Assessing energy production gains in icing conditions when utilizing de-icing equipped wind turbines under different operational modes

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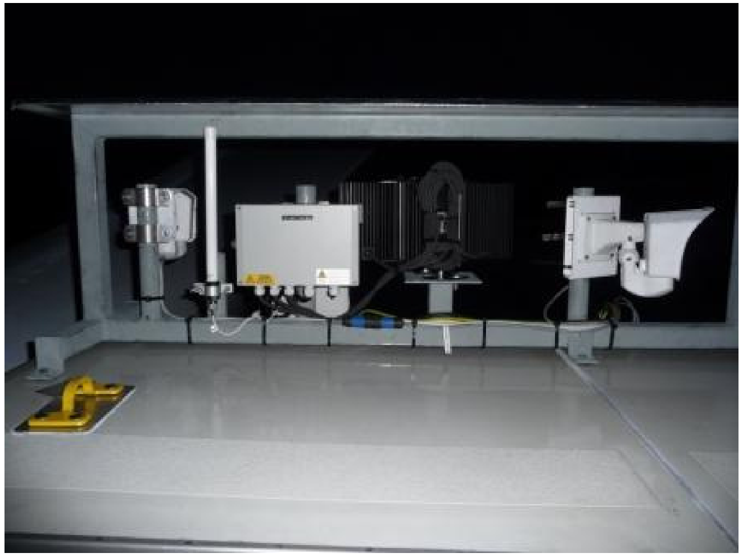
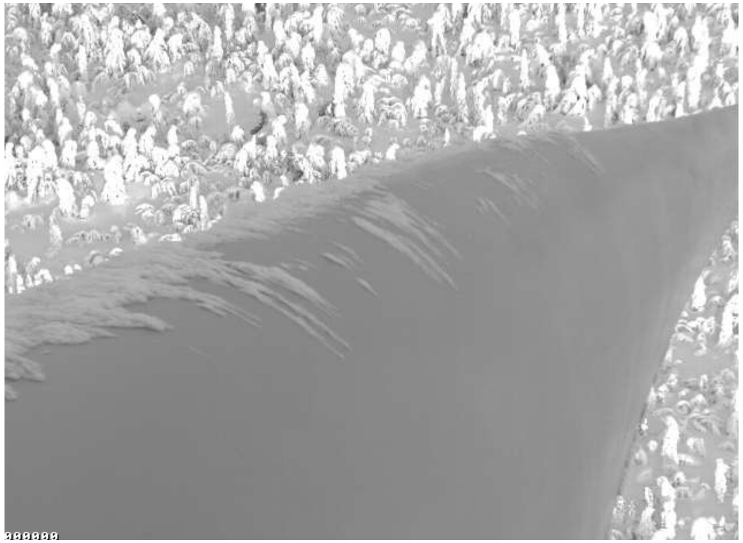
Background

- Since 2011, Vattenfall coordinates an internal R&D program in Icing (TIP Program)
  - Ice detection & measurements
  - Mitigation technologies
  - O&M adaption to cold climate
  - Modelling
  - Health & Safety (ice throw risk)
- 6 Master thesis, 1 PhD (started this January)
- Ultimate goal: Gain knowledge / expertise for proper development of Wind Energy in Cold Climate
- Modelling → Assessment of site specific production losses due to icing
  - Develop in-house competence that supports project related decision making





