

Estimating wind power production losses due to icing, Vindforsk V-313

presented at

Winterwind 2013, Östersund 12-13 feb.

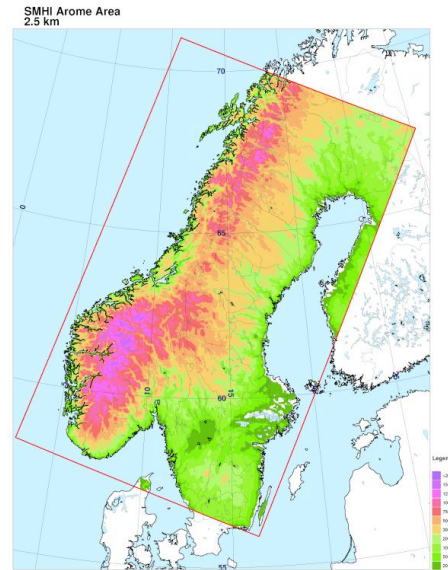
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Outline

- Meteorological Models
- Icing calculations
- Relating icing to power loss
- Results from last winter
- Forecasting power production loss

Meteorological Models

- AROME (ECMWF/HIRLAM)
 - 2.5 km, 65 levels
- COAMPS (GFS)
 - 1-3 km, 40 levels
- WRF (GFS)
 - 1-3 km, 40 levels



Icing calculations

The Makkonen icing equation has been used:

$$\frac{Dm}{dt} = \alpha_1 \alpha_2 \alpha_3 wAV - Q$$

- Makkonen is originally designed for cloud water only.
- Probably also frozen particles contributes to ice loads when there is a mix of liquid and frozen.
- Equations have been modified to take this effect into account.
- Further research needed on this issue.



Relating icing to power production losses

- Relationship between observed ice loads and ice loads on wind turbine blades not known.
- Compare observed ice loads, where available, with observed production losses to establish empirical relations between them.
- Uncertainties in the observed ice loads, (instruments not totally reliable) means uncertainties in these relationships.
- Power curves are calculated using “ice free” production data.
- Comparisons of observed ice loads and production data suggests that losses mainly occur during ice build-up.
- When the ice build-up ends the production picks up rather quickly.
- The losses are greater at low wind speeds.

Results from last winter

- Observed and forecasted power production losses are shown.
- Two sites in Northern Sweden.
- Icing calculated using cloud water only and using all condensates.
- The observed losses are mean values calculated from all turbines at each site.
- The tables on the following slides shows monthly model estimated and observed losses in percent.
- cw = cloudwater only all = all condensates used

Results from last winter

Site 1

Year Month	arome cw	coamps cw	wrf cw	arome all	coamps all	wrf all	obs
201110	2	3	2	2	4	3	0
201111	3	4	3	6	5	6	3
201112	6	17	10	39	42	52	22
201201	1	9	17	16	21	46	53
201202	0	3	9	8	5	12	12
201203	1	4	8	9	5	13	1
201204	3	11	13	17	23	52	1

Results from last winter

- Comments on the results site 1:
 - High observed production losses for December-February.
 - The modelled losses are higher using all condensates as expected.
 - They are close to the observed values for some months, a bit further away for some of the others.
 - It's only WRF with all condensates that is close to the observed high value in January.
 - All models predict rather high production losses for April but the observed value is low.

Results from last winter

Site 2

Year Month	arome cw	coamps cw	wrf cw	arome all	coamps all	wrf all	obs
201110	5	6	5	6	9	6	5
201111	6	5	5	13	8	7	6
201112	13	19	19	57	34	55	28
201201	5	10	21	46	32	41	47
201202	4	7	12	14	13	28	29
201203	3	8	6	11	13	11	4
201204	6	14	13	15	29	32	12

