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Experiences analysing operational wind farms in cold climate

Jennie Molinder, Utku Turkyilmaz

Wind farm constructed in the cold climate - How does it perform under icing conditions?

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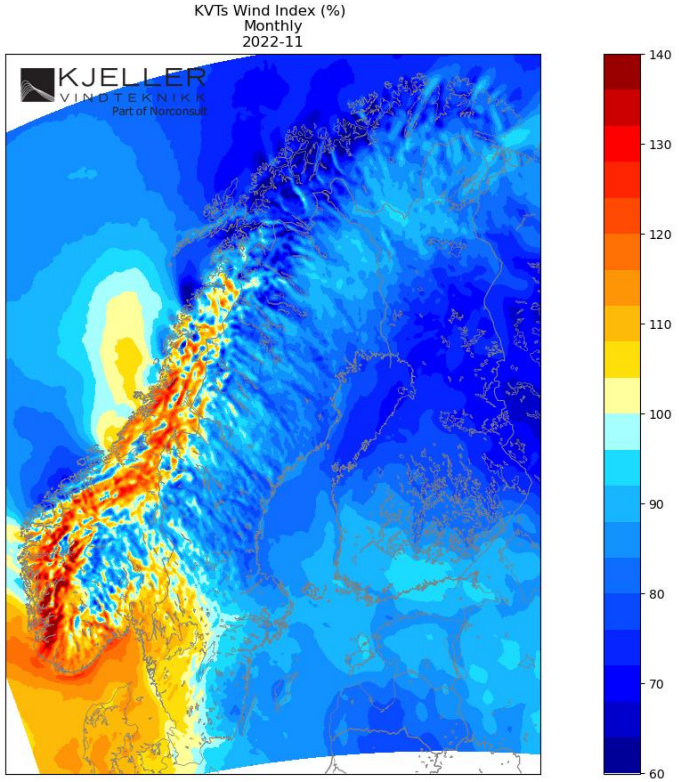
Wind energy production and wind speed variability

- November 2022 wind index?
  - A bad scenario with cold weather coinciding with low winds



Wind energy production and wind speed variability

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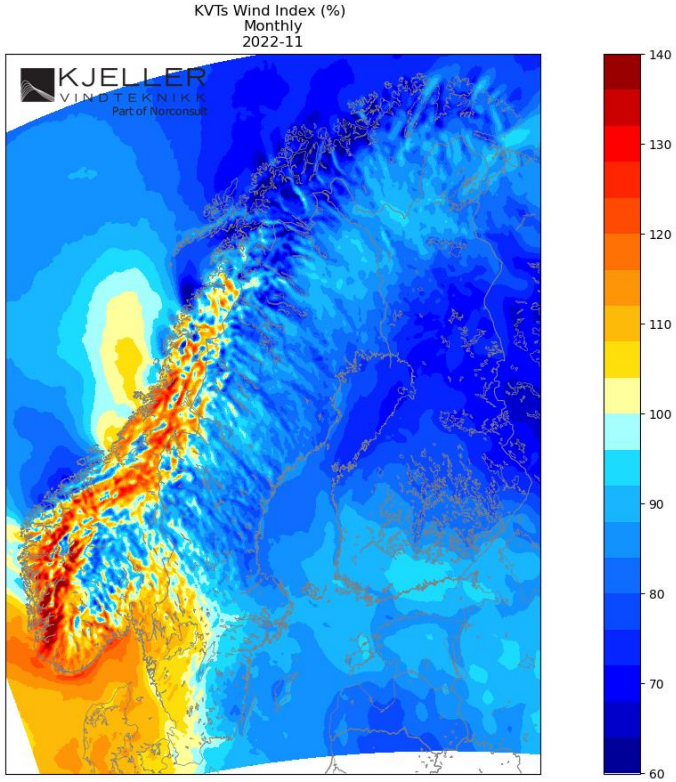
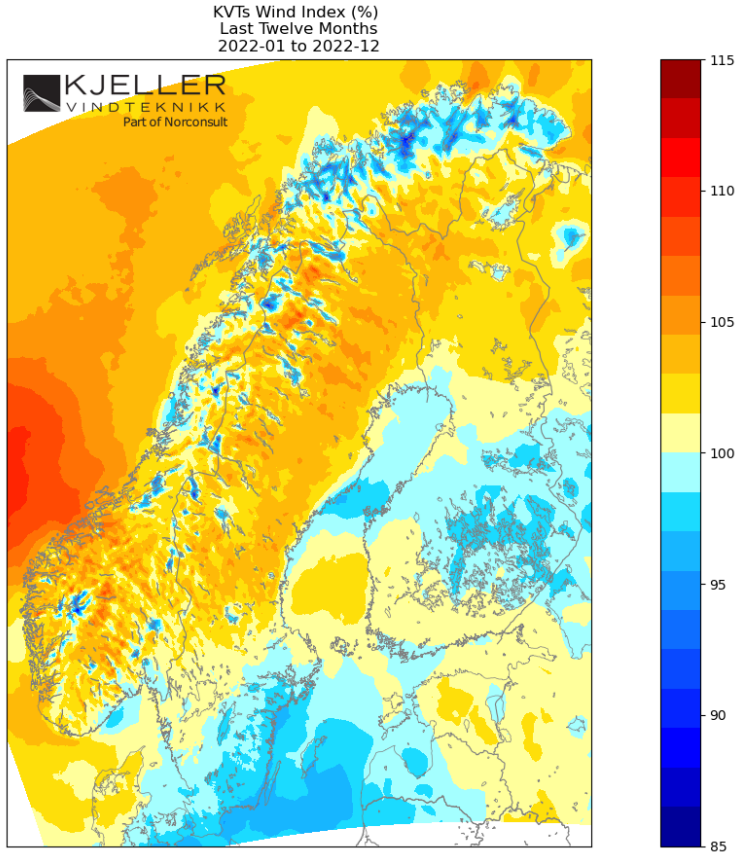


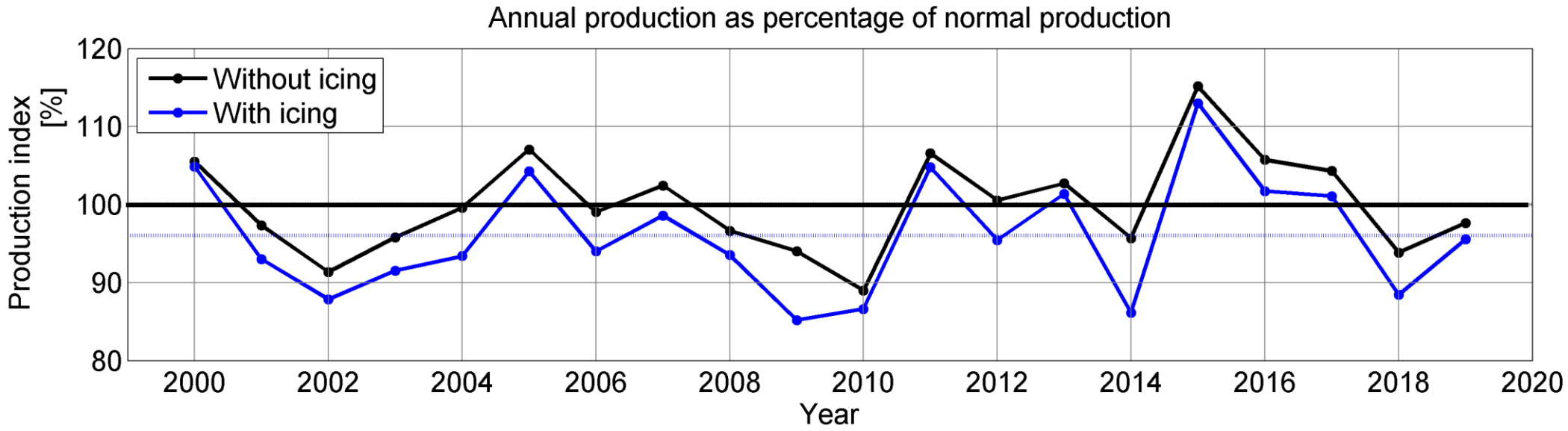
- 2022 average wind index?



Wind energy production and wind speed & icing variability

- Production index
  - Wind index
  - Icing index

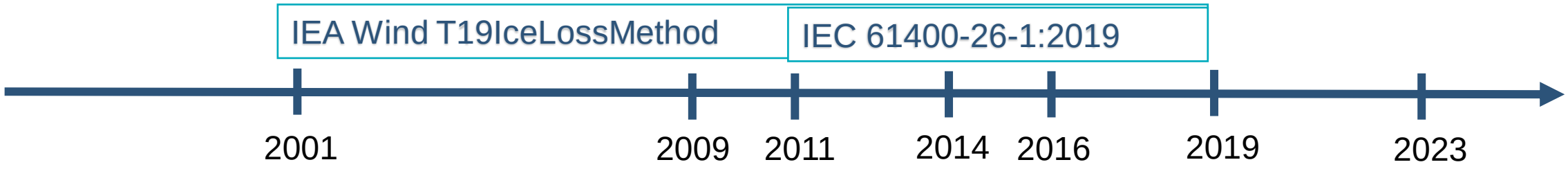
	Mean [%]	Max [%]	Min [%]
Without icing	100	115	89
With icing	96	113	85
Icing	4	10	1



Framework: How do we analyse operational wind farms in cold climate?

Post-construction production assessment (PCPA) based on SCADA data

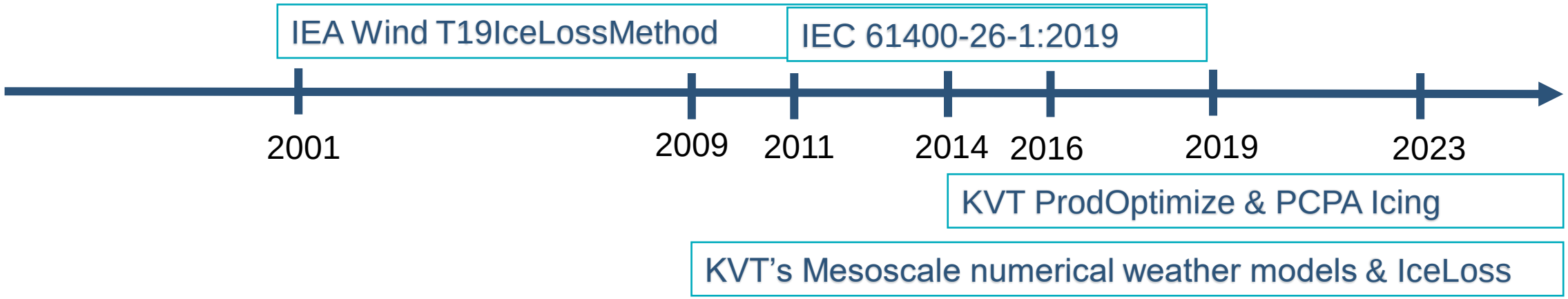
- **Methods combined by Kjeller Vindteknikk (KVT):**
  - IEC Standards
  - IEA Wind Task19



Framework: How do we analyse operational wind farms in cold climate?