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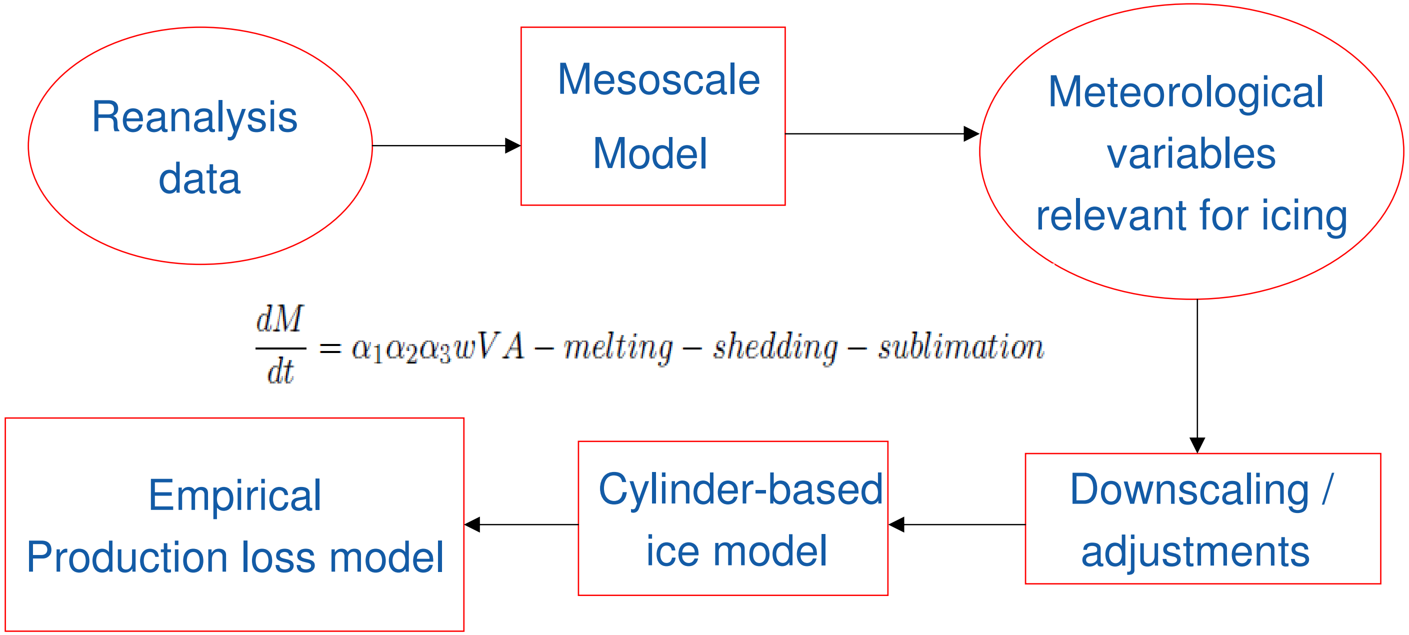
Motivation

- In-house expertise with regards to production loss assessment in non de-icing equipped WT's via state-of-the-art methodology [1]:



$$\frac{dM}{dt} = \alpha_1\alpha_2\alpha_3 wVA - melting - shedding - sublimation$$

- But Vattenfall plans to build wind farms in the Northern Part of Sweden where de / anti-icing systems will be needed
  → Next step is to work towards a site specific production loss assessment methodology when deploying de / anti–icing equipped WT's

[1] Wind power in cold climates. Ice mapping methods. Elforst report, March 2013

Challenges

- Relatively new technology with low penetration
  - scarce data sets from where to build engineering models from
- Losses will highly depend on:
  - the control system
  - efficiency of the ice detection system
- Very site dependant
- Wide variety of systems on the market

Modelling is challenging since too little is known …

Modelling de-icing systems

Despite the apparent difficulties:

• The behavior of de-icing systems can be approximated by slightly modifying the state-of-the-art methodology [1] for assessing losses

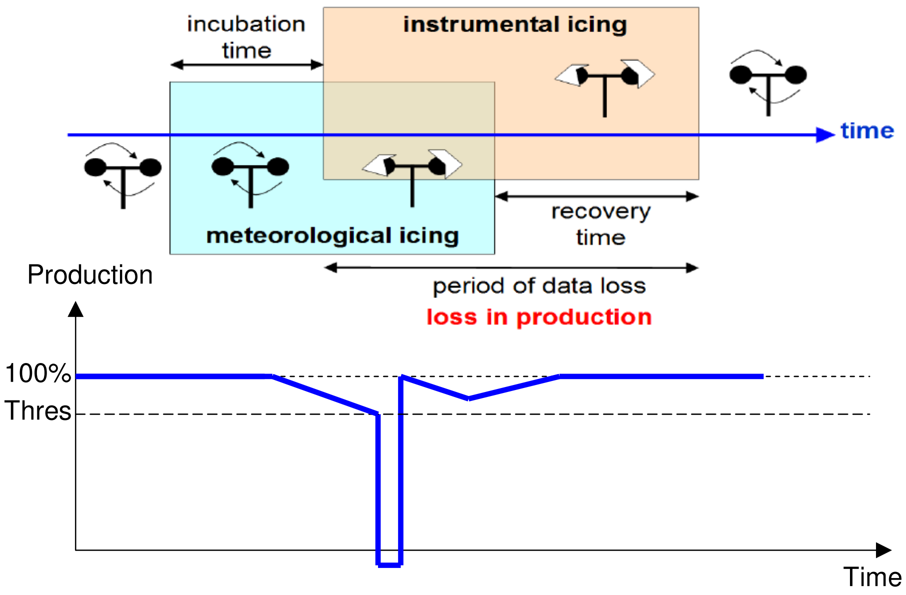
- Based on previous methodology → accumulates its uncertainties
- No data → deterministic model
- Efficiency of de-icing = 100 % → Lower limit of production losses
- De-icing time is fixed & system running at nominal power
- Considers 100% efficient ice detectors (no false alarms)
- Can be tuned easily to on-site data

