MEASURING ROUTINES OF ICE ACCRETION FOR WIND TURBINE APPLICATIONS

The correlation between production losses and detection of ice

WINTERWIND 2011, VIKTOR CARLSSON

SKELLEFTEÅ kraft

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Photo: Kent Larsson, abvee

Introduction – Scope and purpose

Master thesis in engineering physics at Umeå University in 2010

Work preformed at Skellefteå Kraft AB, data provided from two wind parks in northern Sweden

Aim:

Preform a survey in the subject; Wind power in cold climates with the focus on ice measurements.

Evaluate if standard measurements can be used to evaluate icing.

Find a correlation between ice measured on a stationary sensor and ice accreted on a moving rotor blade, the presence of ice on the rotor blade will be assumed from deviations in the power curve.

Introduction – Issues treated

STANDARD MEASUREMENT

STATIONARY ICE SENSORS

ICE ACCRETION ON WIND TURBINE

WIND SPEED

HUMIDITY

TEMPERATURE

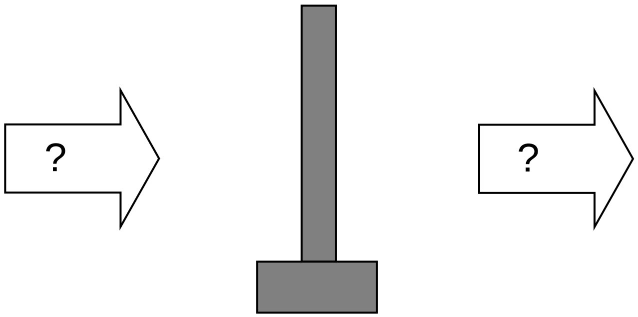


Photo taken at Uljabuouda,
Skellefteå Kraft AB

Theory – Physical model used

The ice rate can be described by:

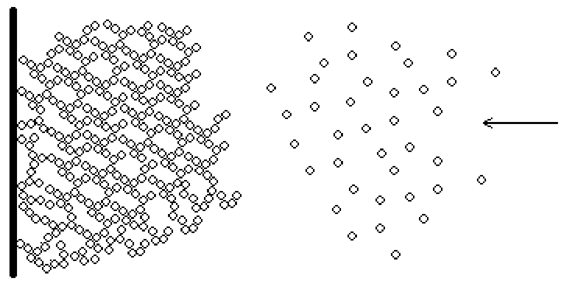
$$\frac{dm}{dt}=\eta_1\eta_2\eta_3 w v A$$

where *m* is the mass of the accreted ice, η are constants describing the accretion efficiency *w* is the mass concentration of liquid water droplets, *A* is the area and *v* is the wind speed.

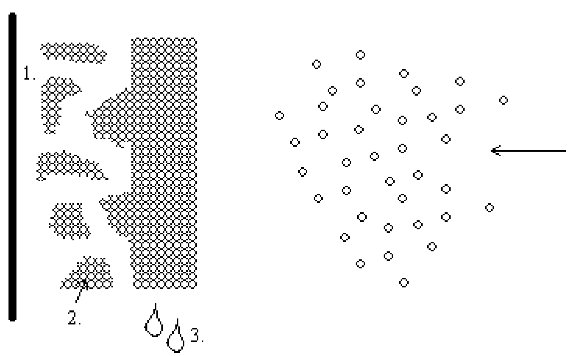
This can be simplified according to the ISO-standard:

$$\frac{dm}{dt}=0.1A$$

DRY GROWTH OF RIME ICE



WET GROWTH OF CLEAR ICE



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Method – Description of the wind farm used in the analysis

Site A

Several multi megawatt wind turbines

Has got no anti- or de-icing equipment

Heavy icing has previously been recorded.

Stationary ice sensor installed at a met mast 18 meter above ground level.

