WICE 2.0 – The new generation of ice loss models

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Winterwind 2019, Umeå

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Part 1: Introduction and Methodology
Introduction

▪ In September 2018 DNV GL joined forces with WeatherTech.

The combined expertise of DNV GL and WeatherTech will enable the development of an innovative new icing model, which can be applied globally to better predict the performance of wind turbines in cold climates.

Published: 13 September 2018  Author: Morte Ghobadi  Keywords: Wind energy, Power and renewables

Contact: Pål Sigurðaröldur Regional Manager, Energy-North West Europe, Middle East & Africa

STOCKHOLM, Sweden - 13 September 2018 - DNV GL, the world’s largest resource of independent energy experts and certification body, today announced that it has joined forces with Swedish atmospheric science experts, WeatherTech. The combined expertise of both companies will enable the development of the most advanced icing model for wind turbines available on the market, allowing customers to better predict the performance of turbines in cold climates.
DNV GL
Empirical production loss model based on considerable amount of production and meteorological data

WeatherTech
A combined atmospheric and machine learning model to predict production losses, the WICE model.
Nordic operational data – Icing vs Elevation

Annual energy loss due to Icing [%]

Effective hub-height elevation

- South Sweden
- Mid Sweden
- North East Sweden
- Norway
- Finland
- Anti/De icing
- Terrain sheltering
A combination of physical and statistical modelling

ANN – Artificial Neural Network

Following IEA Task 19
WICE model chain

- **NWP**
  - WRF model
  - High resolution
  - Microphysics
  - 2013
  - 2016

- **Ice model**
  - Makkonen
  - Turbine blade
  - IPS
  - 2013
  - 2014
  - 2018

- **Production loss**
  - WICE
  - SCADA
  - 2013

- **Long term**
  - 30 yrs
  - Condensates
  - 2012
  - 2015
  - 2017
Part 2: Validation of WICE model chain
Validation

- 10 sites
- Chosen to cover different regions

SCADA
- 1-7 years of operational data
- 263 turbines

Weather modelling
- WRF
- In-house setup
- 1000m / 333m model grid resolution
Validation – weather modelling

- Time series and statistics have been analysed
  - In general a good agreement
Validation – WICE model chain: intra-farm variability

- Individual WTG losses
- SCADA vs WICE 1000m grid resolution
Validation – WICE model chain: intra-farm variability

- Individual WTG losses
- SCADA vs WICE 1000m and 333m grid resolution
Validation – WICE model chain: intra-farm variability

- Individual WTG losses
  - Terrain elevation vs SCADA

![Graph showing production loss vs terrain height](image)
Validation – WICE model chain: intra-farm variability

- Individual WTG losses
  - Terrain elevation vs SCADA and WICE 1000m grid resolution
Validation – WICE model chain: intra-farm variability

- Individual WTG losses
  - Terrain elevation vs SCADA, WICE 1000m and 333 grid resolution
Validation – WICE model chain: intra-farm variability

- Individual WTG losses
  - Turbines arranged by elevation.

<table>
<thead>
<tr>
<th></th>
<th>SCADA</th>
<th>WICE 1000m</th>
<th>WICE 333m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
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<td>7.9</td>
<td>8.4</td>
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<tr>
<td>Max</td>
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<td>9.4</td>
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<tr>
<td>Min</td>
<td>4.5</td>
<td>6.1</td>
<td>5.2</td>
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Validation – WICE model chain: long term correction

- Long term correction approach
  - One year with high resolution model data.
  - Long term reference modelled with coarser model grid resolution.

- Question:
  - How sensitive is the estimated long term production loss to which year that is modelled with high resolution?
Validation – WICE model chain: long term correction

- 4 years of WRF 1km and long term reference data
- Long term correction one season at a time

<table>
<thead>
<tr>
<th>Year</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<tr>
<td>High res</td>
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<td>6.2</td>
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</tbody>
</table>
Validation – WICE model chain: production losses

- Total wind farm losses
  - slope: 1.0533
  - std dev: 1.7064
  - corr: 0.9062
Validation – WICE model chain: production losses

- Total wind farm losses
  - slope: 1.0533
  - std dev: 1.7064
  - corr: 0.9062

Without outlier:
  - slope: 1.0008
  - std dev: 0.9667
  - corr: 0.9716
Part 3: Improvements – WICE2.0
What is new
  – Training data from new sites (and more coming soon)
  – Machine learning improvements:
    – “Extreme Gradient Boosting” (XGBoost) – a tree-based model that typically performs better than neural networks on this kind of multi-dimensional regression problem
    – Refinements to feature selection and feature engineering
  – Updated long term correction method
WICE 2.0

- Icing losses estimated by WICE2.0 are in line with previous DNV GL models
  - Outliers are better represented
Conclusions
Conclusions

- In general a good agreement between modelled and observed wind and temperature
- Capture intra-farm variability quite well
  - a higher model grid resolution is recommended for sites with complex terrain
- Estimated long term losses agree well with observed losses
- Icing losses estimated by WICE2.0 are in line with previous DNV GL models
Thanks for listening

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