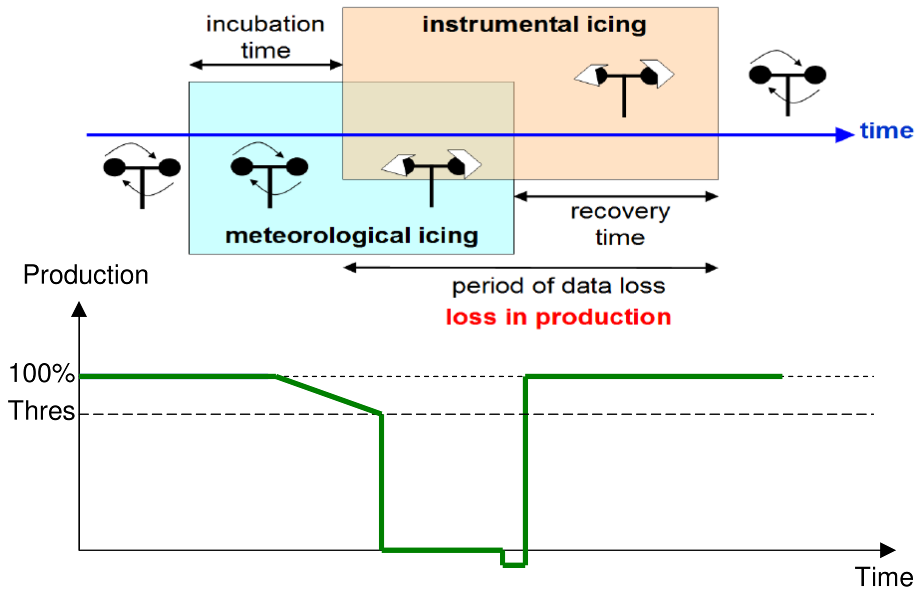
An reasonable order of magnitude of the energy gains due to these systems can be computed easily

