Challenges for a smart algorithm controlling wind turbines under icing conditions – Winterwind 2023

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Verbund

Winterwind
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Fact sheet: SOWINDIC

Iced wind turbine Ellern

Smart operation of Wind Turbines under Icing Conditions

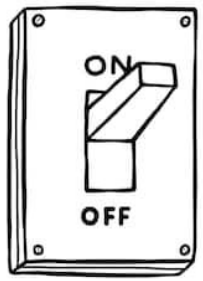
- Funded by the Austrian Climate and Energy Fund
- Project period: 1. April 2021 to 31. March 2024

Project partner

- Austrian Institute of Technology (AIT) – Vision, Automation & Control
  - Real-time data processing of complex dynamic systems, control solutions
- University of Vienna – Data Science @ Uni Vienna
  - Applied mathematics with a focus on optimization (machine learning)
- Meteotest – Wind & Ice
  - Research on icing in wind power, weather forecasting
- VERBUND Green Power (Consortium leader)
  - Operation of wind turbines under icing conditions, research projects about icing

Concept and Goals

- Operating data (SCADA, icing sensors)
- Weather forecast (wind speed, temperature, etc.)
- Production prediction via learned power curve (icing vs. no icing)
- Performance rotor blade heating system
- Electricity prices



Rotor blade heating system

Data collection: Heterogeneous real-time data streams collection on central data platform.

Data processing: Machine learning as well as physics-inspired heuristic model development.

Turbine control: Real-time algorithm deployment on a decentralized edge device.

Aim: Reduction of unplanned icing-losses due to a smart rotor blade heating system.

Q&A: Data collection I

Q1: Are you up for the task? Data is collected in **harsh conditions** and maintaining a high availability is tricky.
A1: Expect the unexpected. Use: UPS, redundant data connections, have spare parts ready, perform summer maintenance …

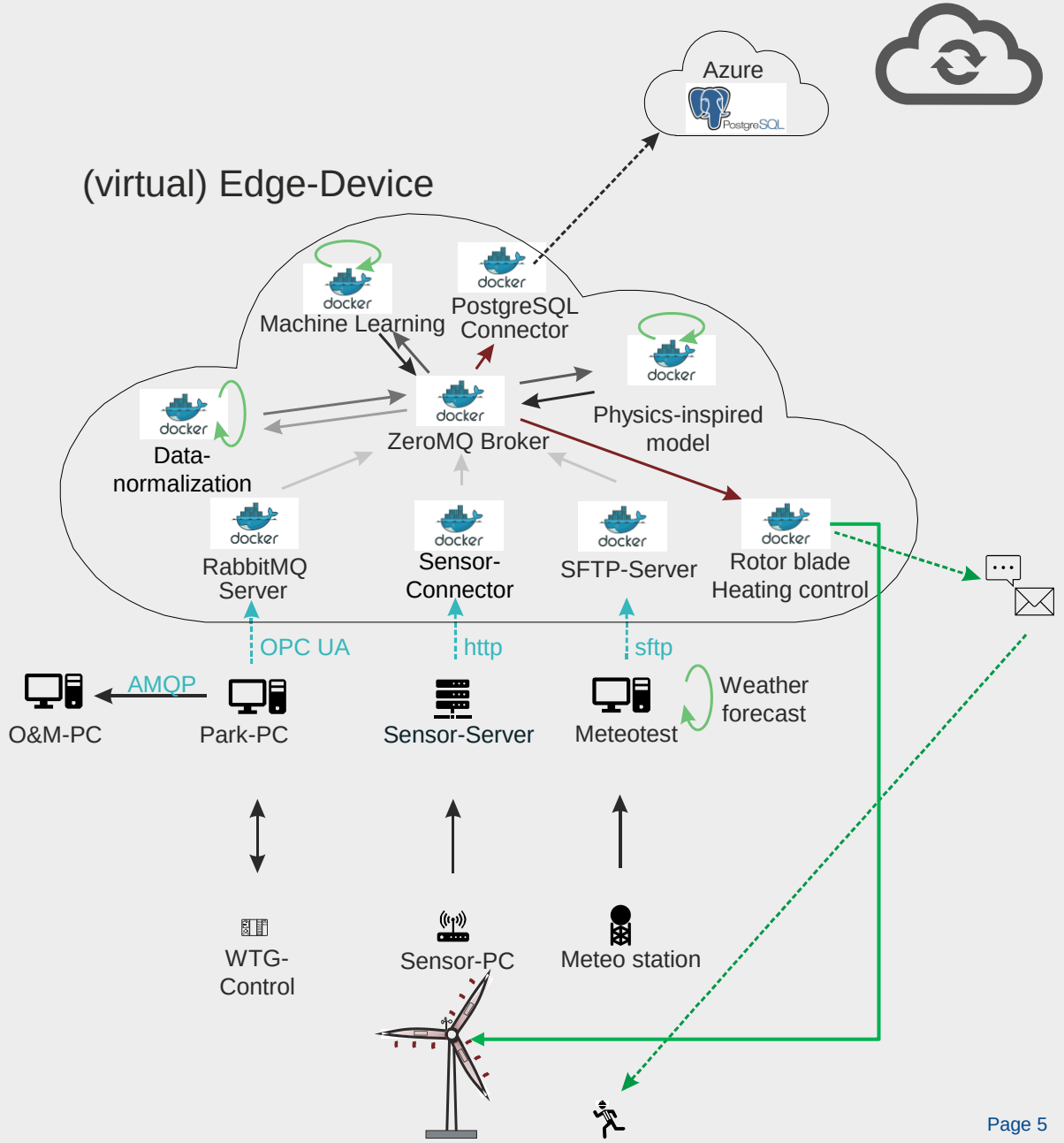
Q2: What are we measuring? There is a difference between **meteorological**, **instrumental** and **rotor blade icing**.
A2: Be aware of what you want to measure and select the right instruments.