Data from half of the winter 2009-2010

Site B

Several multi megawatt wind turbines

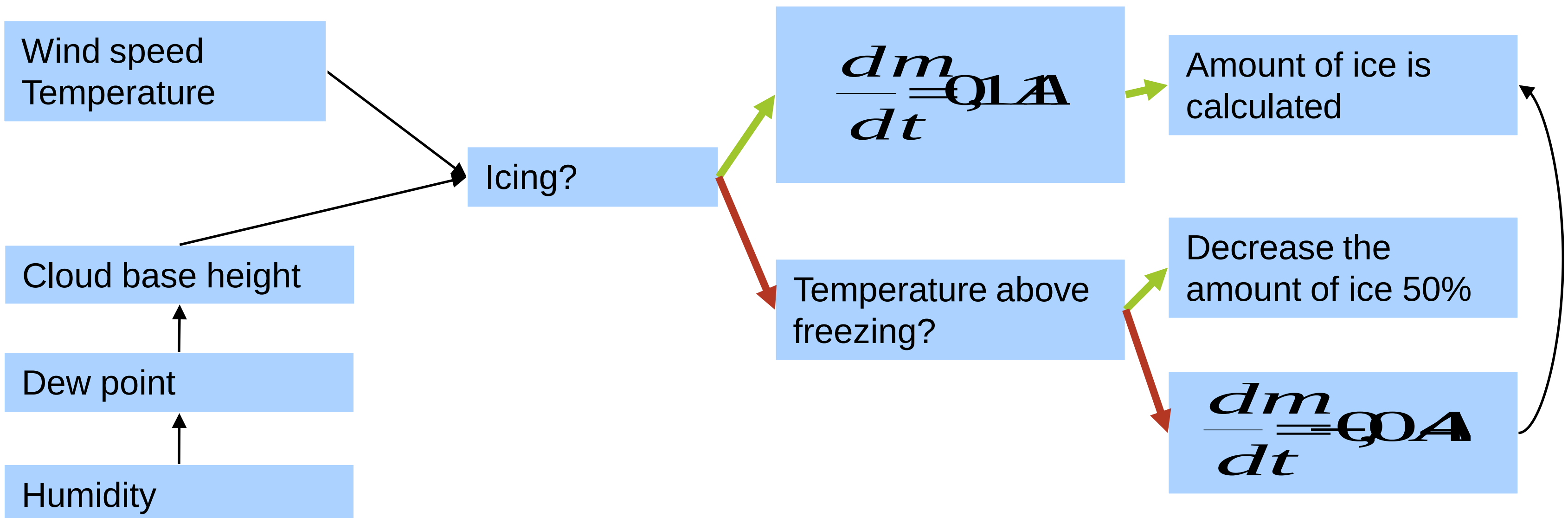
Has got no anti- or de-icing equipment

Heavy icing has previously been recorded

Two stationary ice sensors of different types installed at one of the nacelles

Data from the winter 2008-2009 and half of the winter 2009-2010

Method – Simple modeling algorithm



Results – Modeling

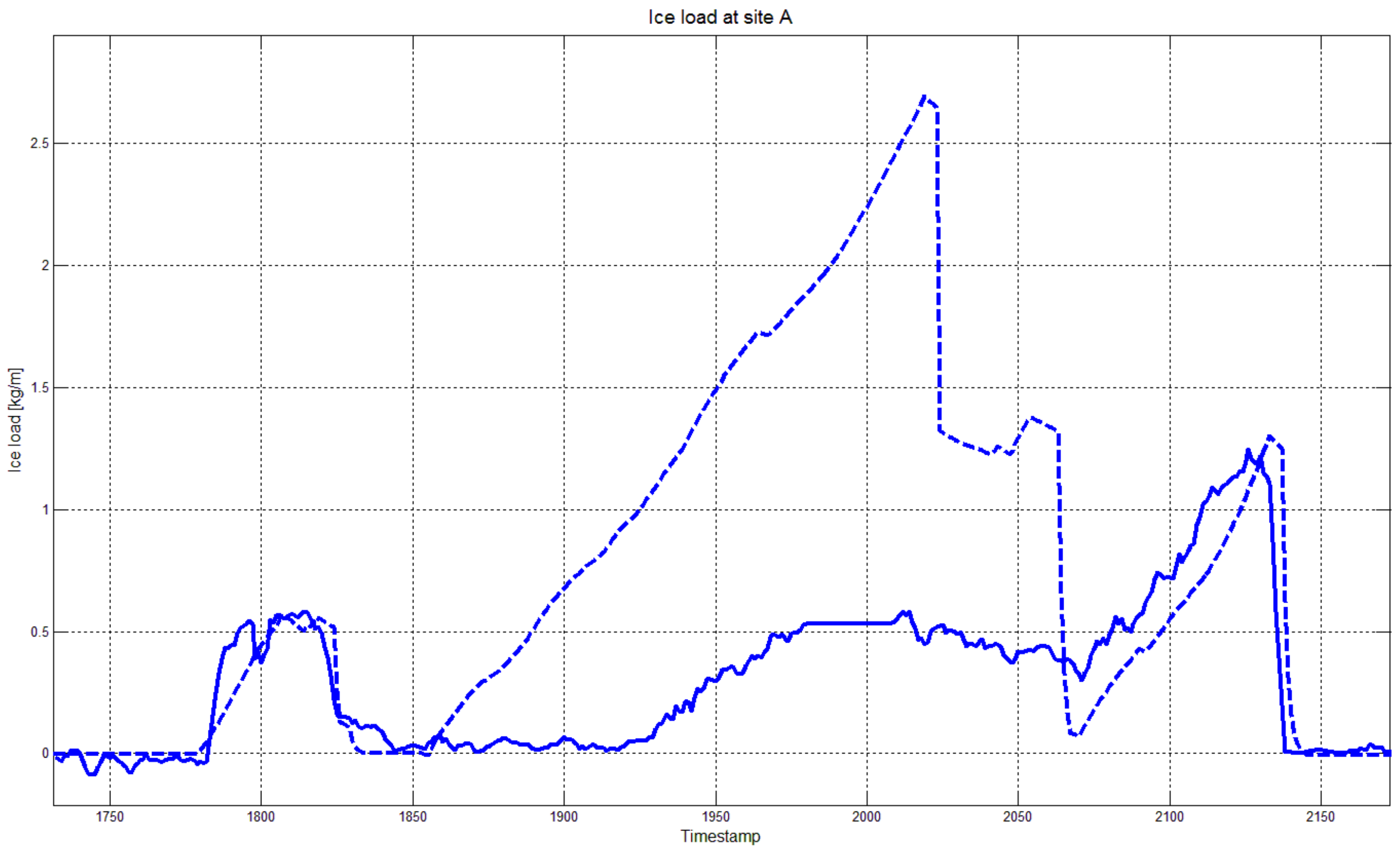
The time of icing is overestimated due to frozen humidity sensors and low availability of data.