[1] Wind power in cold climates. Ice mapping methods. Elforst report, March 2013

Modelling de-icing systems

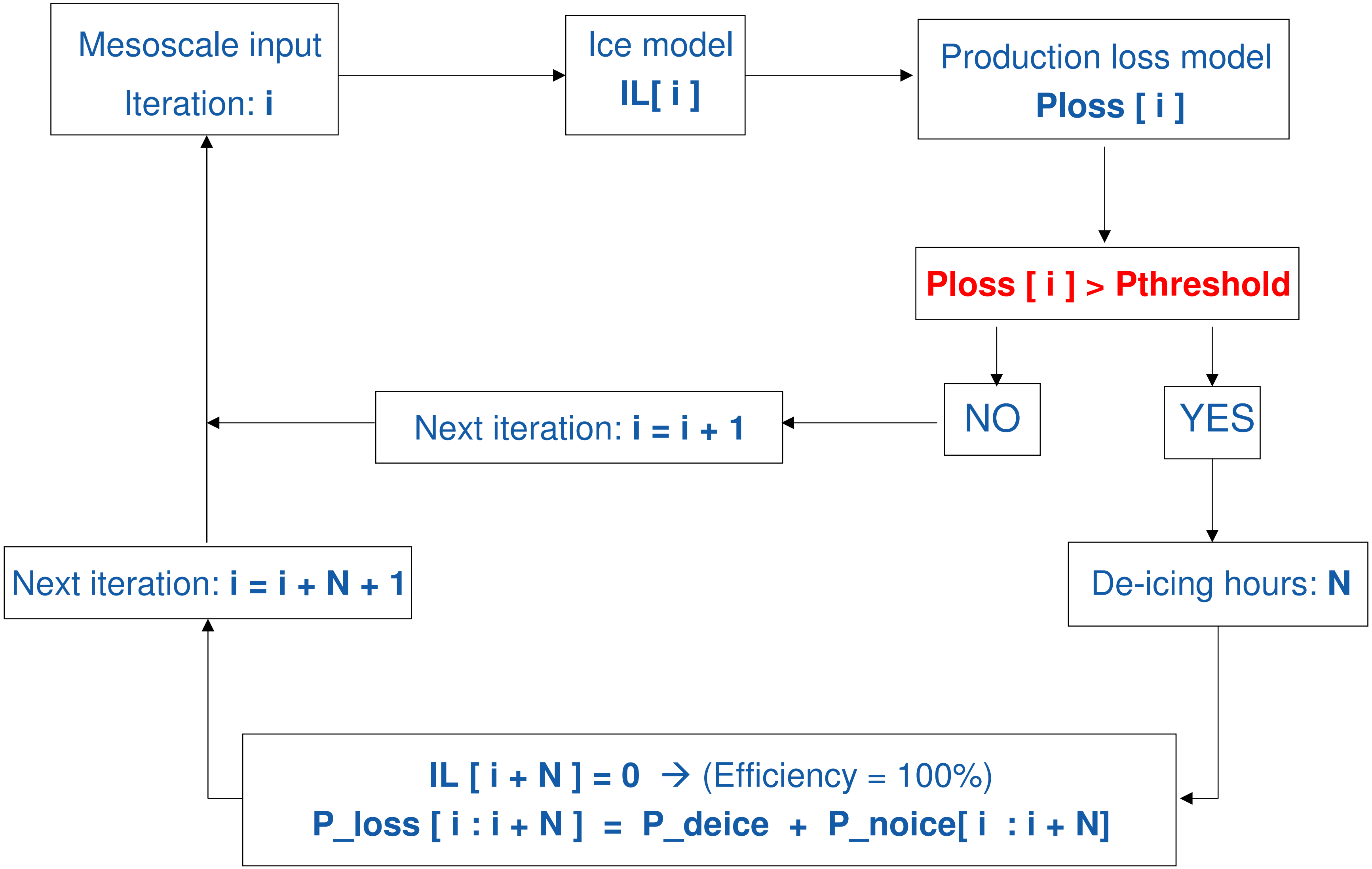
- 2 Operational modes are considered & modelled:





OP1	**OP2**
WT stopped after ice detection De-icing right after detection	WT stopped after ice detection De-icing only when icing event is over