Q: Question; A: Answer; UPS: Uninterruptible power supply

Q&A: Data collection II

Q3: What would you do? Measurements of the rotor blade icing are **affected by the operation mode** of the wind turbine.
A3: (Try to) understand the turbine control and sanitize the data.

Q4: Don't forget about the **data integrity**. Synchronizing data from different sources with different protocols and (most of the time) different sampling rates is challenging.
A4: Ask an expert i.e., AIT ;-)

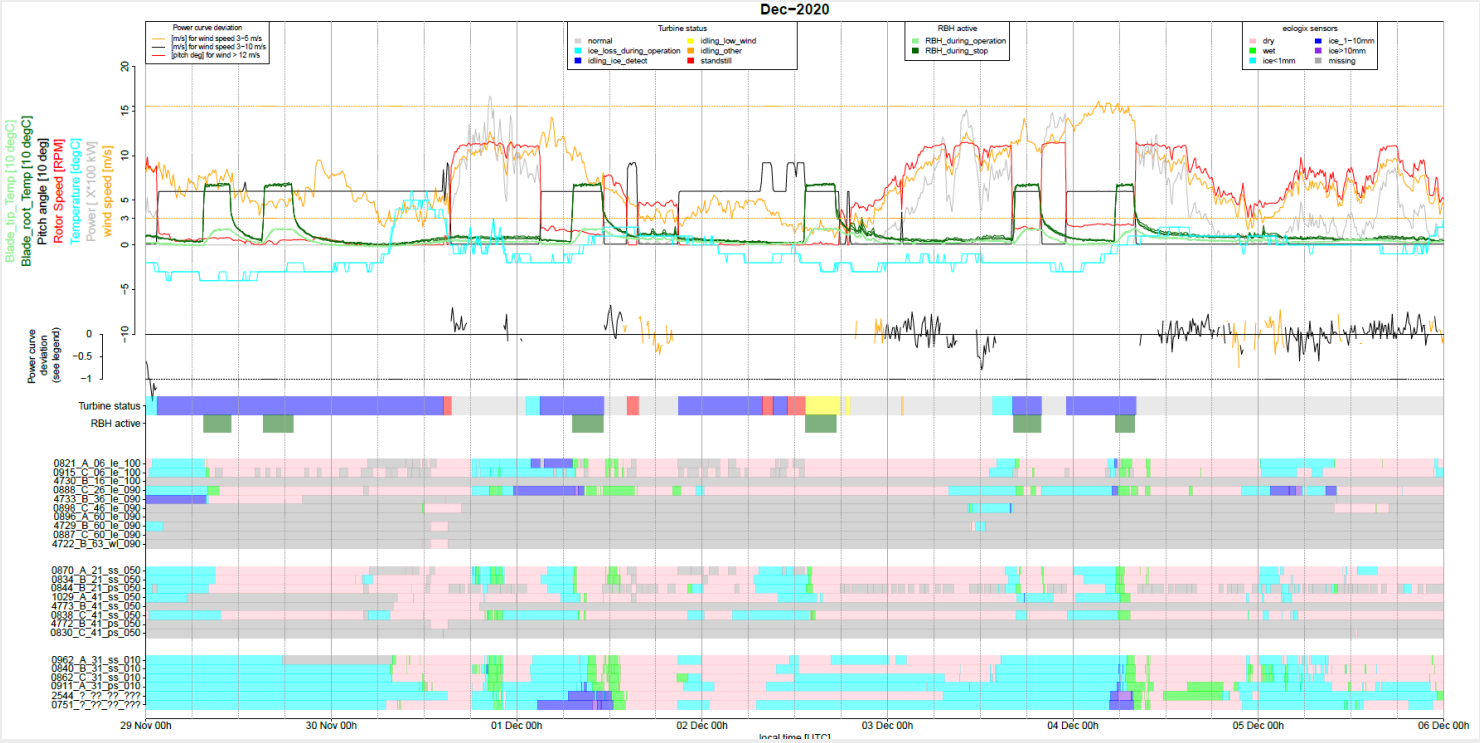


Q&A: Data processing I

THE *Q5*: What is the **ground truth** for icing?

- Turbine → Affected by turbine control. “No” false alarms, just hits?
- Instrumental → Why is the turbine (not) stopping?
- Meteorological → A lot of false alarms.

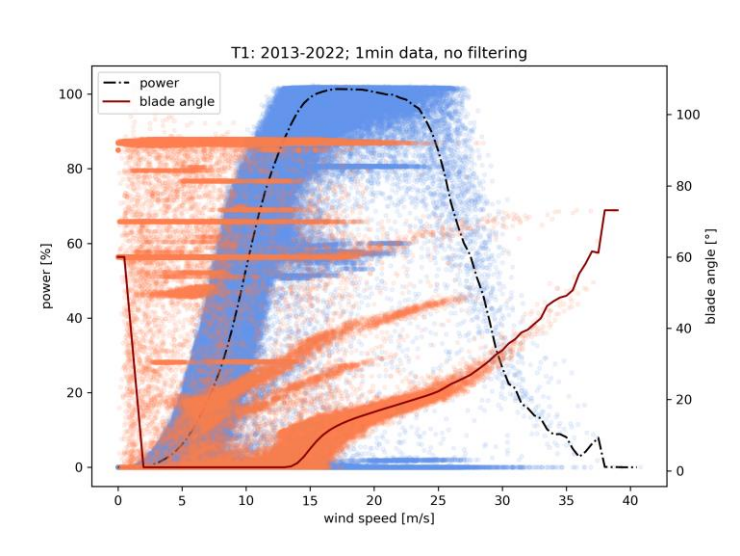
A5: Within SOWINDIC the **turbine icing** is the ground truth → Goal: Reduction of production losses. Again, (try to) understand what the turbine is doing. Compare the sensor data when the turbine is icing and find “common ground” i.e., correlations.

