A novel model approach to test de-icing strategies and de-icing efficiency

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Introduction

A novel test of de-icing strategies and de-icing efficiency

- how much can the production losses be reduced by installing a de-icing system?

A few (but a growing number) turbines with de-icing systems are offered today

- control system and detection varies.

Objective of presentation:

- a principal understanding of how a de-icing system can reduce production losses depending on system setup.

WRF model data

Basis for the study

- Modelled atmospheric data from a high resolution WRF model run
  - www.wrf-model.org
  - 1x1 km^2 model grid resolution
  - One full year modelled, Sept 2012 to Aug 2013
  - Wind speed/direction, pressure, temperature, cloud condensates
  - Thompson microphysics, YSU PBL, Noah land surface

Production loss due to icing

Cloud water droplets & T< 0

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Accretion of ice on turbine blade

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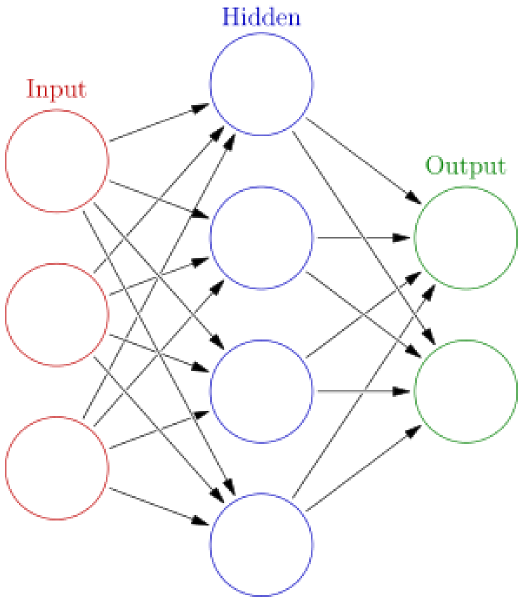
Reduced efficiency of turbine

WICE – Weathertech ICE model

- Artifical Neural Network
  - Trained with clean and iced production
  - Mesoscale model data and modelled iceload as input
- Tested for different turbines and locations
- The production loss model can be used in two modes:
  - Site assessment (shooting blind). Possible to use different turbine types.
  - Forecasting. If available, site specific data can be used to train the model.