However the start of an icing period can be estimated quite well.

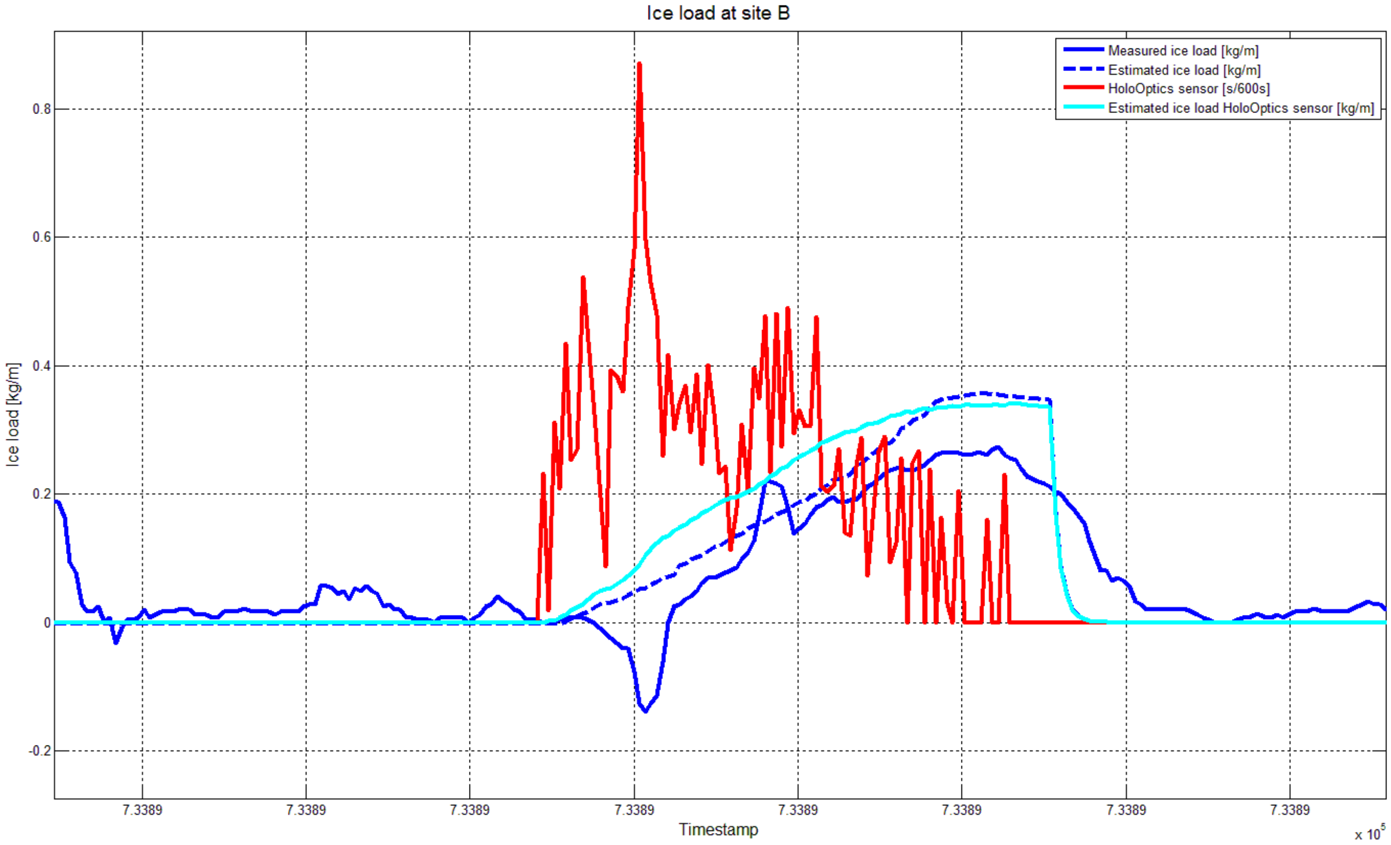
Icing conditions estimated				
Parameter	**Site A**		**Site B**	
	Measured	Model	Measured	Model
Active icing time	15.8%	28.5%	23.2%	27.8%
Maximum ice load [kg/m]	3.05	5.53	11.4	16.8

The table show an overview of the results obtained.