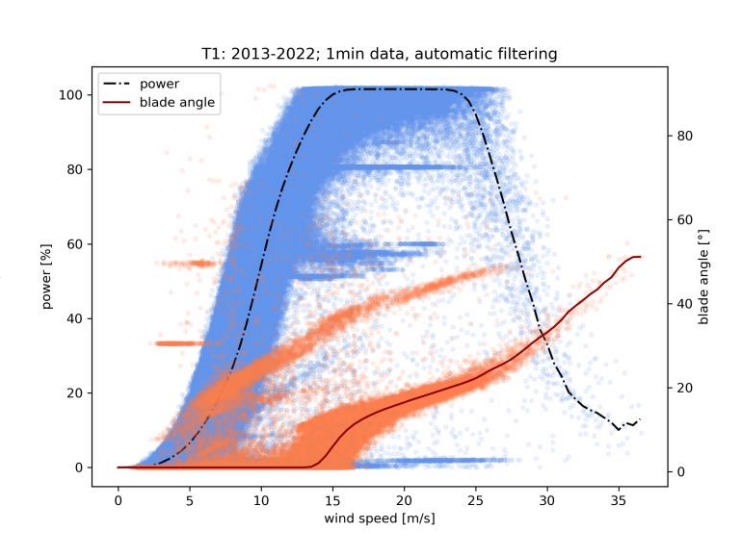


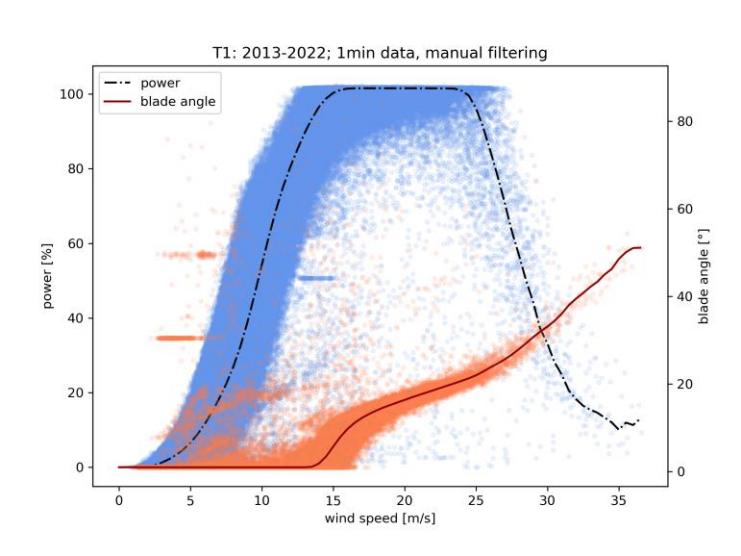
Q: Question; A: Answer

Q&A: Data processing II

Q6: What do we train today? There must be **enough high-quality** data when it comes to training a machine learning model. **Icing** is still a **rare** event to train with.
A6: Use as much data as possible and be innovative i.e., use "Cross Validation“, "Data Augmentation“ for increasing the training/test data or ask Uni Vienna ;-)
Q7: What did you just say? Comparisons/correlation with neighboring turbines may seem tempting but **microclimatic effects** may interfere.
A7: **Neighboring turbines can be helpful** but use filtering/clustering – maybe weather patterns – to keep the test data sufficient.