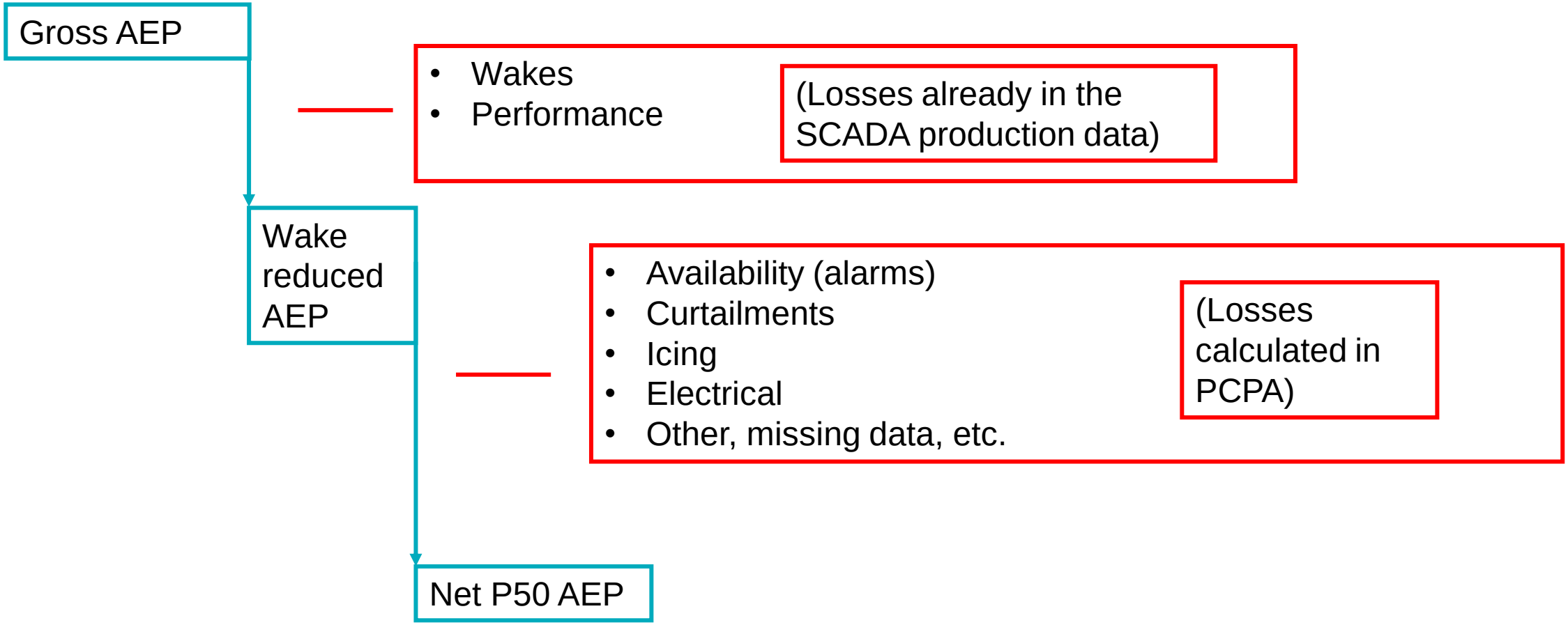
Post-construction production assessment (PCPA) based on SCADA data

- **Methods combined by Kjeller Vindteknikk (KVT):**
  - IEC Standards
  - IEA Wind Task19
  - KVT's Mesoscale WRF & IceLoss model
  - KVT's PCPA method – developed within research project ProdOptimize



Post-construction production assessment (PCPA) based on SCADA data

- Gross to net energy yield



Post-construction production assessment (PCPA) of icing losses

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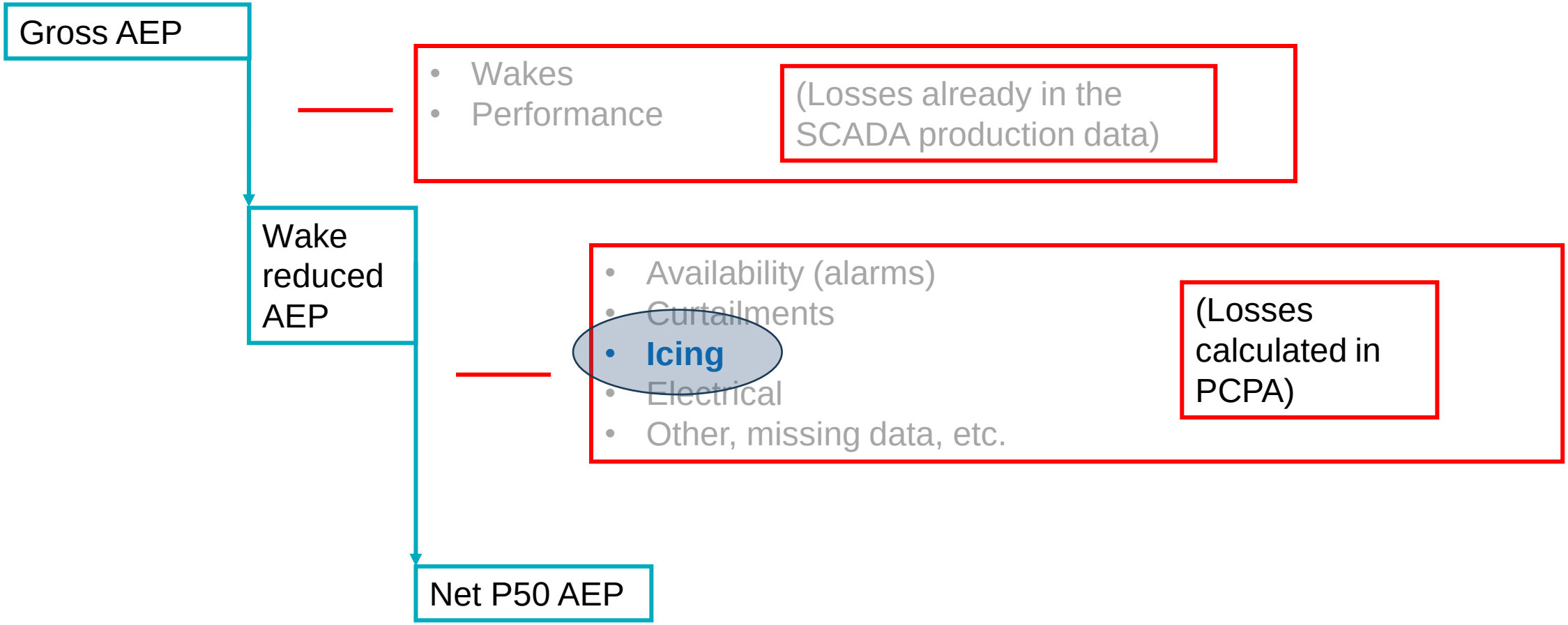
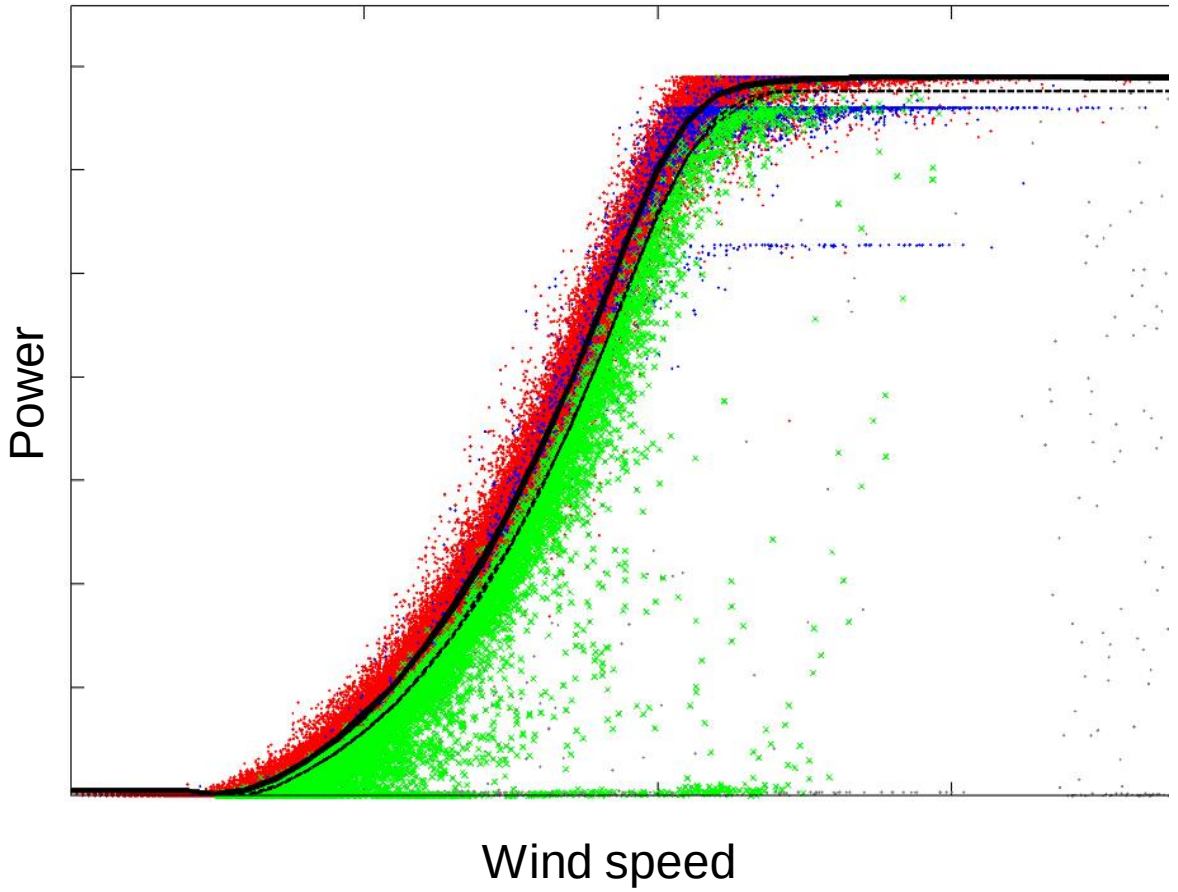