Result – Modeling at site A

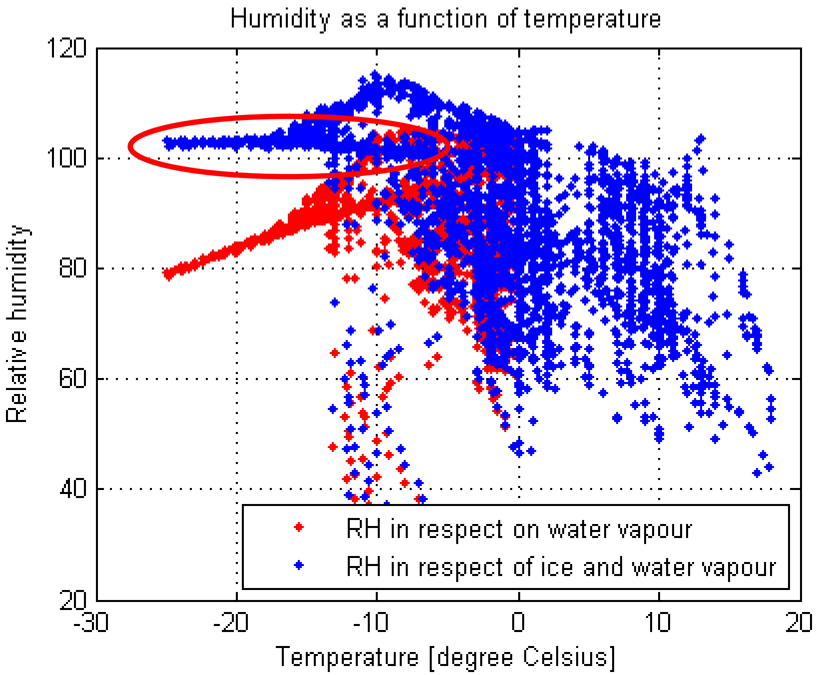


Result – Modeling at site B

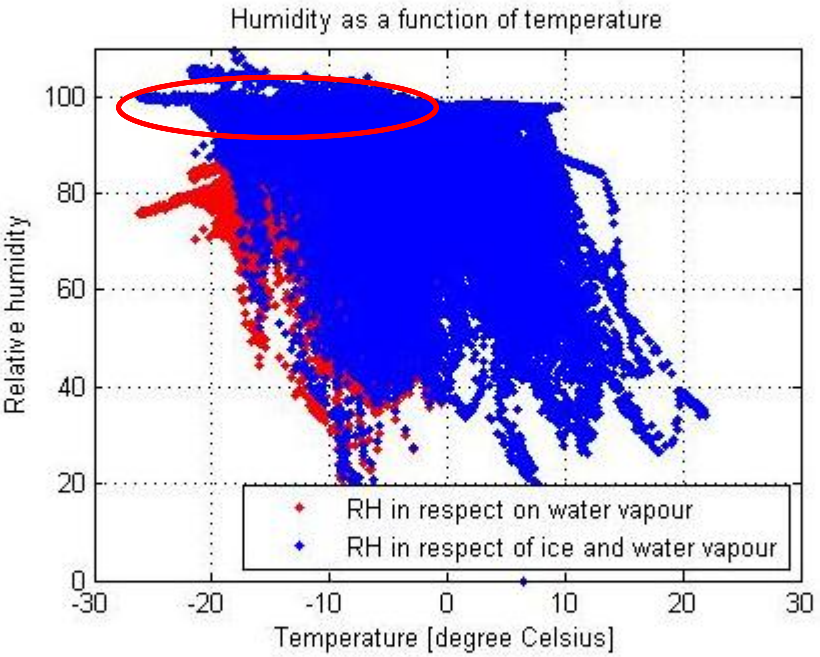


Results – Probable cause of overestimation

Site A



Site B



Conclusion: Use heated sensors if possible

Issues treated

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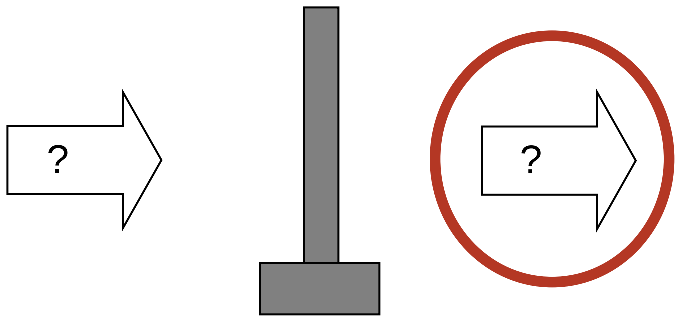


Photo taken at Uljabuouda,
Skellefteå Kraft AB

Method – Correlation between icing measurements and production losses

Definition of icing event:

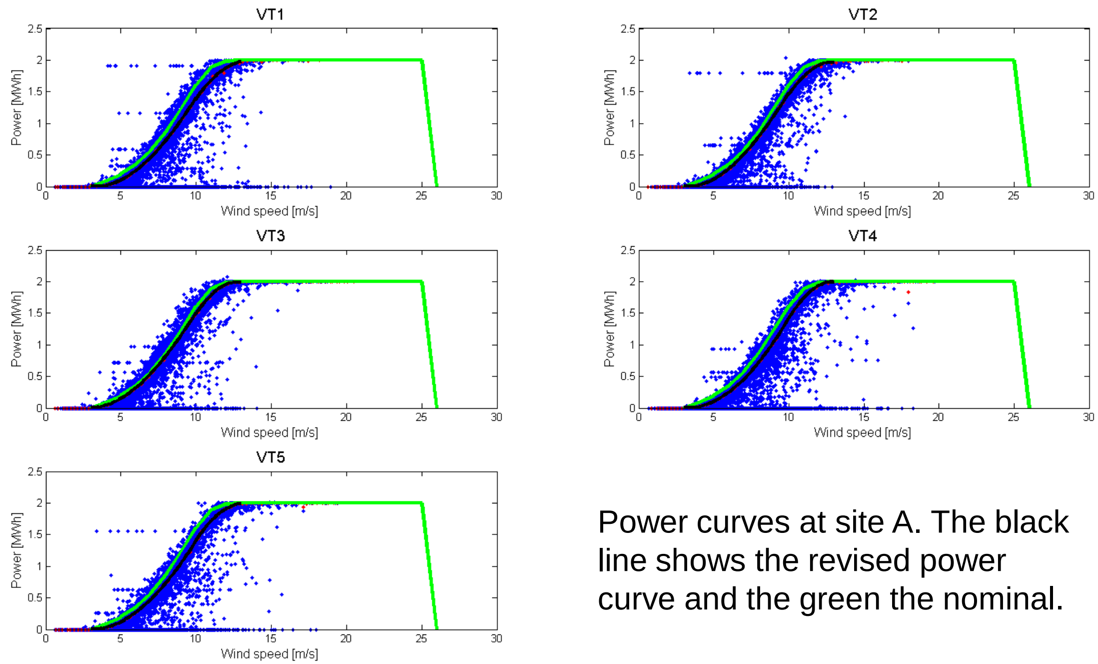
The ratio between real and estimated power is less than 0.85.