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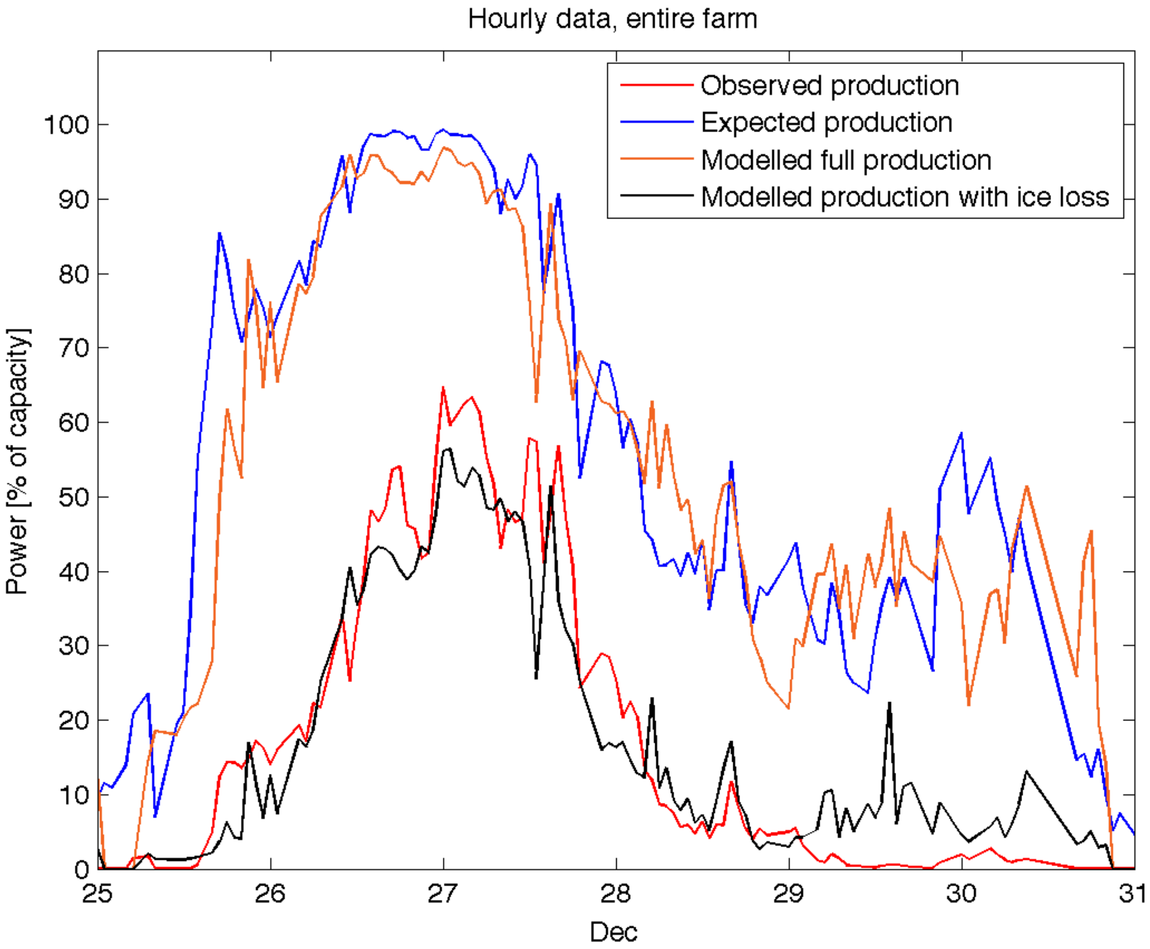
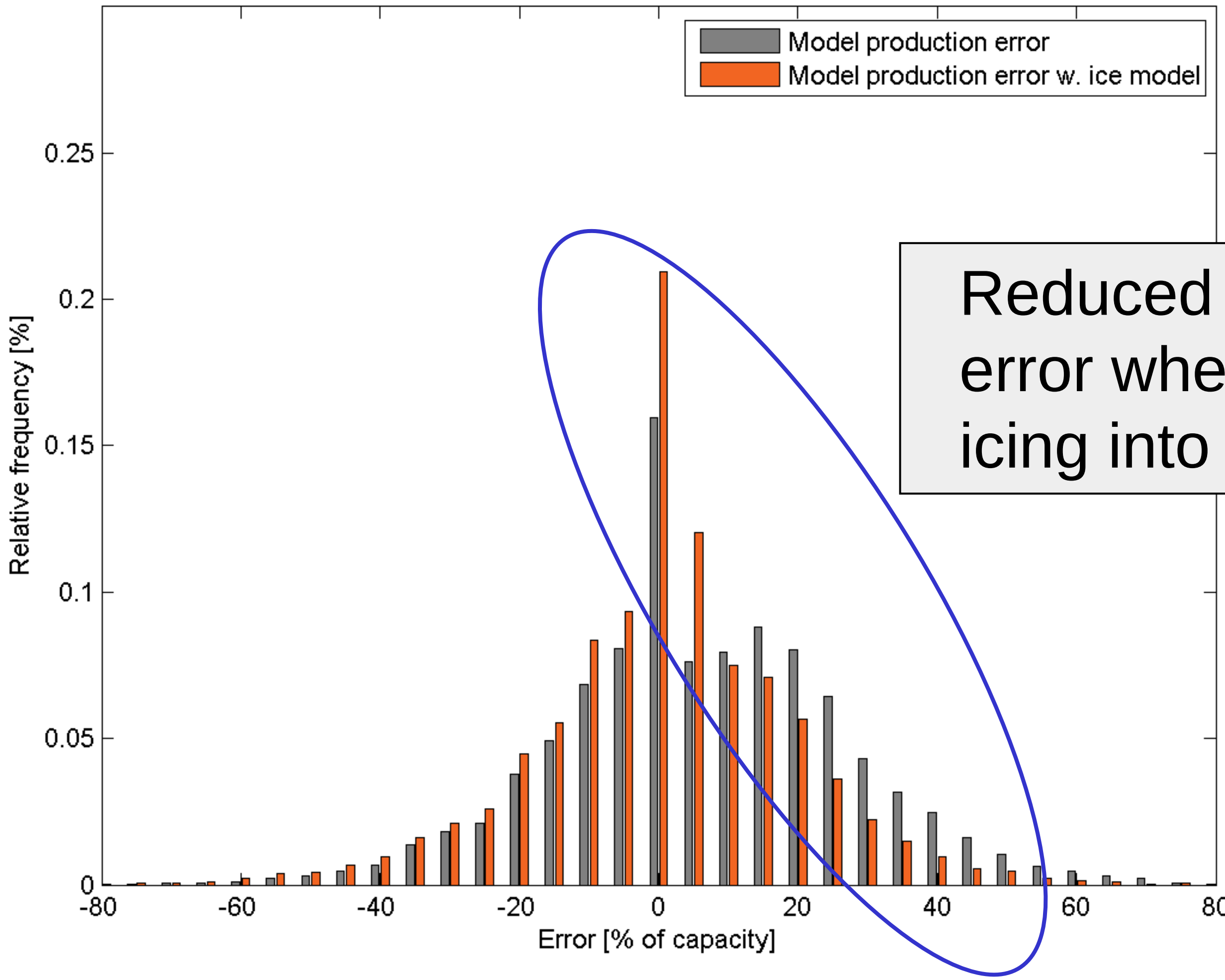
Icing event example