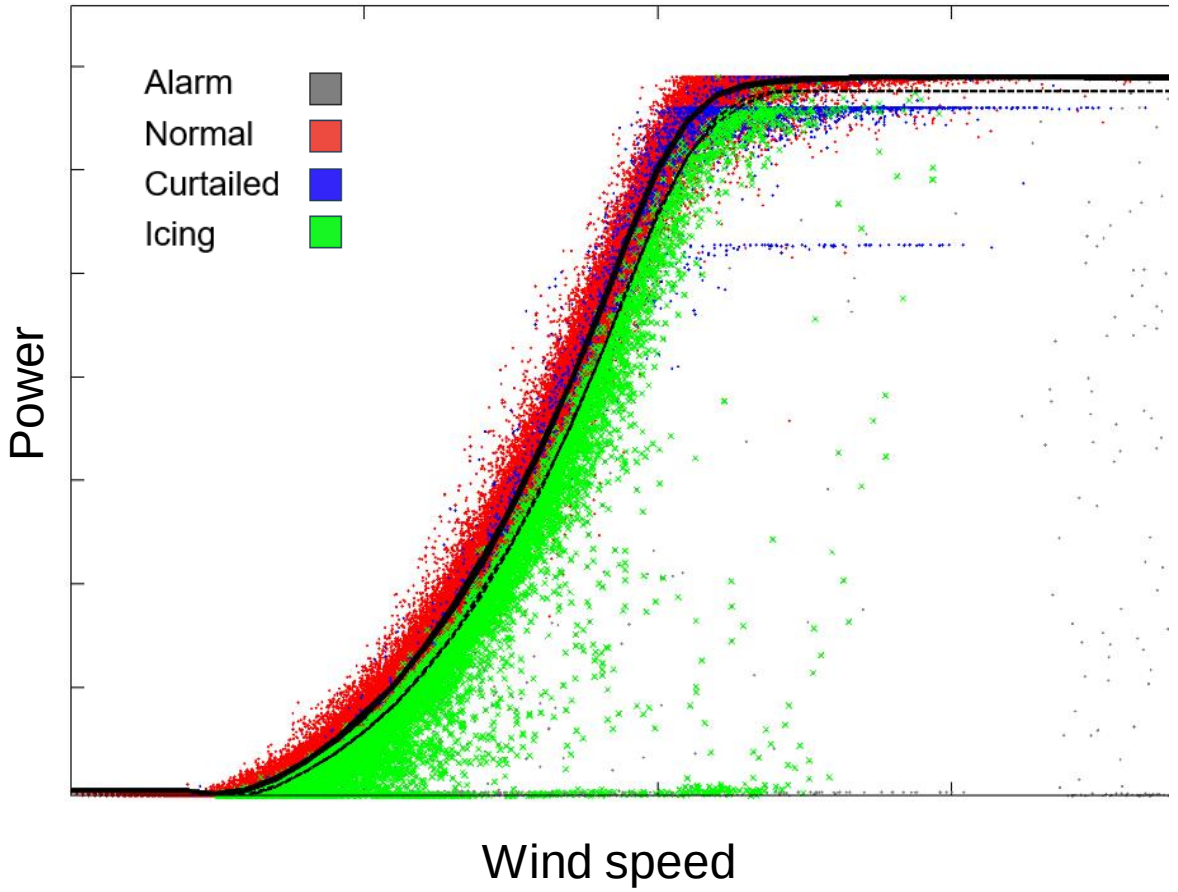
Post-construction production assessment (PCPA) based on SCADA data

- Historical power curves
  - SCADA data filtering



Post-construction production assessment (PCPA) based on SCADA data

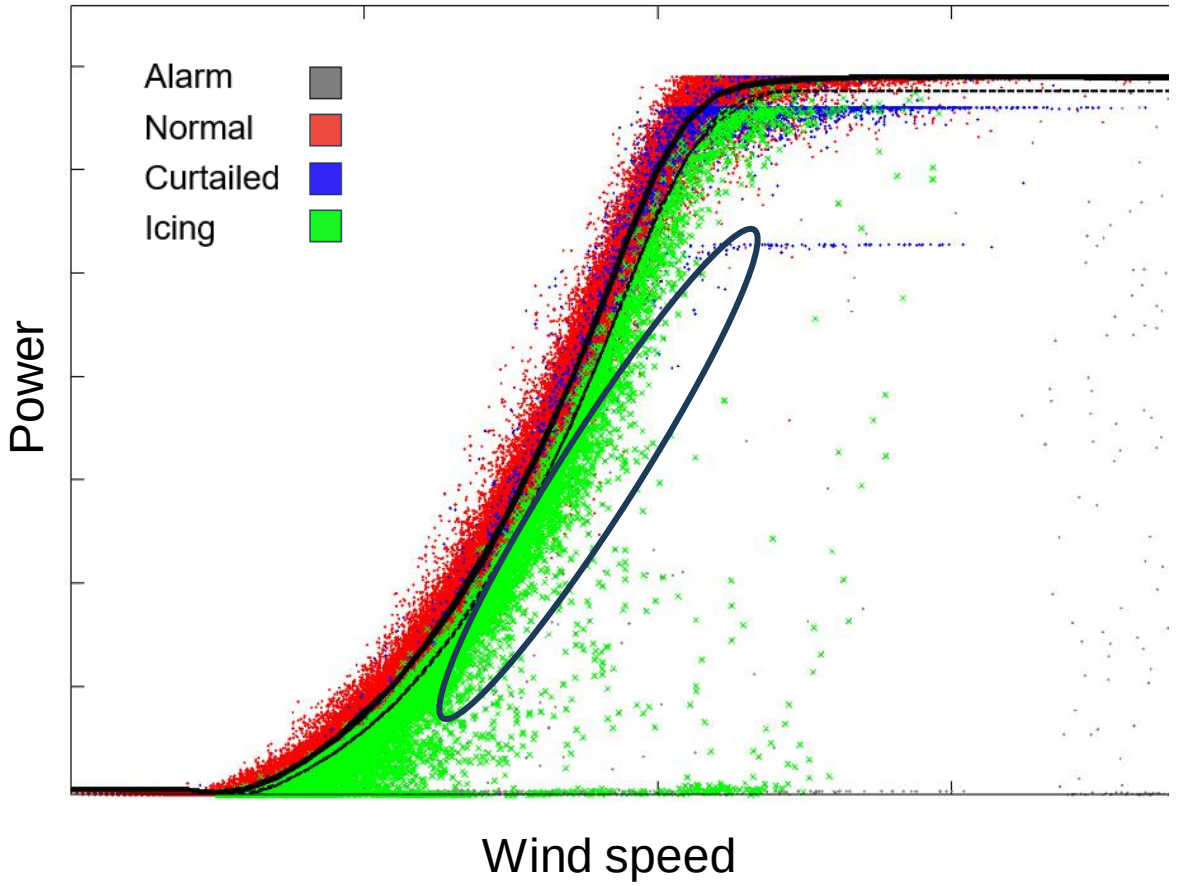
- Historical power curves
  - SCADA data filtering
- Categorization of losses



Post-construction production assessment (PCPA) of icing losses

Historical icing loss calculations

- T19IceLossMethod:
  - Operation icing losses



Post-construction production assessment (PCPA) of icing losses

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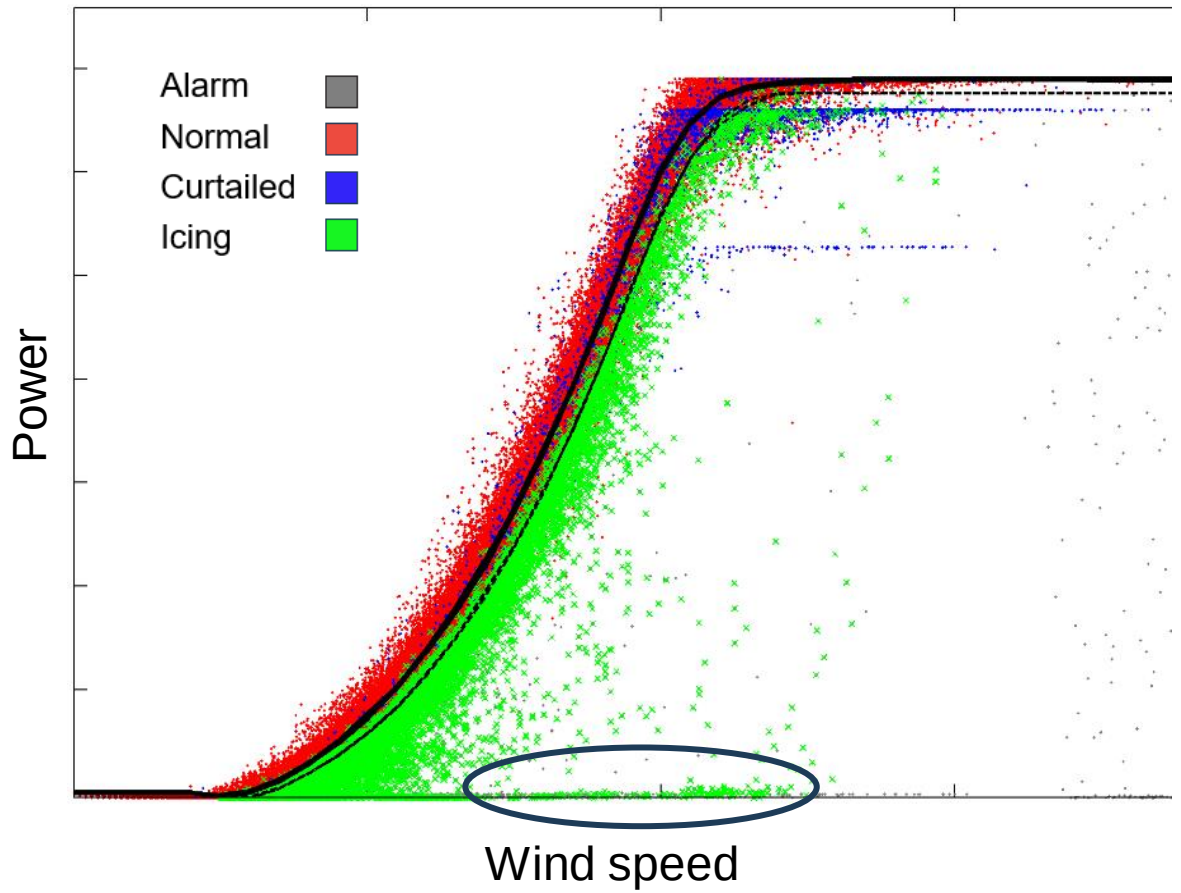