$$ratio = \frac{P_{rea}}{P_{non}}$$

1.Calculation of power curve.

2.Selection of icing events according to the definition.

At site B events when the ice sensors indicated was chosen.



Power curves at site A. The black line shows the revised power curve and the green the nominal.

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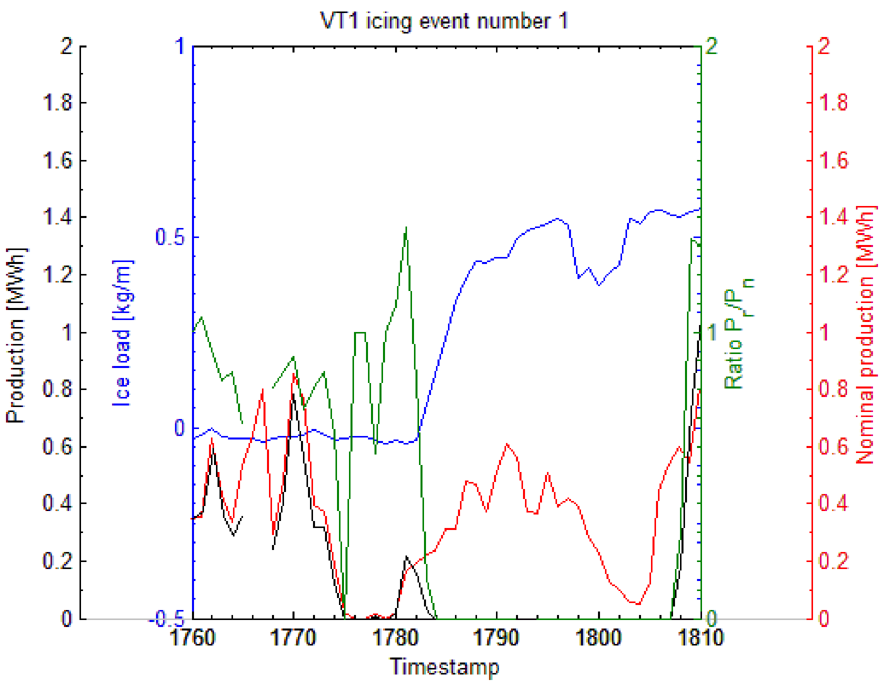
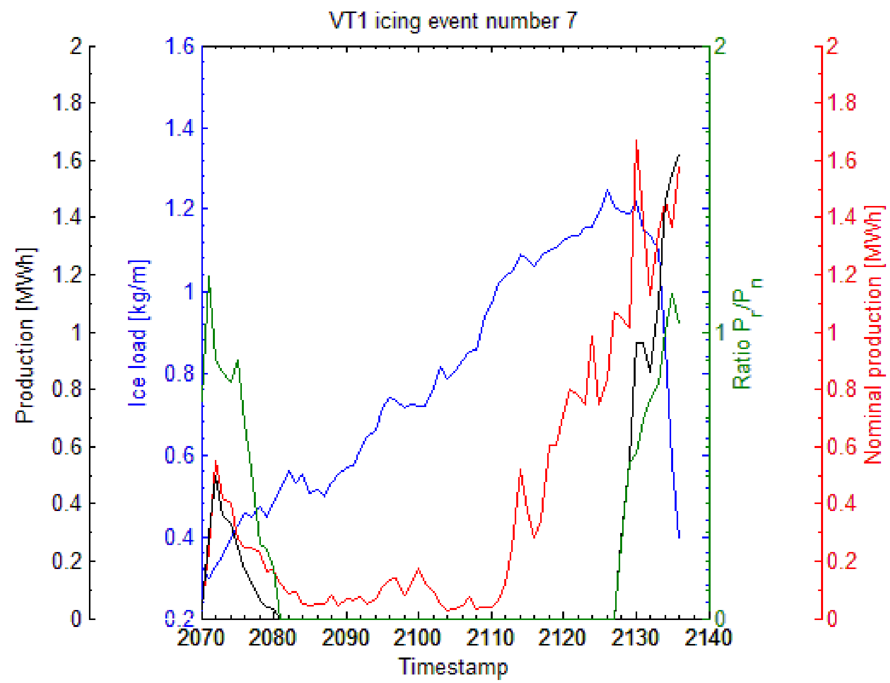
Results – Correlation between icing measurements and production losses at site A