Modelling de-icing systems: OP1



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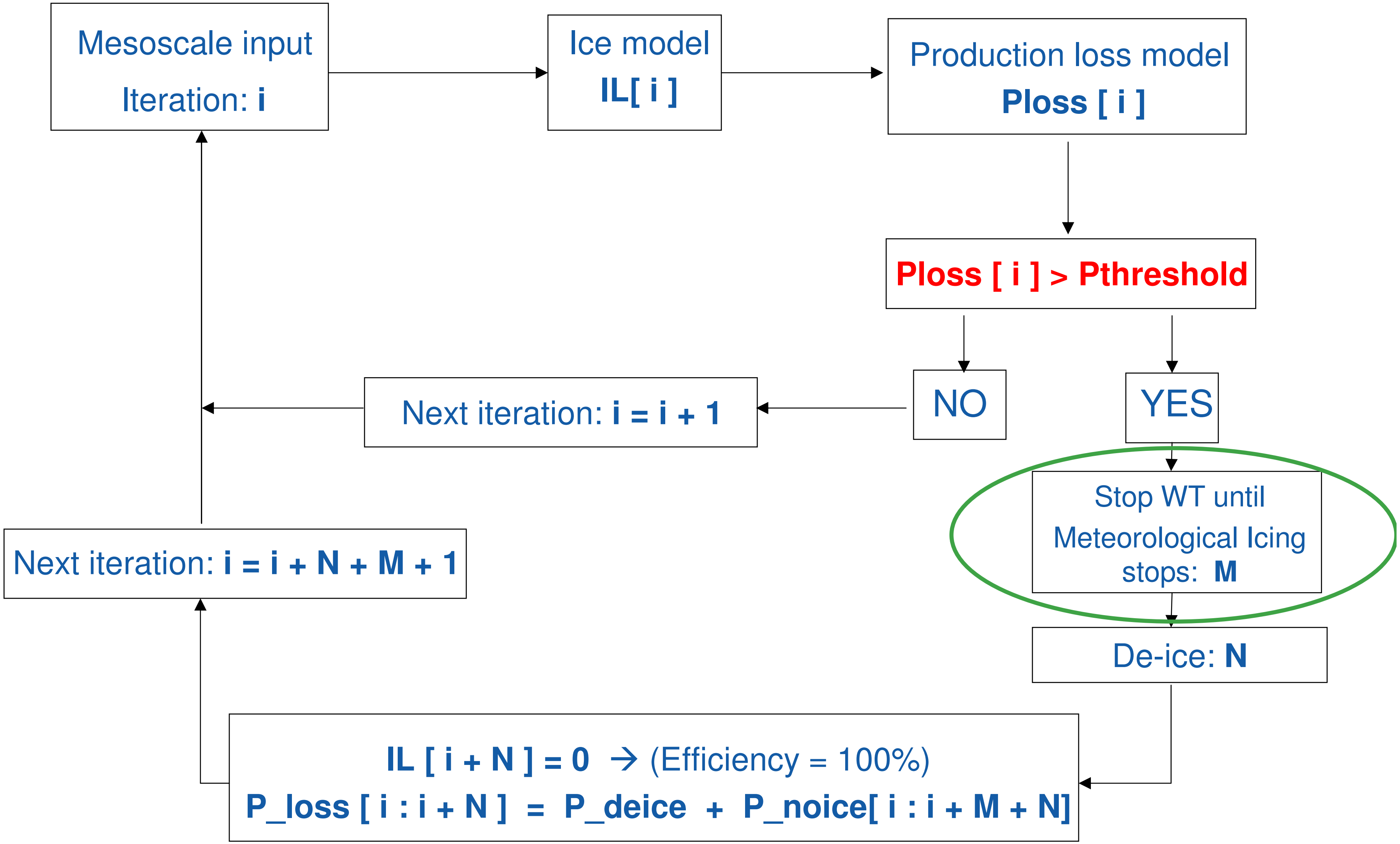
Modelling de-icing systems: OP2