Post-construction production assessment (PCPA) of icing losses

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- T19IceLossMethod:
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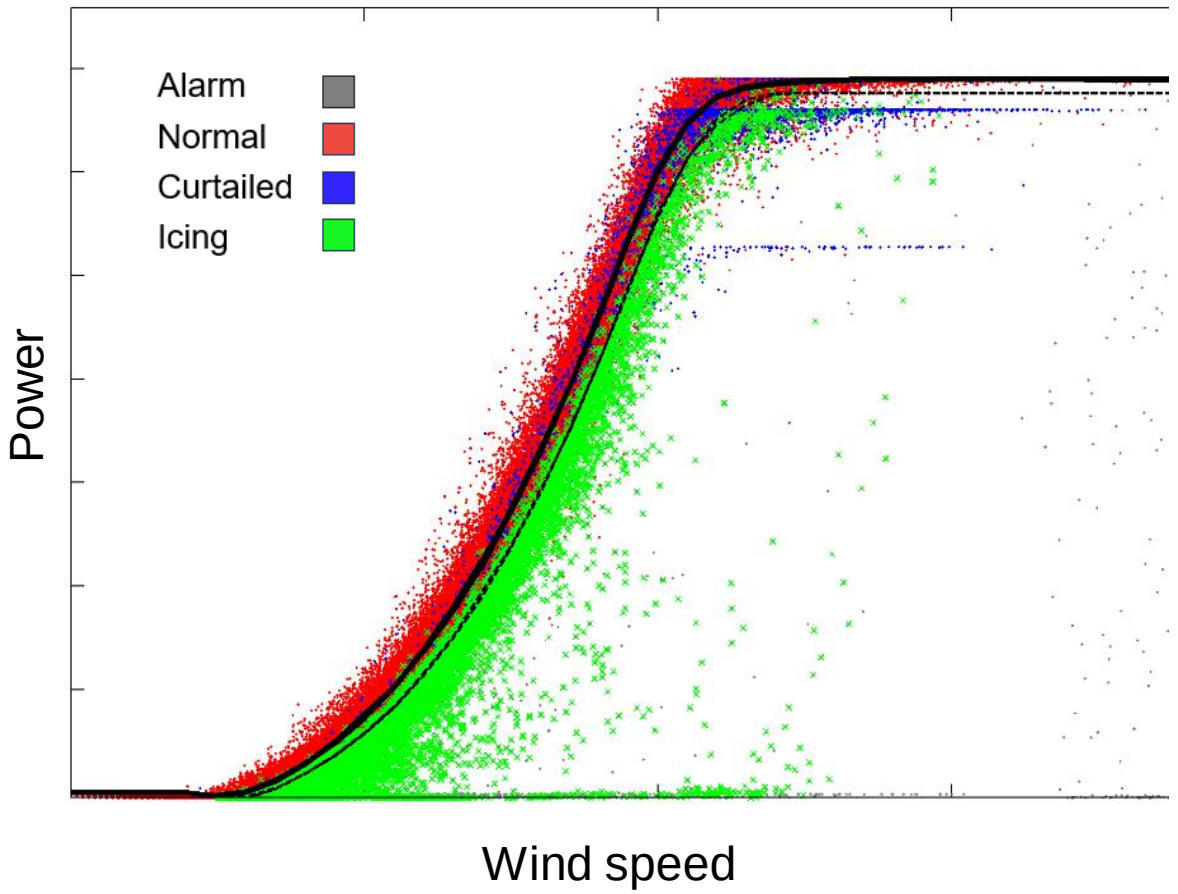
  - Standstill icing losses
- SCADA status and detailed alarm logs



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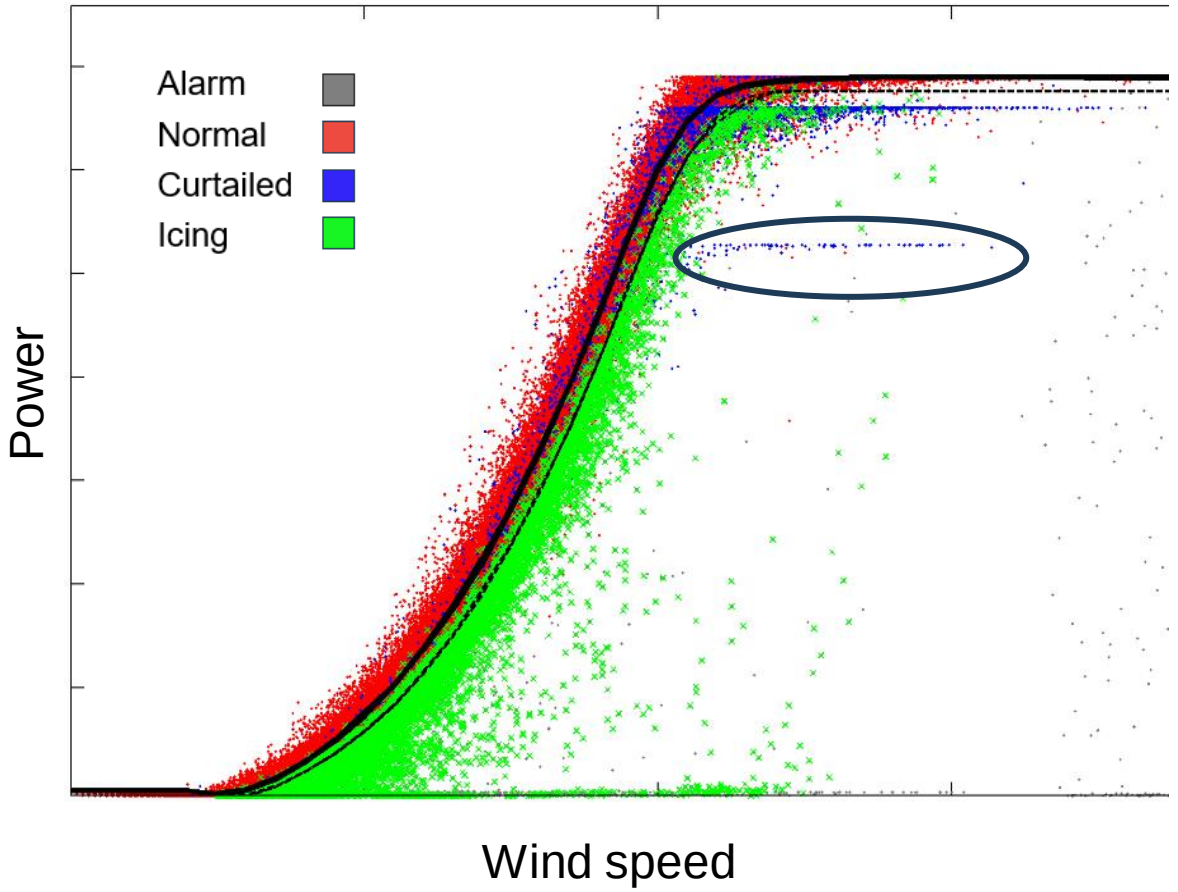