Icing event example



Reduced forecast error when taking icing into account.

De-icing model

A simplified model to describe a de-icing system.

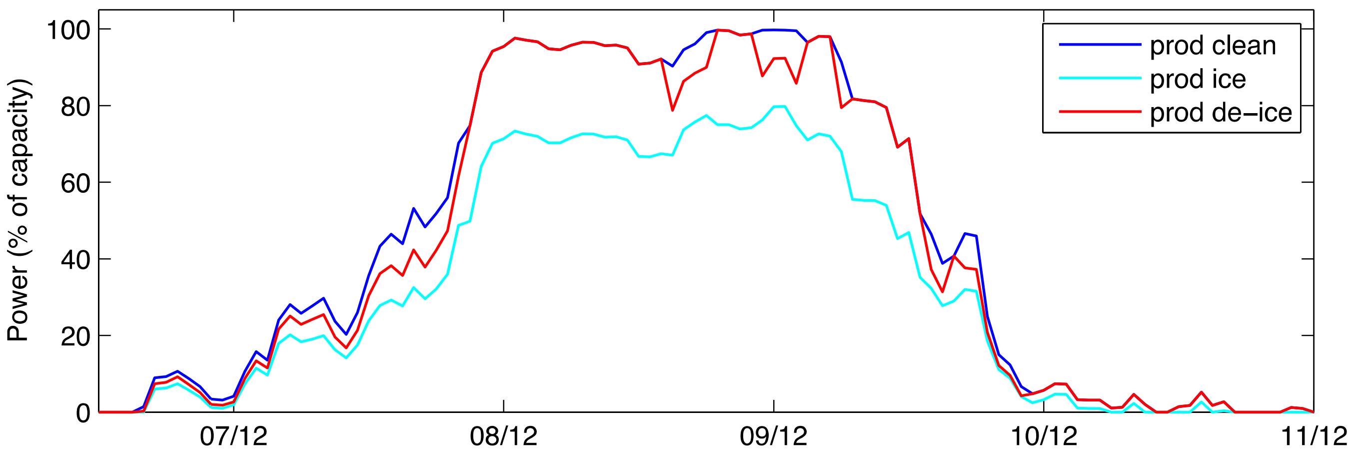
Omitted:

- overheating of blades
- shortage of power necessary for de-icing
- stand stills (health and security)

Base setup:

- De-icing started when ice has started to build on the blades.
- The turbine is able to generate power while de-icing
- Ice accreted during one hour is removed in the next hour
- The system can operate in all temperatures

De-icing model



De-icing – results I

2012-09-01 to 2013-08-31, 100m hub height, generic 2MW turbine

De-ice case	Temperature limit °C	Detection	Prod_clean MWh	Prod_ice MWh	Prod_loss %
-	-		6089.6	5484.3	9.9

De-icing – results I

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De-ice case	Temperature limit °C	Detection	Prod_clean MWh	Prod_ice MWh	Prod_loss %
-	-		6089.6	5484.3	9.9
1	none	Ongoing icing	6089.6	5997.3	1.5