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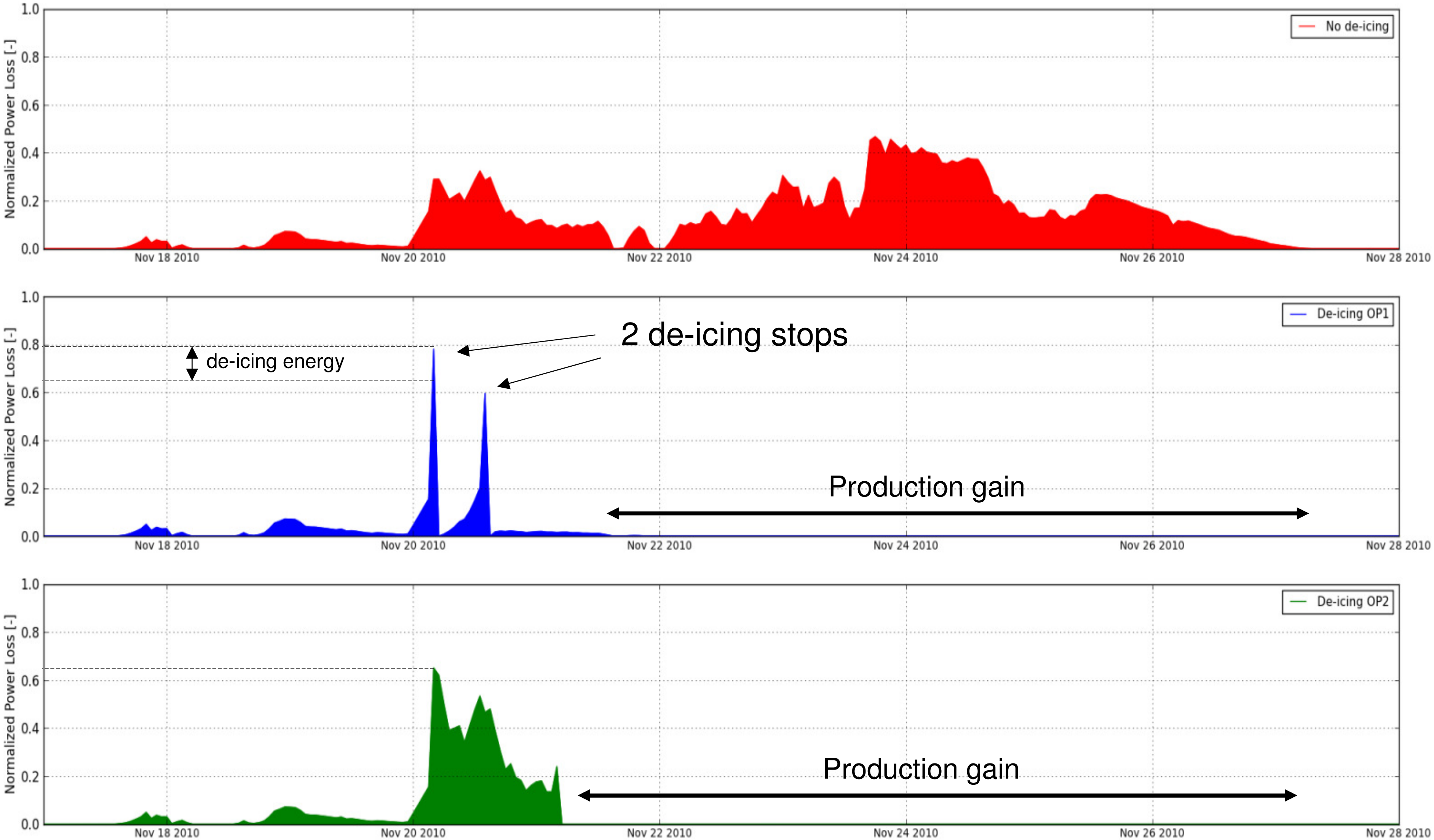
Ice event example



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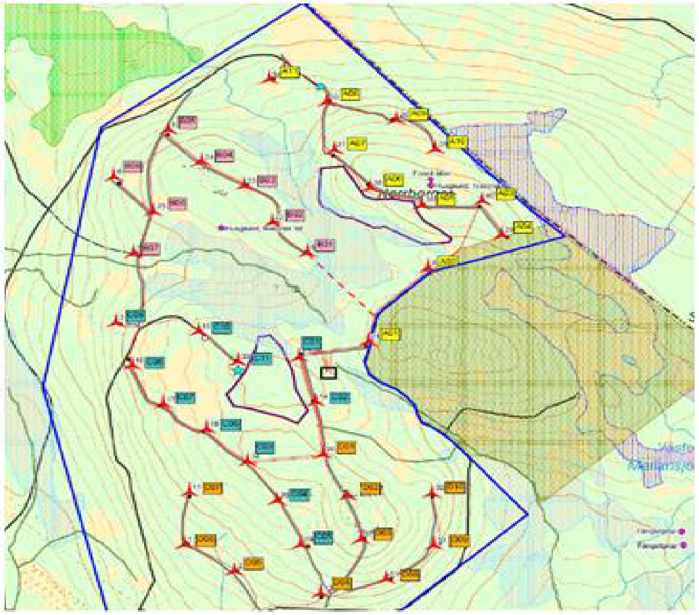
Model tests at the Stor-Rotliden Wind Farm

- Focusing on a single winter season
- Sentitivity tests comparing OP1 and OP2:
  1. 2 threshold curves (ice detection system → A: sensible, B: conservative)
  2. 2 de-icing nominal powers (35kW & 100kW)
  3. 2 de-icing times (1h & 2h)