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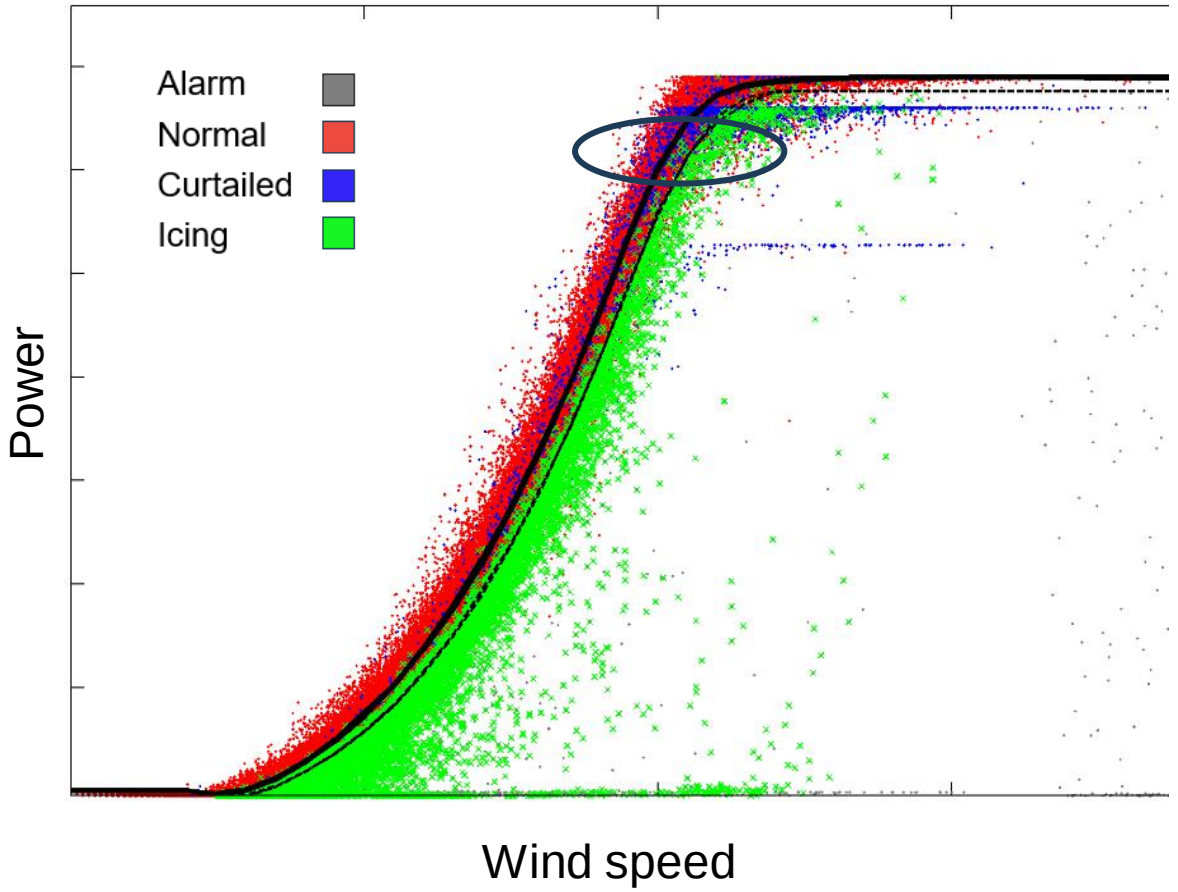
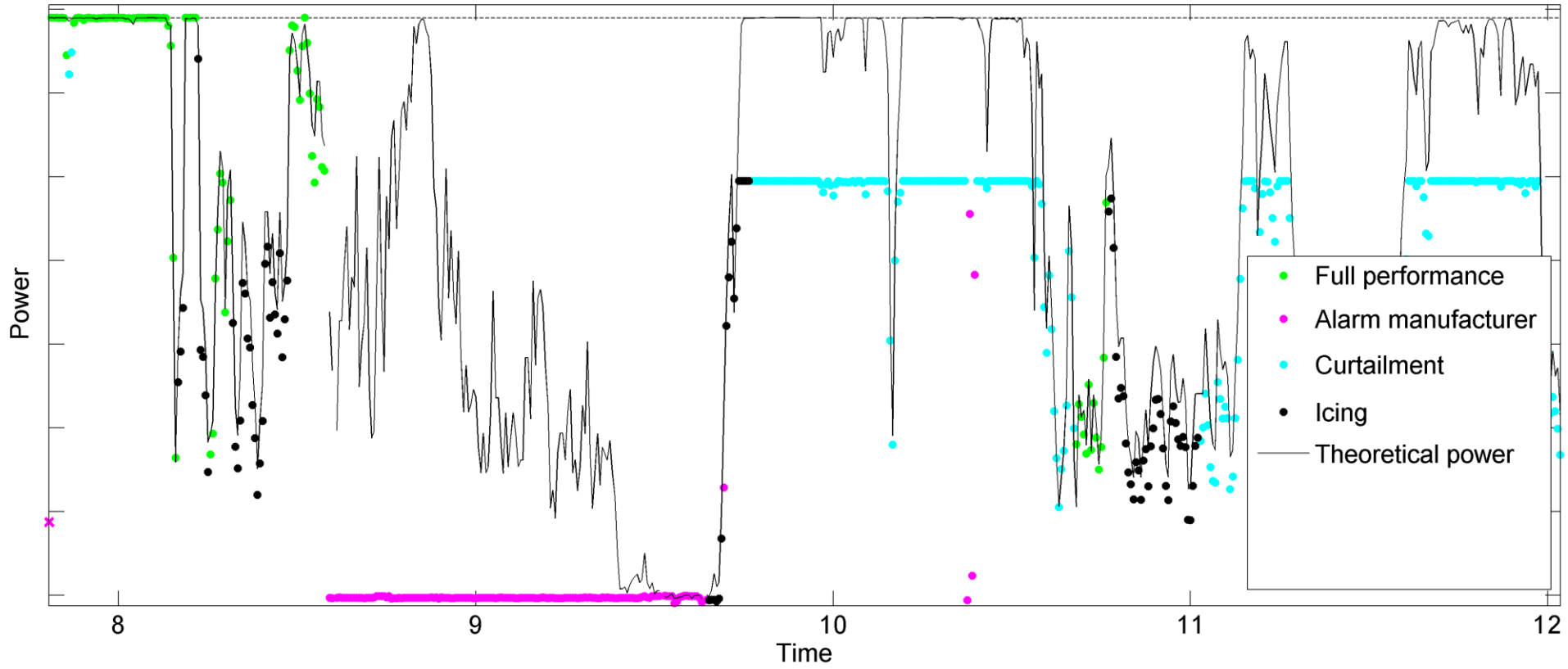
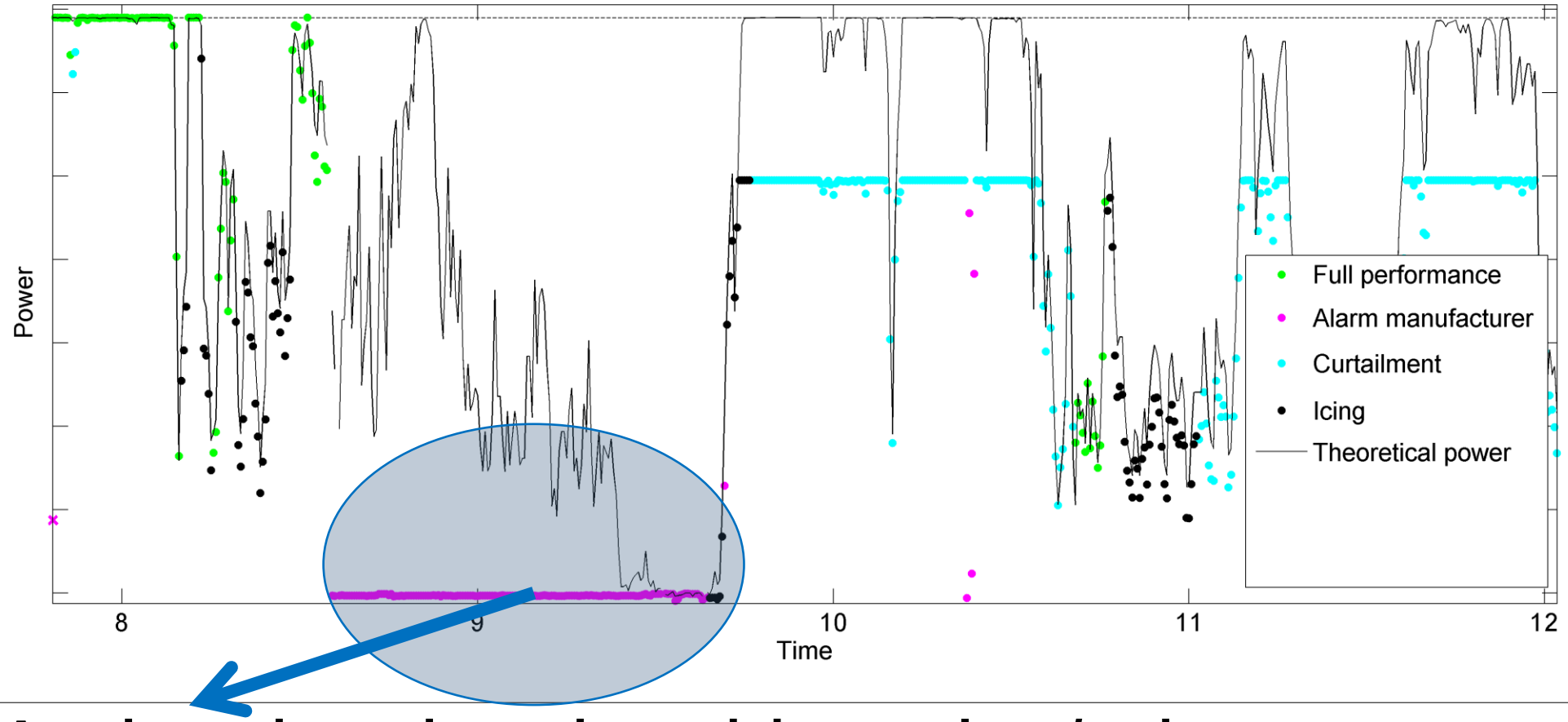


SCADA production time series – data filtering



SCADA production time series – data filtering

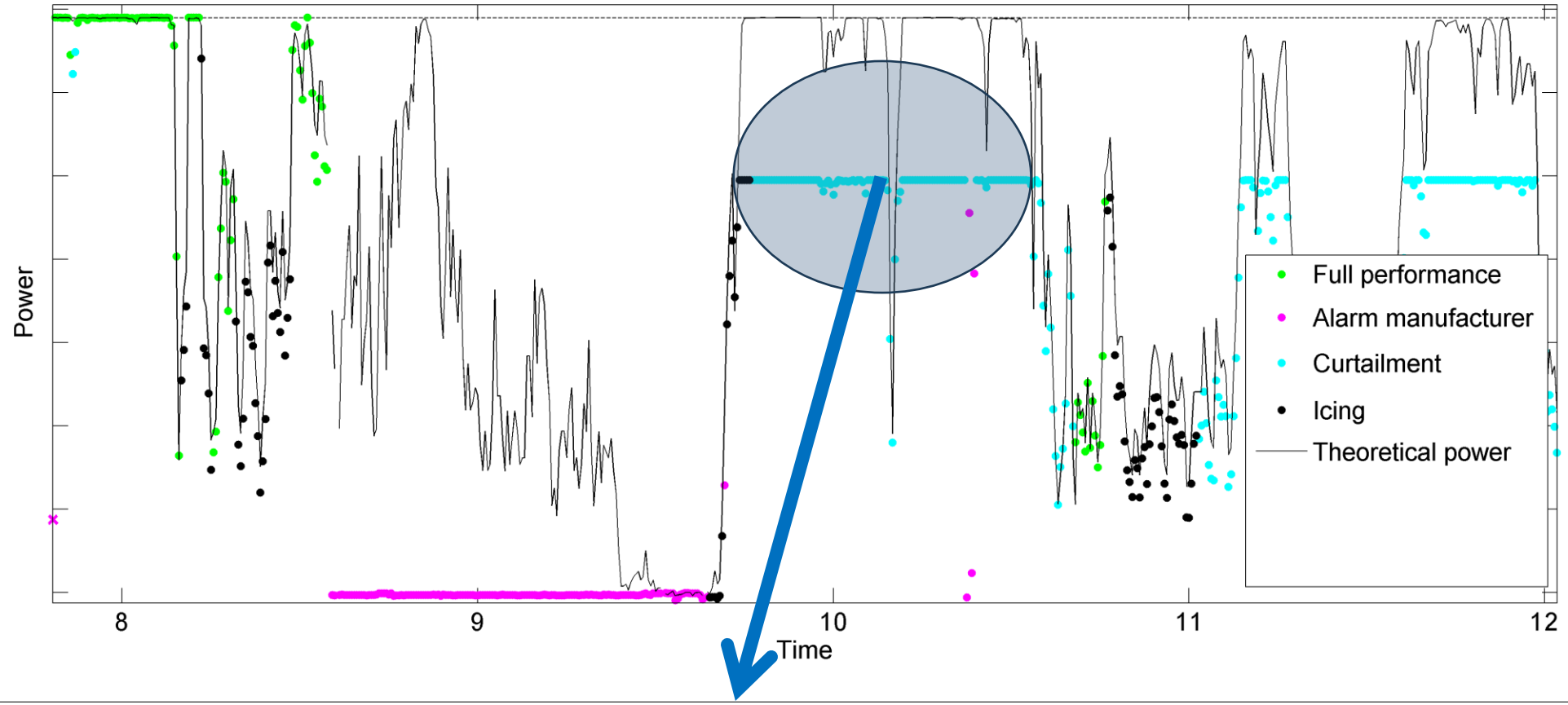
- Down times



Are these down times due to icing or alarm/maintenance or something else?

SCADA production time series – data filtering

- Curtailments



Are these curtailments due to “iced blade” operation or something else?