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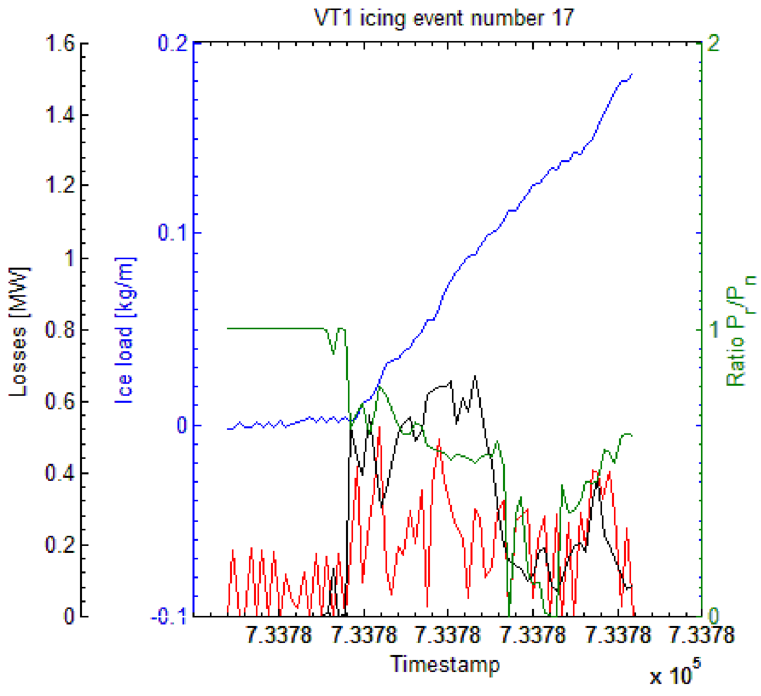
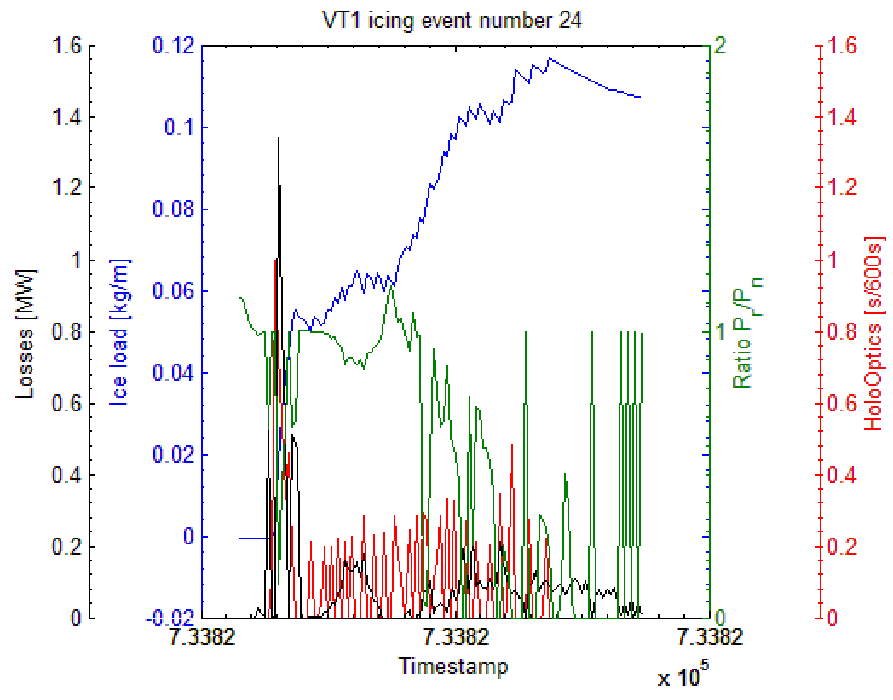
Results – Correlation between icing measurements and production losses at site B