Results from last winter

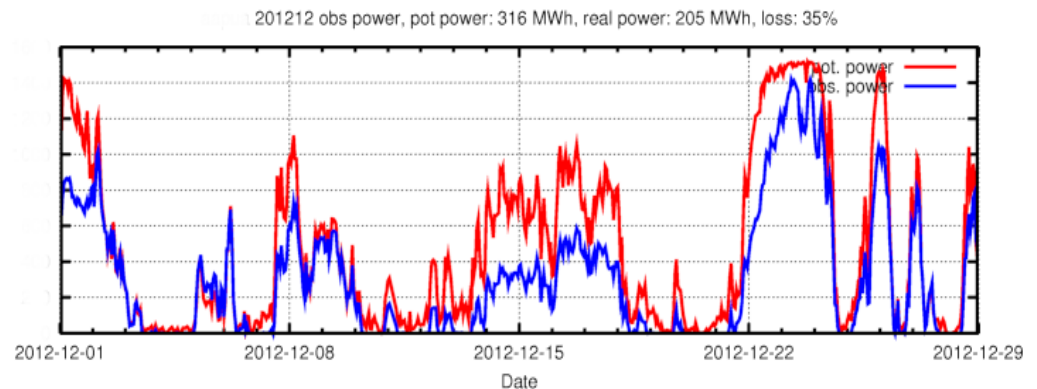
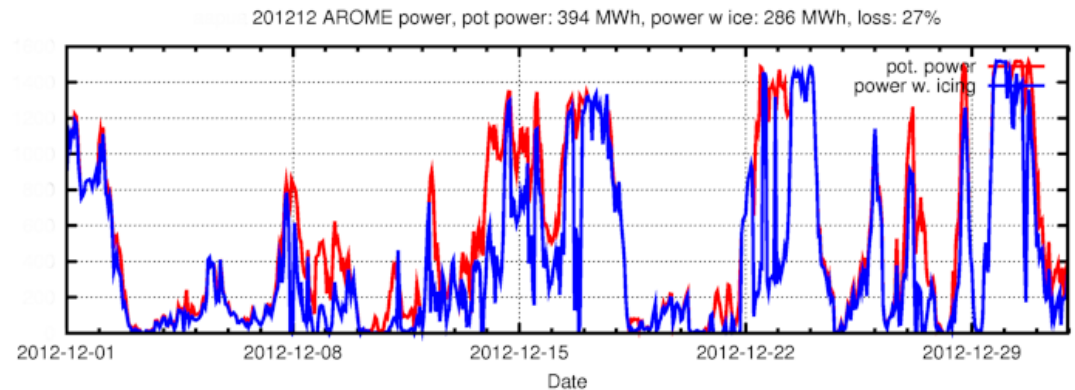
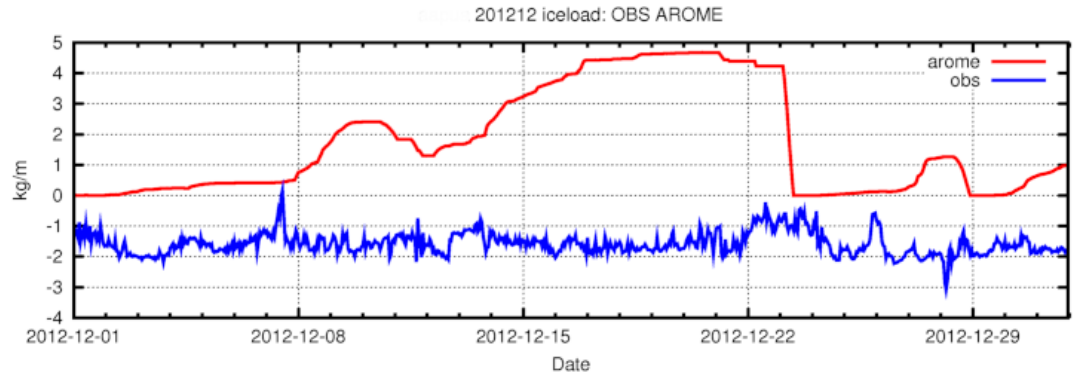
- Comments on the results site 2:
 - The observed losses are high, especially for December-February and a rather high value also for April.
 - The model (all condensates) estimated losses are too high in December, fairly close in January and for February WRF is almost spot on but the other two are a bit low.
 - All models are a bit on the high side in March and April.

Example this winter

Figures shows:

1. modelled and observed ice load
2. modelled potential power and power taking icing into account.
3. potential power using observed wind speed and observed power

Both modelled and observed potential power are calculated using an “ice free” power curve.



Forecasting power production loss

- The method presented to relate icing to power production losses can also be used in forecasting mode.
- Meso-scale models are typically run up to 48 hours ahead, 4 times every day.
- Their output can be used to predict production losses due to icing hour by hour.
- As shown there are still uncertainties in the empirical relationships which of course also makes forecasts a bit uncertain.
- Forecasts can hint when icing will occur but maybe the severity will be hard to predict in detail.
- There are some tests going on this winter.