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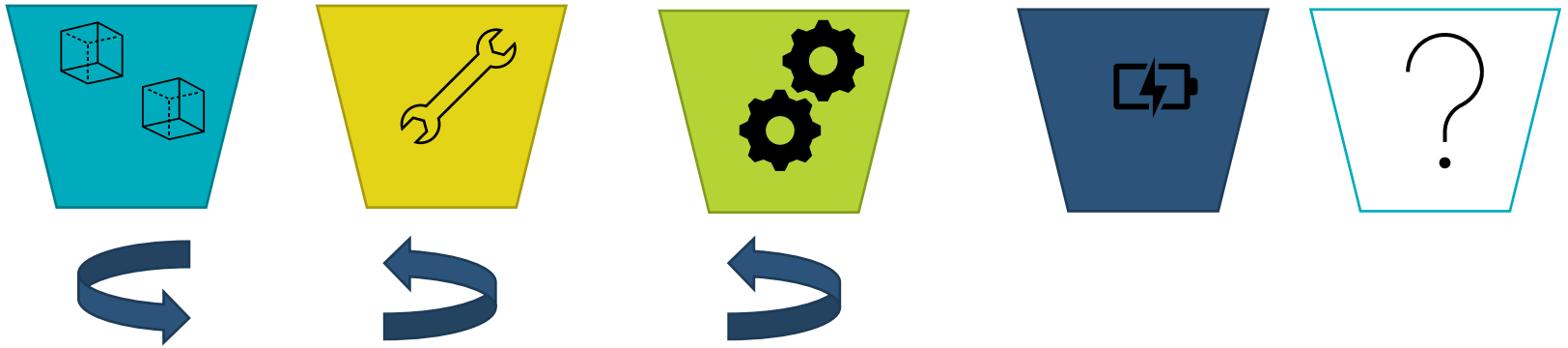
Gross to net energy yield – How do we categorize filtered data?

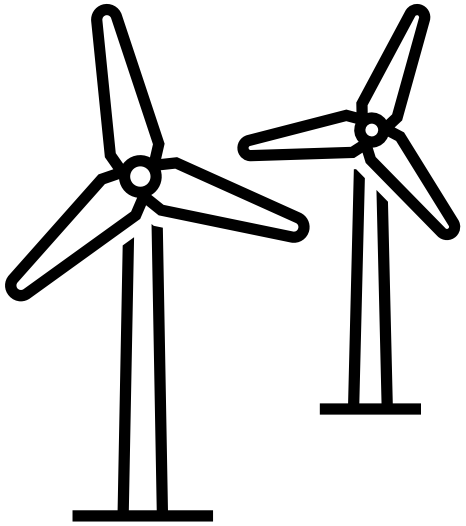
Typical annual production losses	Icing	Availability (Alarms)	Curtailments	Other performance	Missing periods
TOTAL WF	5.0 %	3.0 % to 10.0 %	0.0 % to 2.0 %	0.0 % to 1.0 %	< 0.5 %



Post-construction production assessment (PCPA) - experiences

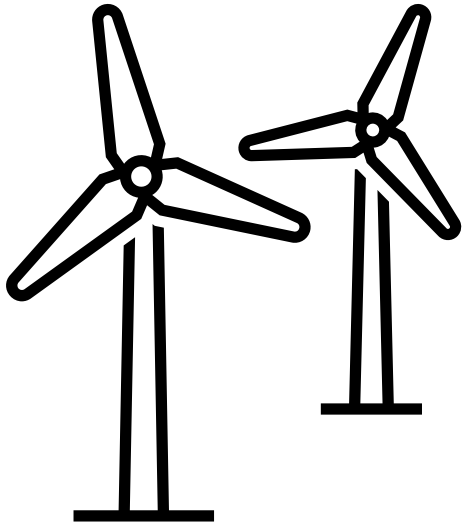
- KVT experiences with SCADA filtering
  - Utilize WRF model and IceLoss model
    - Biased SCADA temperature data
    - Periods with problems in SCADA based wind speed
    - Find outlier turbines

Historical (short-term) icing losses from SCADA found, what is next?



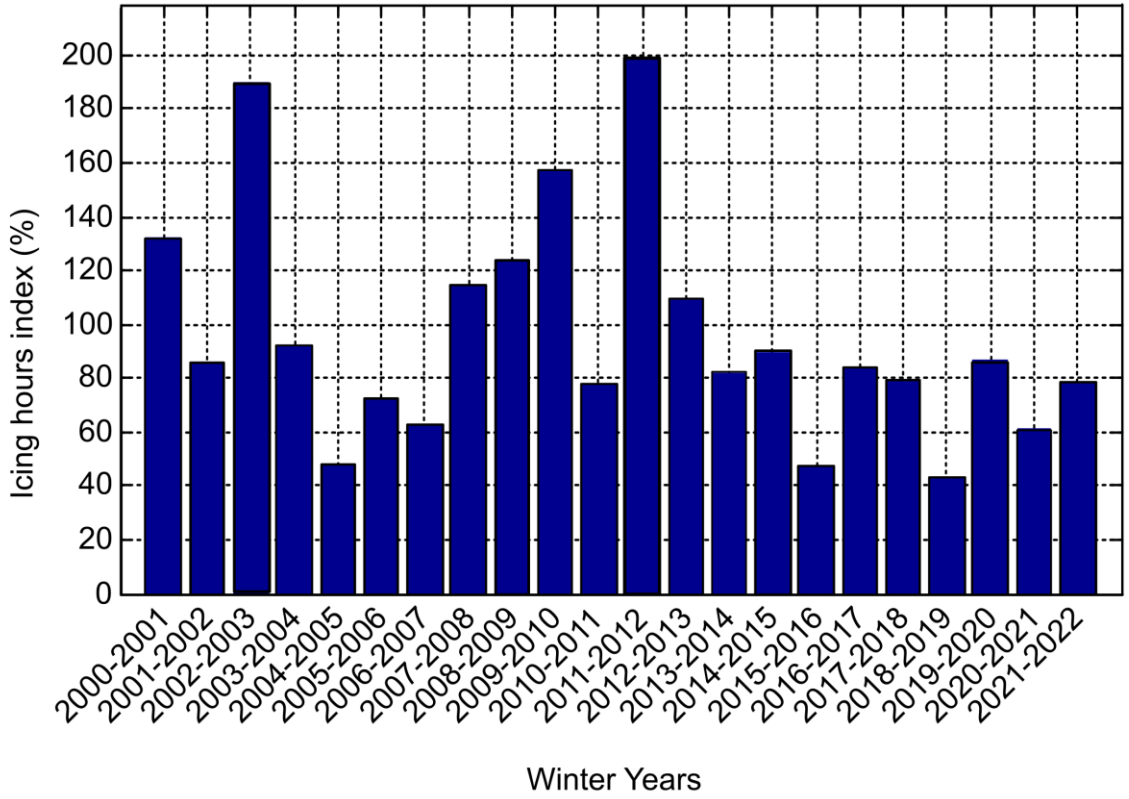
Historical (short-term) icing losses from SCADA found, what is next?

Long-term adjustment



Long-term adjustment of icing losses found in SCADA

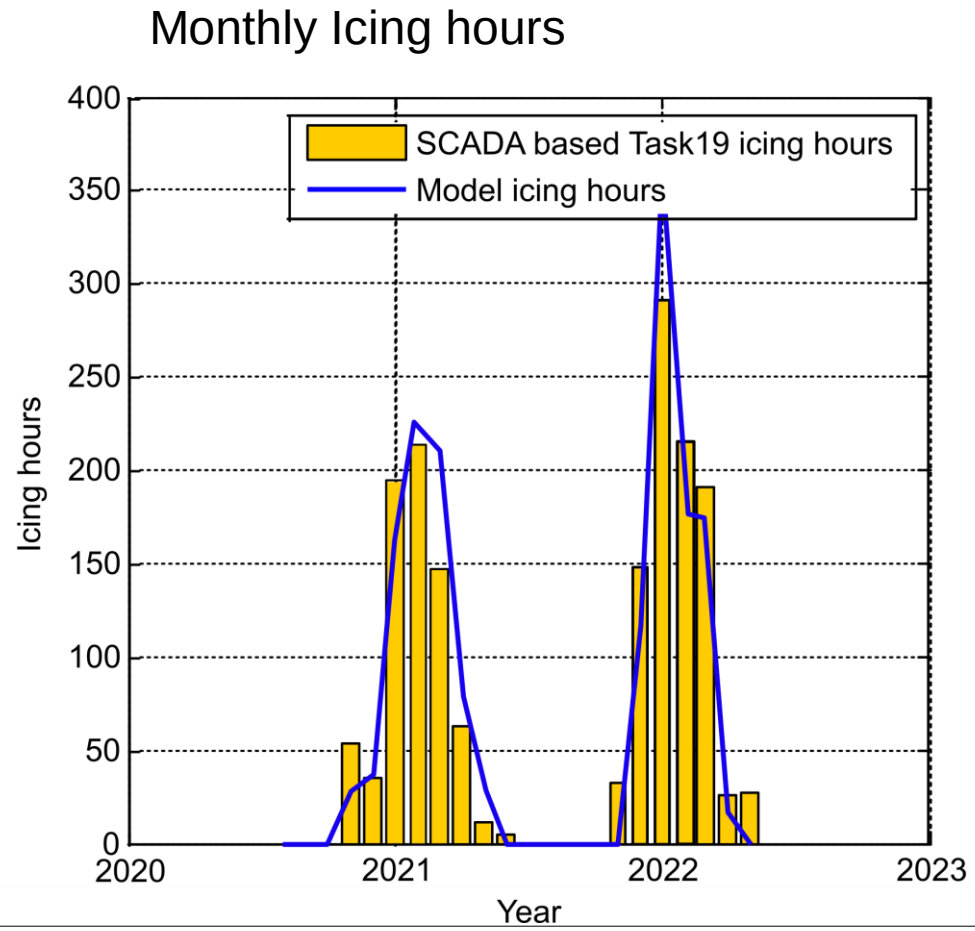
- KVT IceLoss model



Long-term adjustment of icing losses found in SCADA

Example:

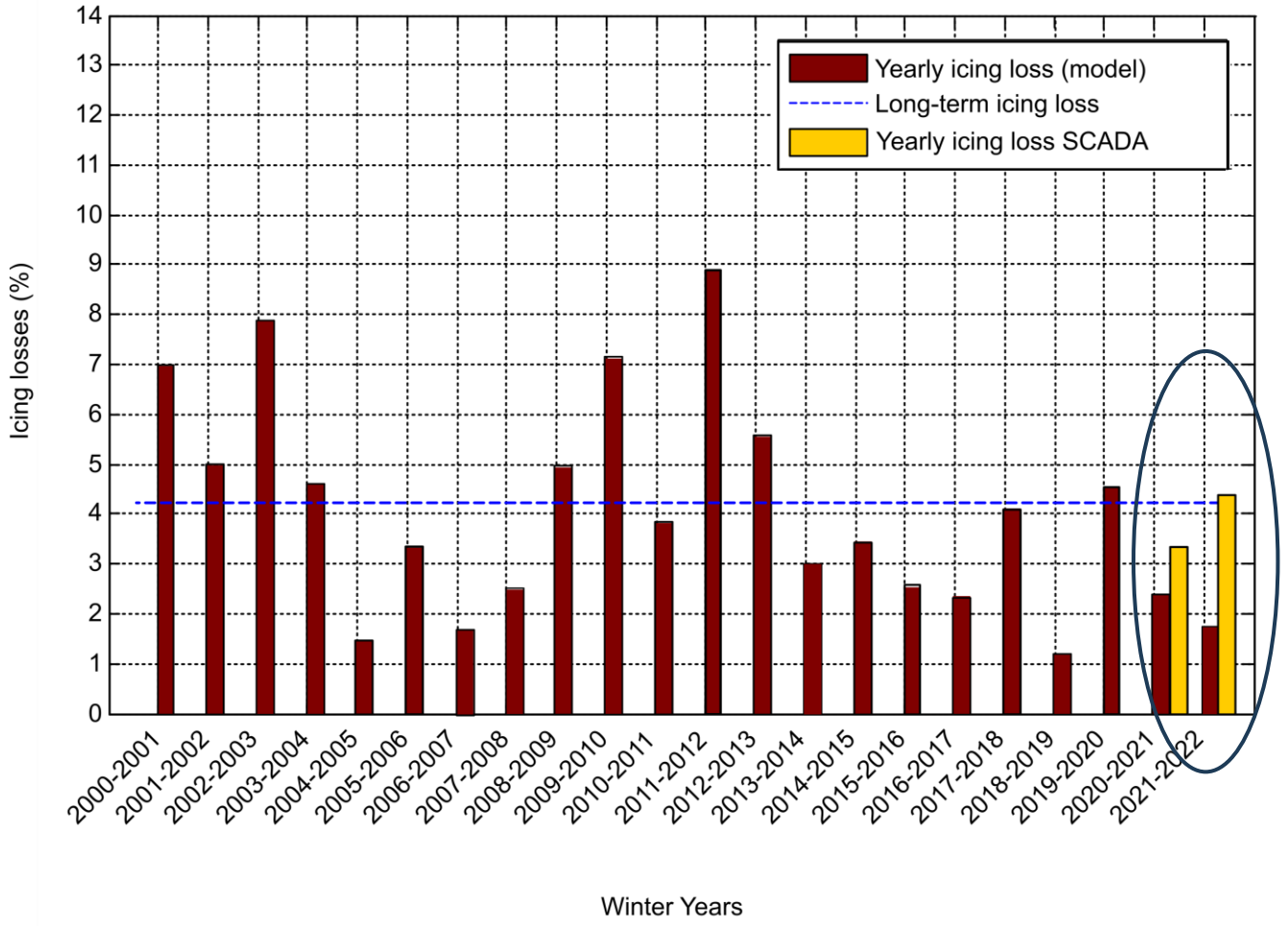
- Monthly comparison SCADA/KVT IceLoss model - 2 years



Long-term adjustment of icing losses found in SCADA

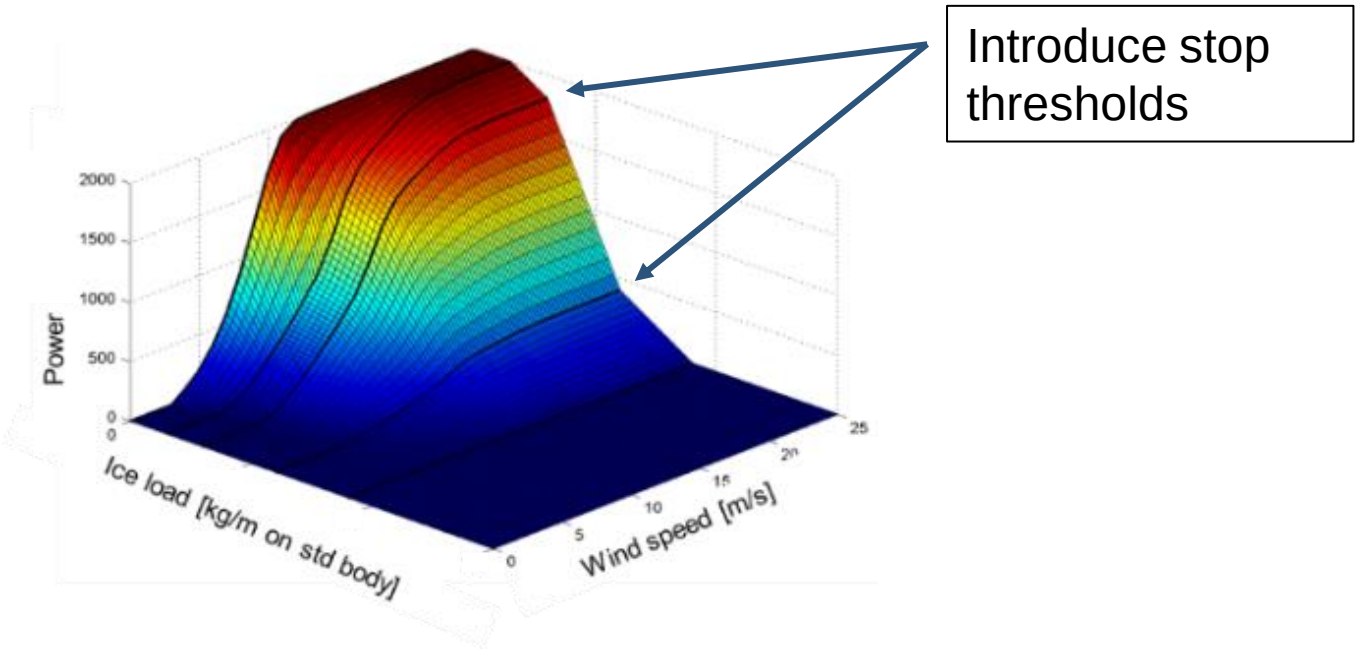
Example:

- Yearly comparison SCADA/KVT IceLoss model



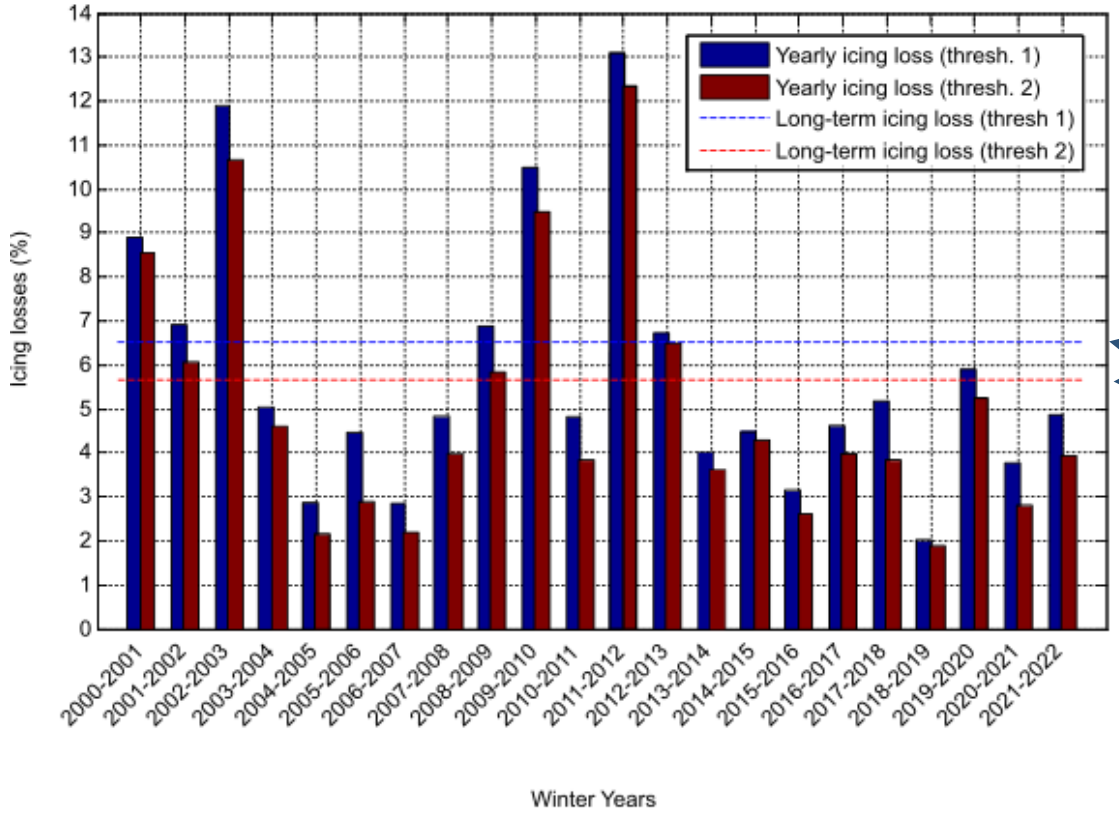
Long-term adjustment of icing losses found in SCADA