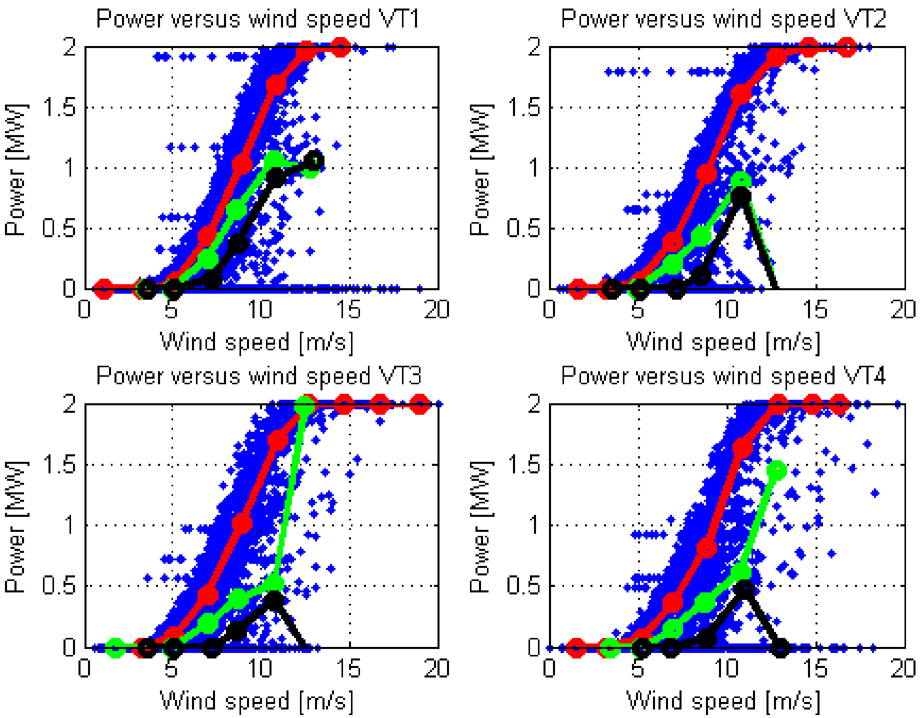




Results – Production losses at certain ice rates, site A

At site A, it appears that production losses are slightly larger (the black line) at the icing rate > 0.1 hg / mh than at> 0.02 hg / mh (the green curve).

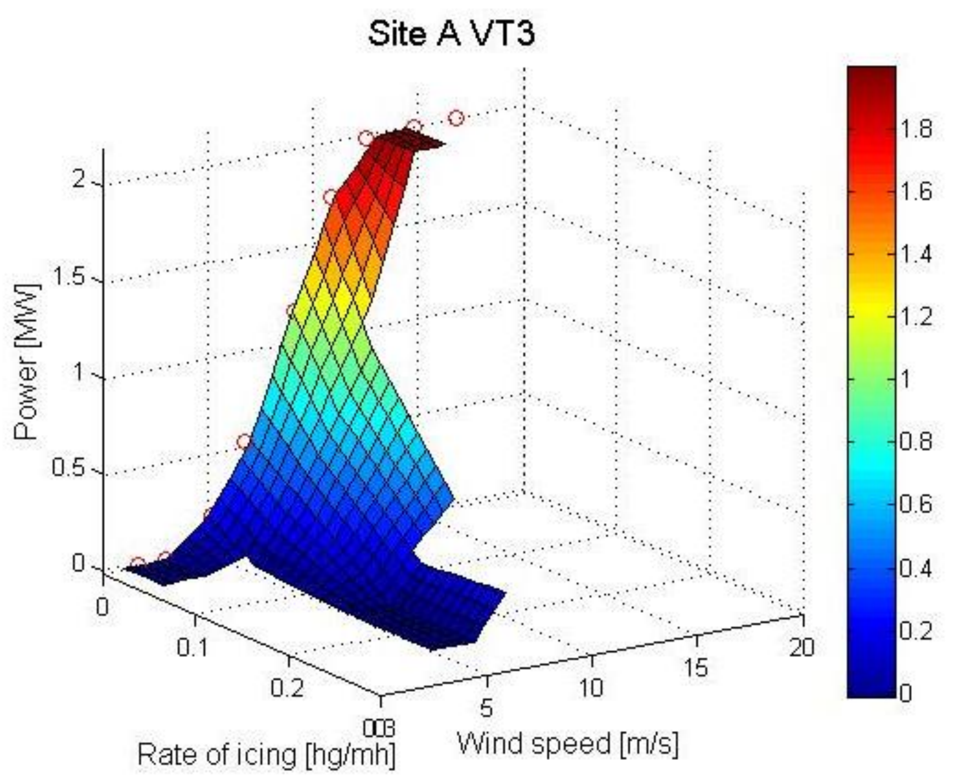
It is difficult to provide general results due to limited amounts of data and that the turbines often stop at heavy icing.



Results – Production losses at certain ice rates, site A

It is difficult to extend this to certain wind speeds and rates of icing due to limited amount of data.

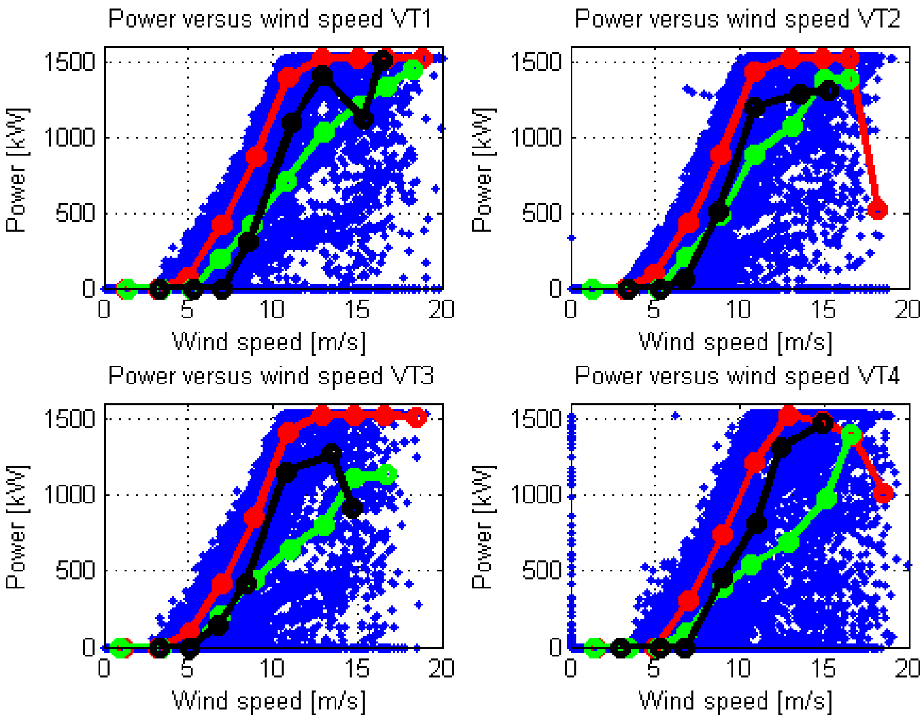
To the right is an attempt made to determine the effect as a function of icing and wind speed.



