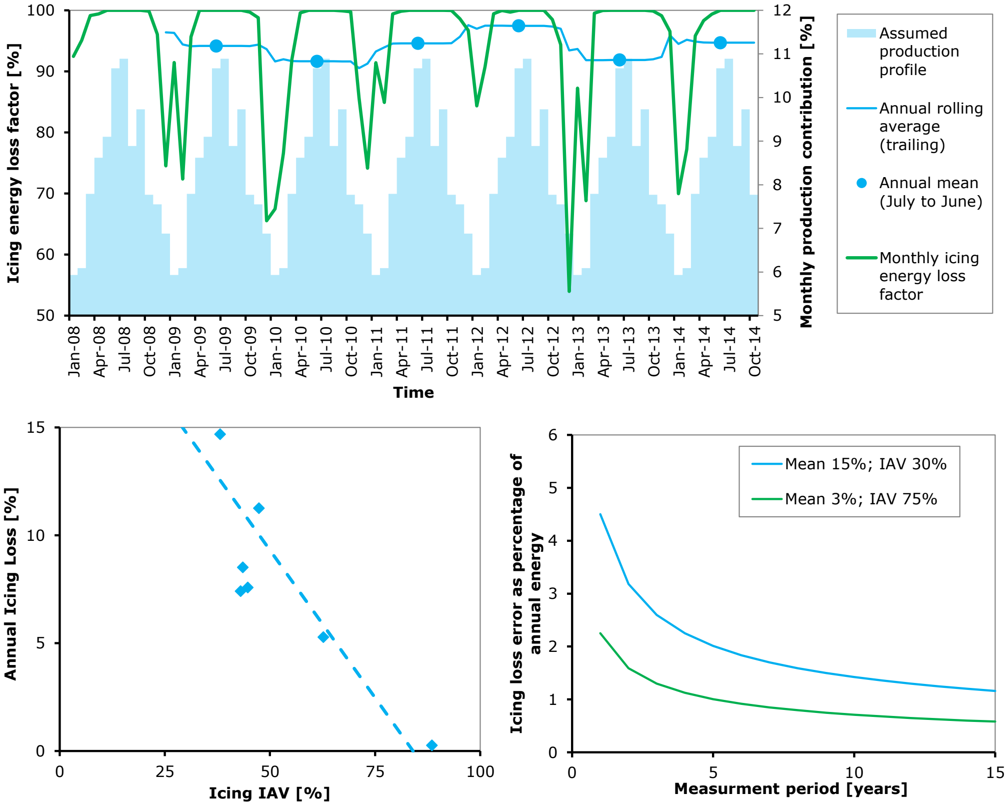
Influence of control strategy

- Question: What’s the potential benefit of keeping turbines operational during icing events?
- Method:
  - Simulate energy losses which would have been incurred during icing for projects which remain operational during icing events
  - Compare actual to simulated losses
  - Assumptions about sensitivity of controller ice detection required.
- Impact on loads not considered