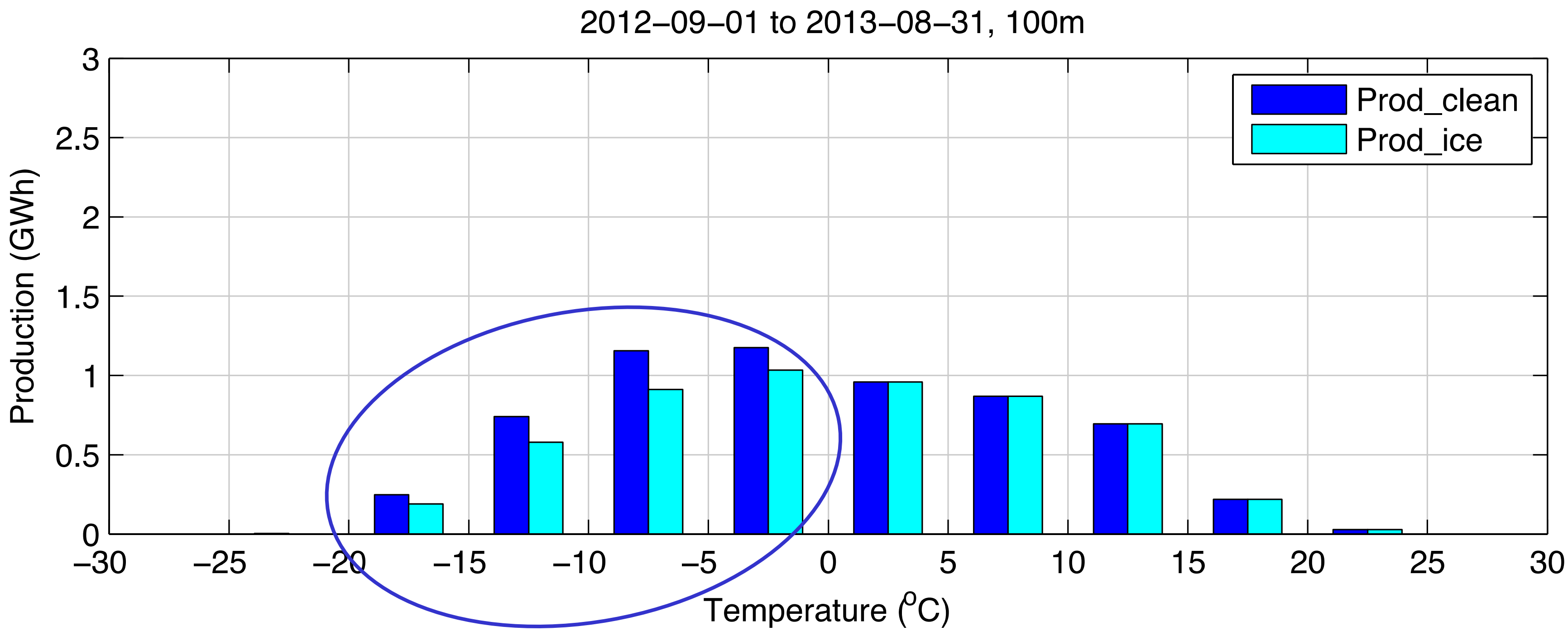
Significant reduction in production losses

De-icing – operating conditions

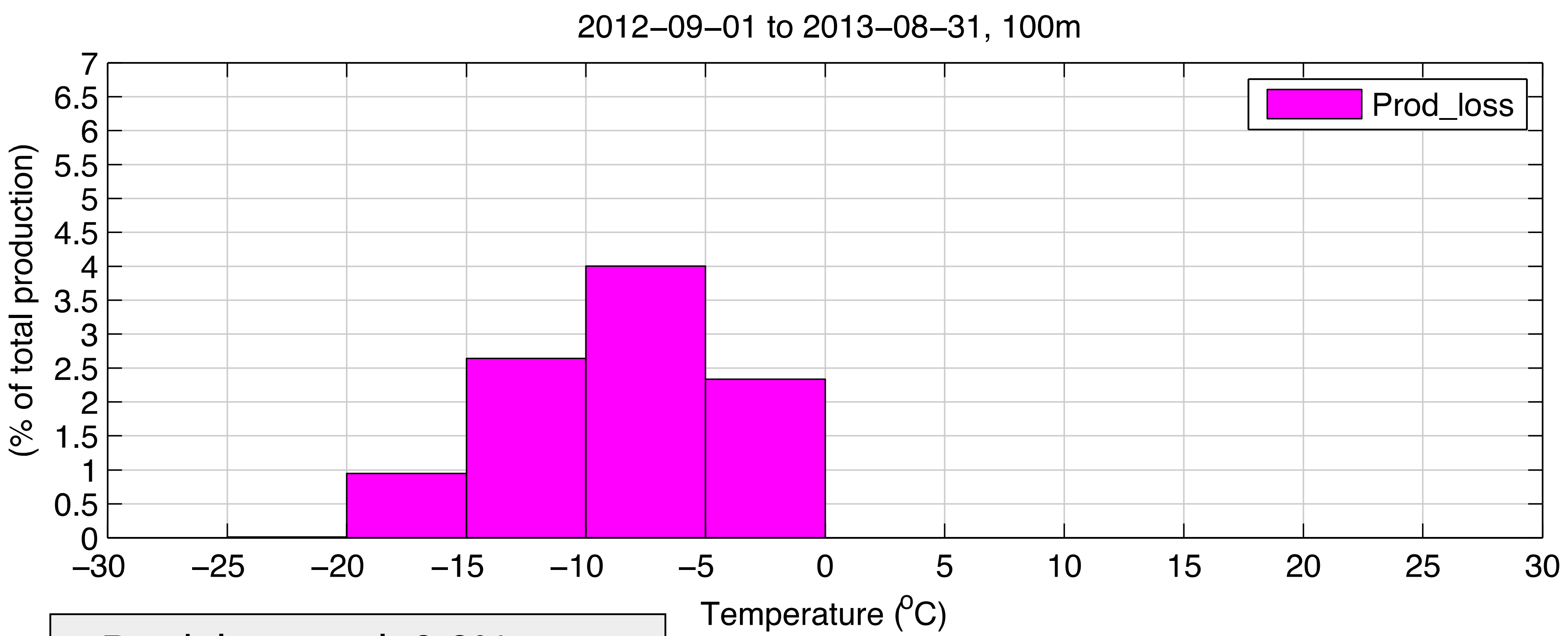
Temperature limits:

- Temperatures down to -5 ^{o}C
- Temperatures down to -10 ^{o}C
- Temperatures down to -15 ^{o}C

Production losses and temperature



Production losses and temperature



Prod_loss total: 9.9%

Prod_loss T < -15 °C: ~1%

Prod_loss T < -10 °C: 3.6%

Prod_loss T < -5 °C: 7.6%

De-icing – results II

2012-09-01 to 2013-08-31, 100m hub height, generic 2MW turbine

De-ice case	Temperature limit °C	Detection	Prod_clean MWh	Prod_ice MWh	Prod_loss %
-	-		6089.6	5484.3	9.9
1	none	Ongoing icing	6089.6	5997.3	1.5
2	-15.0	Ongoing icing	6089.6	5974.2	1.9
3	-10.0	Ongoing icing	6089.6	5886.6	3.3
4	-5.0	Ongoing icing	6089.6	5714.9	6.2

Still a considerable production loss

De-icing – detection

Power loss:

- Deviations from the expected power for a given wind speed and power curve

Detection limits: production loss 5%, 10%, 15%, and 20%

De-icing – results III

2012-09-01 to 2013-08-31, 100m hub height, generic 2MW turbine

De-ice case	Temperature limit °C	Detection	Prod_clean MWh	Prod_ice MWh	Prod_loss %
-	-		6089.6	5484.3	9.9
1	none	Ongoing icing	6089.6	5997.3	1.5
2	-15.0	Ongoing icing	6089.6	5974.2	1.9
3	-10.0	Ongoing icing	6089.6	5886.6	3.3
4	-5.0	Ongoing icing	6089.6	5714.9	6.2
5	none	P_loss 5%	6089.6	5967.4	2.0
6	none	P_loss 10%	6089.6	5946.8	2.3
7	none	P_loss 15%	6089.6	5929.9	2.6
8	none	P_loss 20%	6089.6	5892.9	3.2

Not as sensitive to detection limits as to temperature limits

De-icing – operation mode

In operation:

- The turbine is able to generate power while de-icing

Stopped:

- The turbine is stopped or idling during the de-icing cycle

De-icing – results IV

2012-09-01 to 2013-08-31, 100m hub height, generic 2MW turbine

De-ice case	Temperature limit °C	Detection	Prod_loss in operation %
-	-		9.9
5	none	P_loss 5%	2.0
6	none	P_loss 10%	2.3
7	none	P_loss 15%	2.6
8	none	P_loss 20%	3.2

De-icing – results IV

2012-09-01 to 2013-08-31, 100m hub height, generic 2MW turbine

De-ice case	Temperature limit °C	Detection	Prod_loss in operation %	Prod_loss stopped %
-	-		9.9	
5	none	P_loss 5%	2.0	10.3
6	none	P_loss 10%	2.3	7.4
7	none	P_loss 15%	2.6	5.9
8	none	P_loss 20%	3.2	4.5

Benefit of the de-icing system sensitive to detection limits if the turbine is stopped while de-icing.

Summary

A well designed de-icing system will reduce the production losses

- A de-icing system should be able to operate in temperatures at least down to -10 ^{o}C.
- If the turbine is able to generate power while de-icing the benifit of the system is not as sensitive to detection limits as to ambient temperature. But, a few % can be gained if the detection limits are chosen wisely
- If the turbine is idling while de-icing, finding optimal detection limits for activation of the system is critical for the system performance.