- Tune the IceLoss model to fit SCADA losses



Long-term adjustment of icing losses found in SCADA

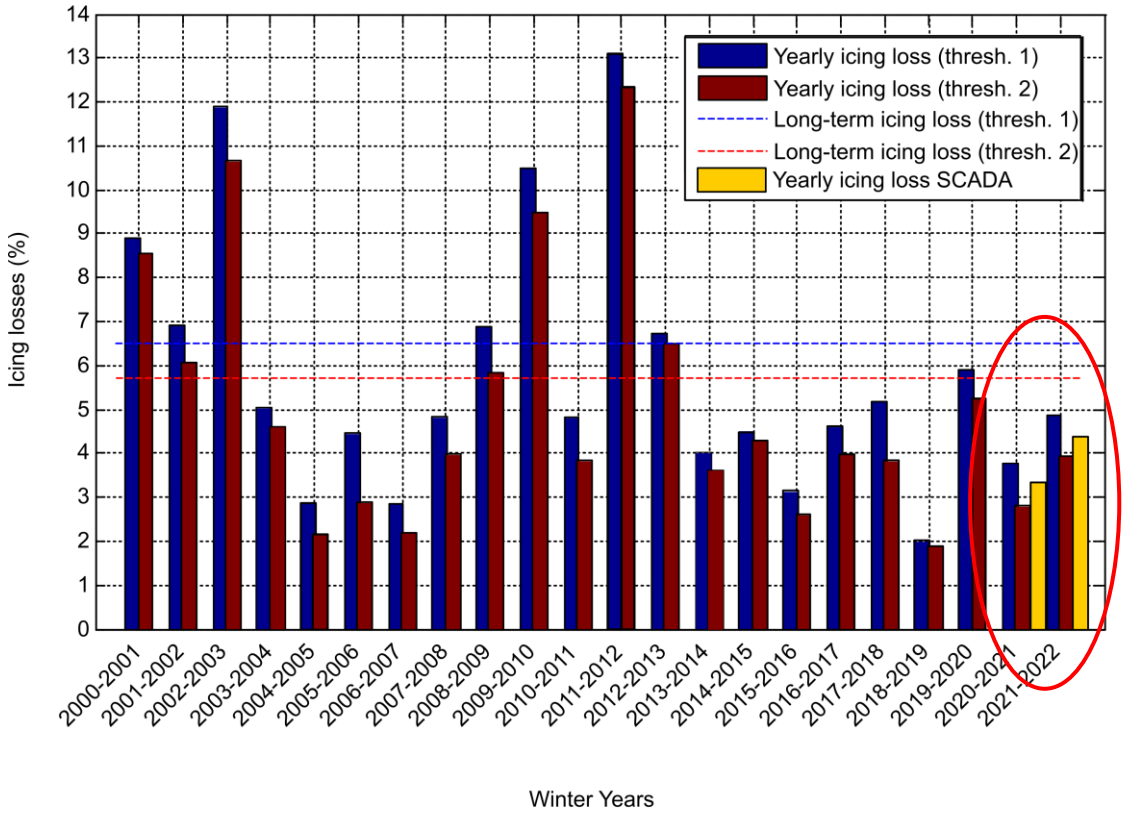
- Introducing stops



Long-term average modelled icing loss

Long-term adjustment of icing losses found in SCADA

- Introducing stops



Years with SCADA

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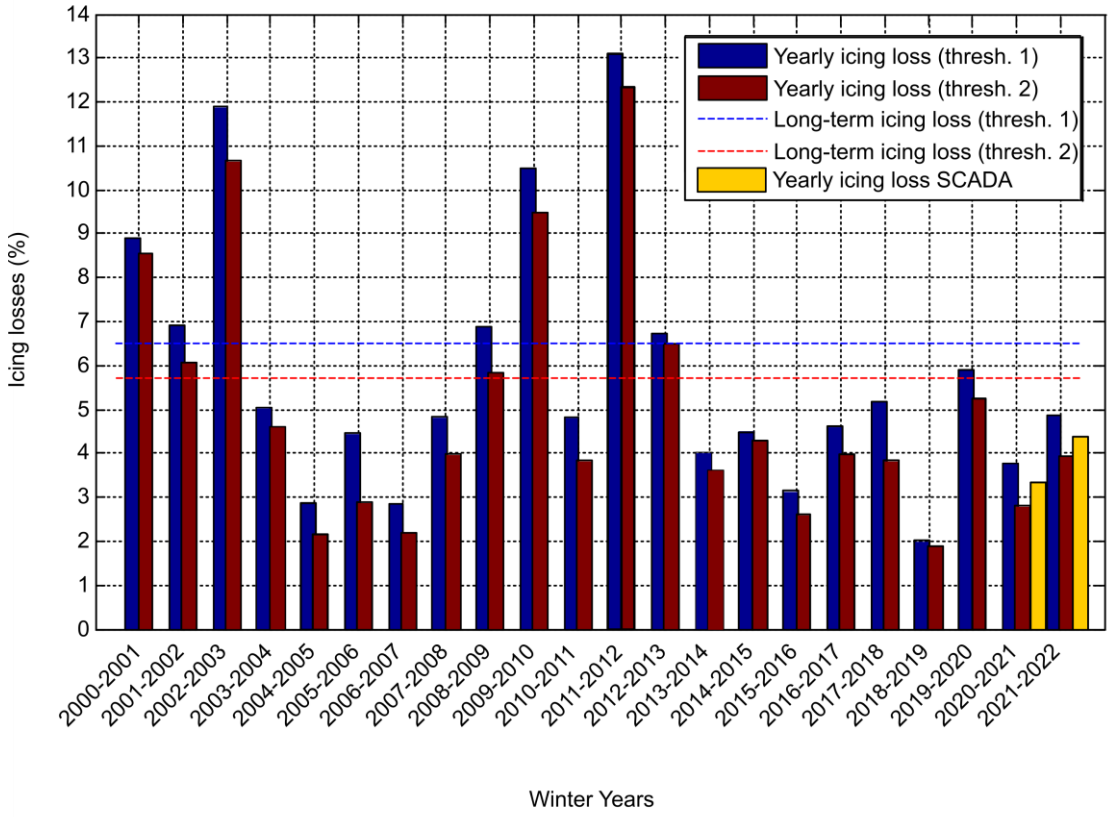
Long-term adjustment of icing losses found in SCADA

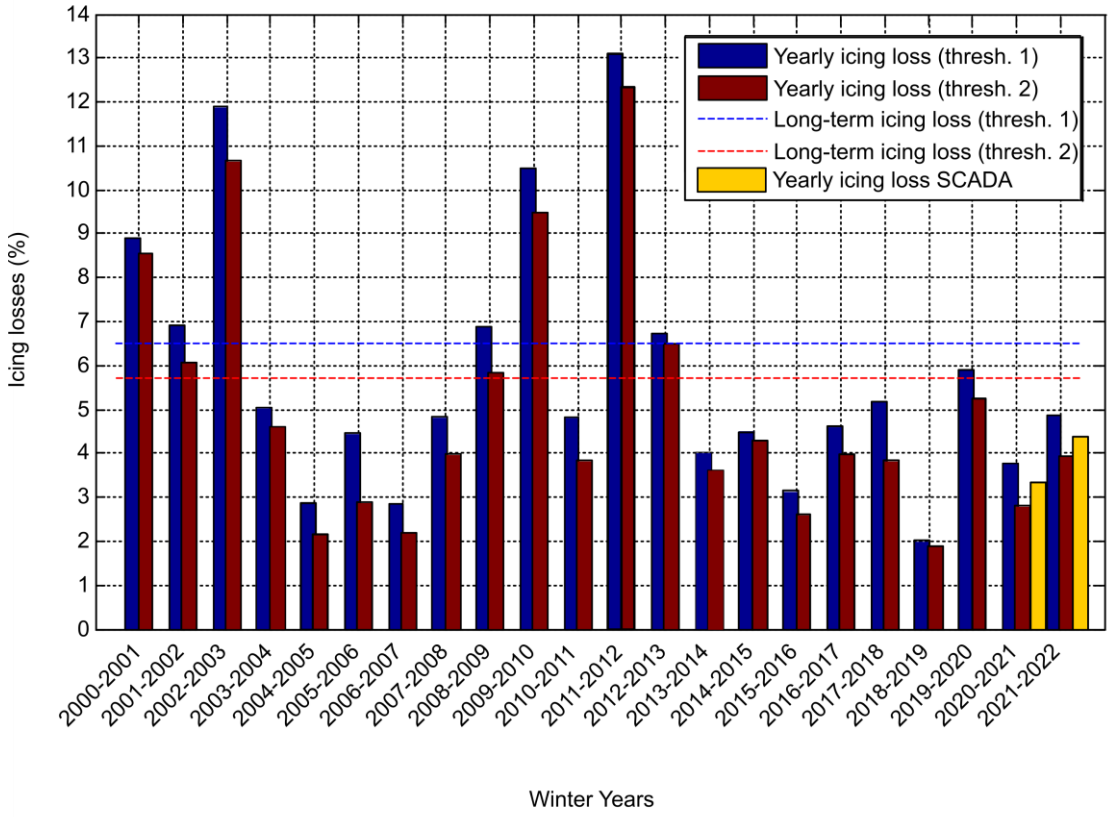
- Final long-term icing losses



Data source	Short term annual average	Long term annual average
Standard Iceloss	2.5 %	4.2 %
Iceloss (thresh. 1)	4.4 %	6.5 %
Iceloss (thresh. 2)	3.4 %	5.8 %
SCADA (2 years)	3.9 % (3.1 % during operation)	6.2 %

Long-term adjustment of icing losses found in SCADA

- Final long-term icing losses



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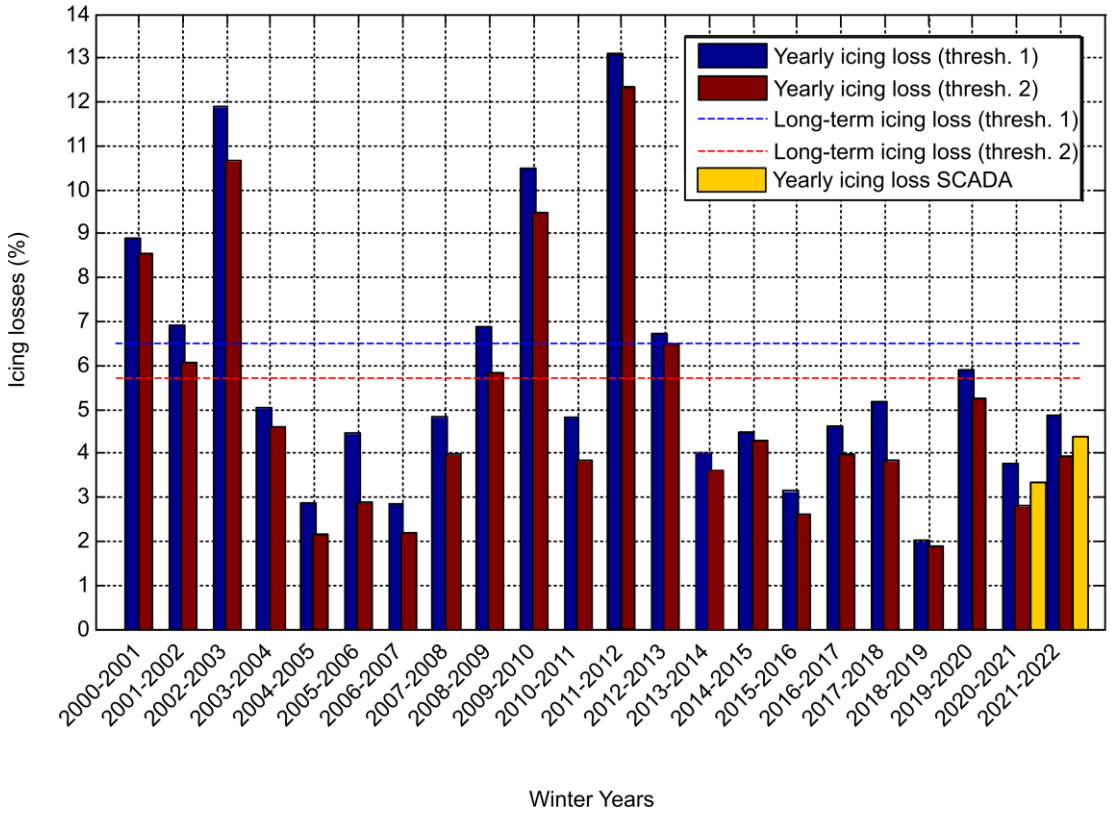

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Final long-term ice loss estimation

Take-away

- Long-term estimations of icing losses are important
- Detailed alarms/logs is key to categorize icing events correctly
- KVT models are useful tools in the long-term correction as well as in the filtering

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Thank you!