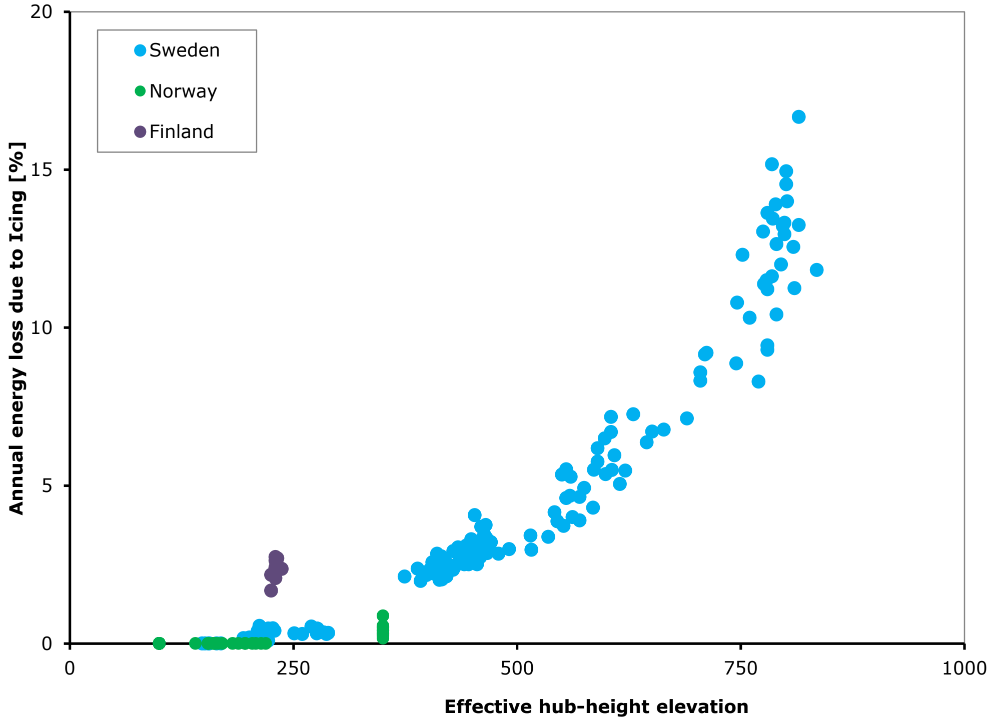
Inter-annual variability

- Question: How much do icing losses vary from year to year?
  - Derive monthly icing loss for each wind farm
  - Calculate annual icing loss (July to June) based on nominal production profile.
  - Only projects with very long operating periods useful
  - Inter-annual variability (IAV) defined by the coefficient of variation
- High mean loss coincides with low variability
- Low mean loss coincides with high variability
- Very long datasets required to accurately determine long-term mean losses



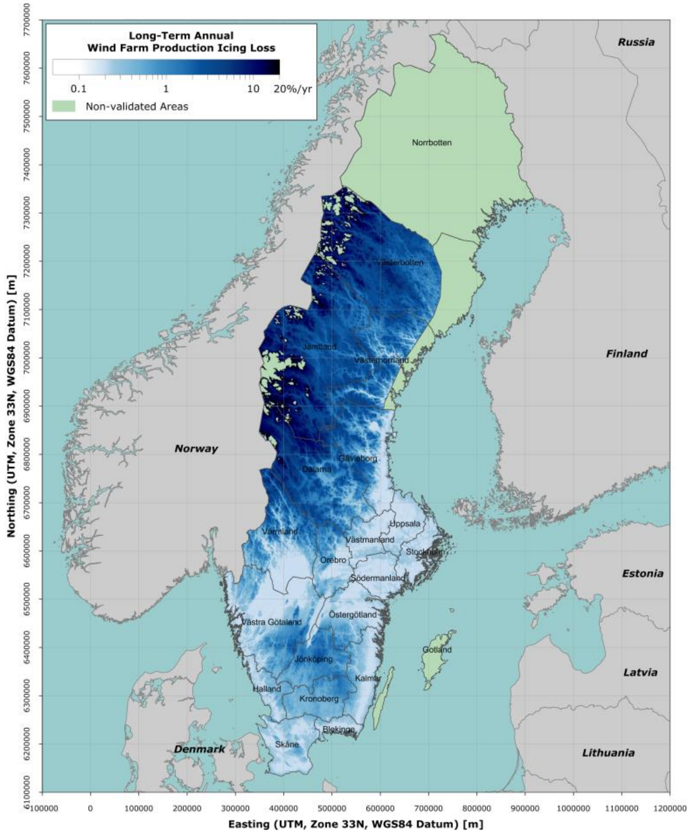
Importance of elevation

- Questions: How do icing losses vary with altitude?
  - Individual turbine mean annual losses calculated
  - Correlation of loss vs. effective hub-height
- Strong relationship between loss and elevation throughout Sweden;
- Coastal Norway and Finland do not follow trend of Swedish sites, although data-sets are small.



Icing loss climatology

- Relationship of annual icing loss and elevation used to define icing climatology
  – Represents loss for projects were turbines remain operational through icing events.
- Geographical coverage limited by:
  – Data availability
  – Reliability of loss / elevation relation
  – General experience of factors driving icing: cloud base elevation, Arctic / Siberian weather systems, Atlantic / Gulf stream effect.
- Uncertainty in loss estimate needs to be recognised
  – High variability inevitable leads to high uncertainty
  – Confidence elevated due to good length of datasets (6+ years) in combination with geographical diversity.



Conclusions

- Increased confidence in using elevation as a proxy for icing loss in Sweden
  - Deemed sufficient to create an icing loss climatology covering most of Sweden.
  - Initial results suggest the relationship is not applicable to Finland and coastal Norway.
  - More data required to patch gaps in Sweden, and understand Norwegian and Finish conditions.

- Great potential for reducing energy loss by keeping turbines operational through icing conditions, rather than shutting down.
  - Relative benefit diminishes with increasing icing loss.
  - Impact on loads not considered here.

- Inter-annual variability in icing losses is very high.
  - Measurement period in excess of 5 years required to reduce loss prediction error below 2% of AEP.

End

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