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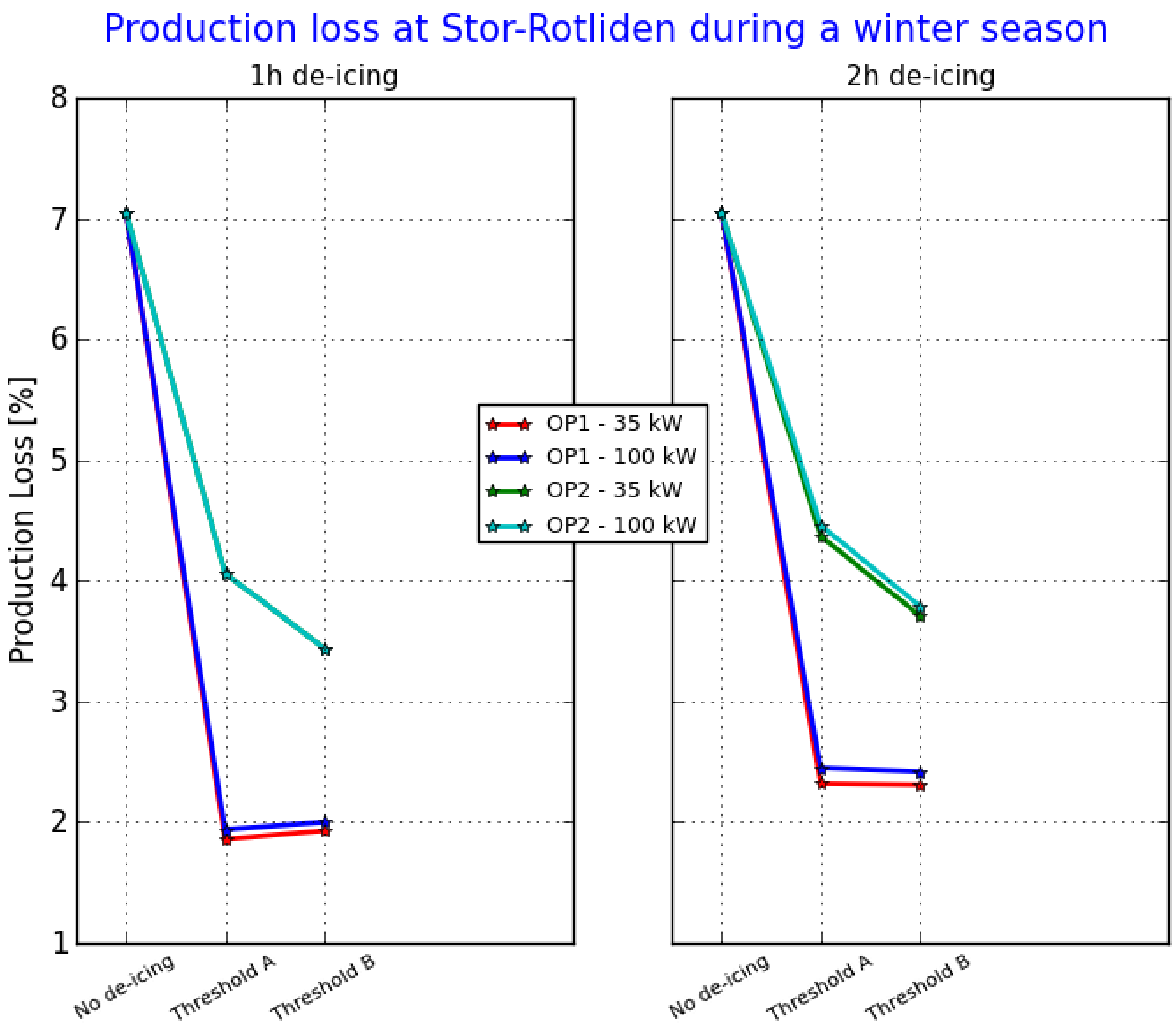
Results



- Using 35kW or 100kW de-icing energy per blade barely changes results
- Gains in the order of 0.5% of winter production are expected when de-icing 1h instead of 2h
- Differences between OP1 and OP2 are higher (up to 2% of winter production) when using a sensible ice detection system (threshold A)
- When operating in OP2 mode, a conservative ice detection system gives less losses (up to 0.5%)

Uncertainties

- Methodology hightly dependant on empirical production loss model
- Considers 100% efficient de-icing system & ice detection system (no false alarms)
  → Lower limit to production losses
- Still the blade is not modelled …
- Limit for deterministic modelling??

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Conclusions

- New method gives reasonable estimates / order of magnitude of the gains in production when using de-icing systems
- Simple to implement and fast to run
- Threshold curve to be tuned with on-site data
- Validation pending…

THANK YOU FOR YOUR ATTENTION !