Results – Production losses at certain ice rates, site B

At site B, one can not draw any conclusions on the production losses at certain ice rates.

This can be seen in the figure to the right. The black line shows the median production at events when the icing sensor gave an output larger than 50 % of maximum output and the green line showed the median of all ice events.



Issues treated

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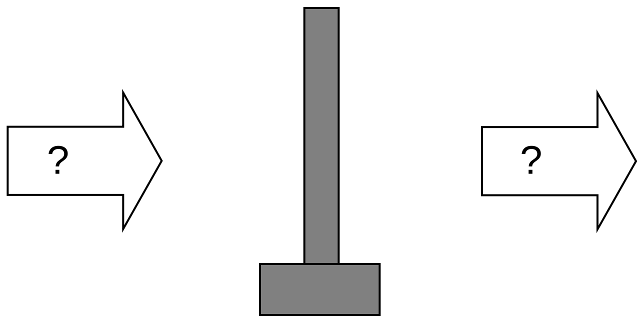


Photo taken at Uljabuouda,
Skellefteå Kraft AB

Are the questions answered?

Conclusions

Modeling

Rough estimates of time of icing can be made using standard measurements.

Difficult to determine the icing rate correctly with the method used.

Recommendations of ice sensors

Both sensors used in the analysis had some problems which indicates that it might be useful to use a combination of different sensors/techniques to control an anti-/de-icing system.

Correlation between icing measurement and production losses (icing of blades)

A clear correlation in most cases. When icing started on the stationary sensor the production started to deviate from the expected production.

Difficult to determine the production loss to a certain degree of icing and wind speed.

Indicative results that stationary ice sensors could be used to operate a de-icing systems.

Discussion

Short period

Low availability of ice measurements

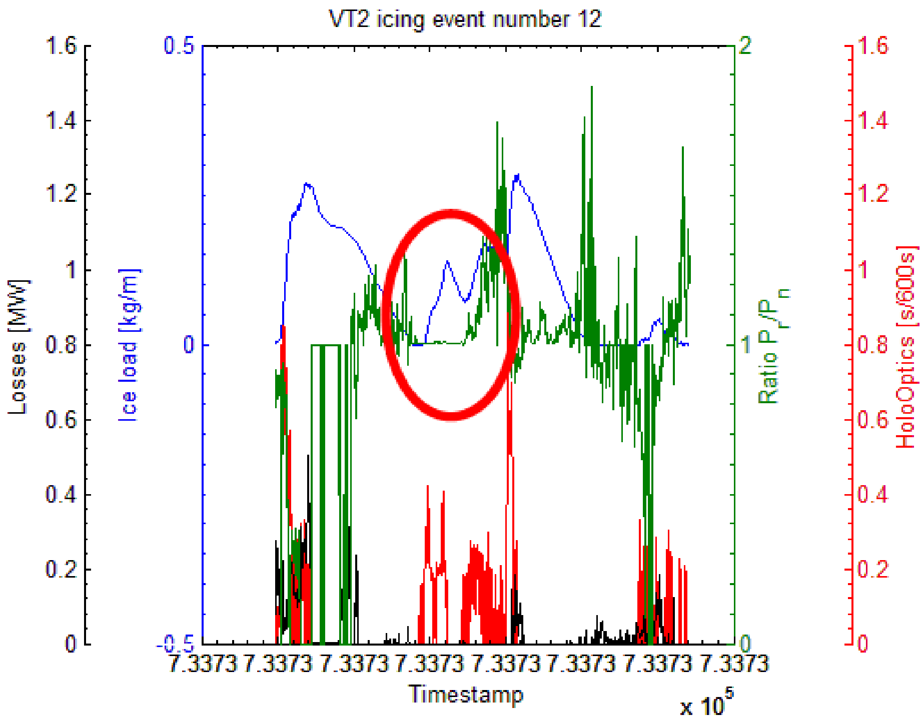
Uncertainties in the ice measurements

Frozen sensors

Assumption that reduced production due to icing, no consideration to e.g. wind direction was taken

Different time resolution of some data

Data processing, including average, floating average



Further work

Longer period of time and more sites

Camera showing the blades and/or observations at the site

Heated probe on the humidity sensor

Correlation between stationary sensors and sensors which measure the icing on the rotor blades should be examined

Simulations

Thank you for your attention!

The report in full text is available at
www.ub.umu.se in the DIVA-database.