Q: Question; A: Answer

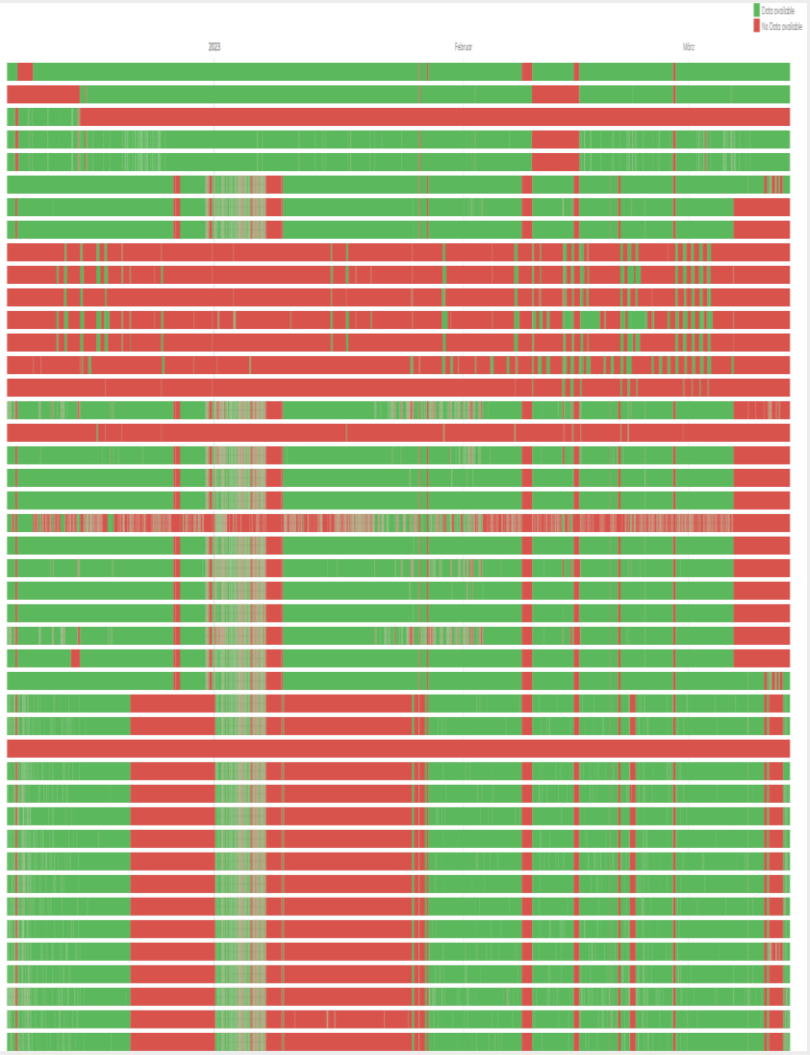
Q&A: Data processing III

Q8: What do you prefer? **Heating during operation** (preventive before ice occurs or proactive whenever (first) ice is detected) or when the turbine is **stopped** (reactive)?
A8: Bes case: Model output but often driven by external circumstances (Turbine type, requirements, …).

Q9: Sell, buy or hold? With **less fixed feed-in** tariffs and **more tender** processes taking place the electricity prices are more and more important.
A9: Include energy prices or an energy market model in the algorithm.

Q10: Do you know it all? A key for setting-up a successful model is to understand the deicing process → **Rotor blade heating envelope**.
A10: Ask Meteotest respectively IEA Wind TCP Task 54 ;-)

Q11: Data integrity – Part II: “Real-time” is even more fun. “Biggest” question: What is the algorithm doing when **data is missing**?
A11: Keep this fact in mind when setting up a model and define fallback scenarios.



Q: Question; A: Answer

Q&A: Turbine control

Q12: Can we use your computer? For performing a real-time algorithm, a sufficient development environment is necessary.
A12: Keep the **operating system adaptive** i.e., docker container. You may need to switch between on-premise or decentralized devices. The advantage of a **decentralized device** is that it increases the "real-time" data availability e.g., when installed within the turbine in the event of mobile network outage the SCADA data is still available.

Q13: What was in the mail today? For SOWINDIC a **decentralized edge device** is used. Spoiler: The delivery time was "madness".
A13: See previous answer and order early ;-)

Q14: Control what you can control. A **direct connection to the SCADA** must be established. This can be challenging since wind turbine OEMs (original equipment manufacturer) are restrictive.
A14: Cooperate with OEMs and be creative i.e., use already established connections. Highest priority: **Cyber Security**!

Q15: Back-up the back-up. What to do when the direct connection to the turbine control is not available?
A15: Have a back-up ready i.e., use **mail- or SMS-notification** to inform the operator.

Q&A: Aim

Q16: What do you have in stock? **Wind turbine OEMs don’t** necessarily **provide rotor blade** heating systems, especially when it comes to larger turbines.
A16: Keep demanding heating systems or retrofit turbines.

Q17: Are you allowed to do this? **Local laws** or **legal requirements** can be **very restrictive** when it comes to control the turbine in cold climate.
A17: Talk to each other. Use science, expert reports, certificates, **best practice** and be adaptive with the heating strategy. Take the concerns seriously.

Q: Question; A: Answer

„Solutions“ and outlook

What you should remember

- Know what you want to measure (meteorological, instrumental or rotor blade icing) and install “the right” measurement equipment i.e., webcams, rotor blade-based systems, meteorological station on the nacelle, …
- Challenge the manufacturers to **explain** their **SCADA system**.
- Demand heating systems from the OEMs.
- Find **best practice** for operating a rotor blade heating system and raise the acceptance.
- **Collaborate** i.e., SOPWICO – Smart Operation of Wind Power Plant in Cold Climate (VGBE). Icing is a rare event and sufficient data is the key.

Next steps within SOWINDIC

- Evaluation of the machine learning as well as physics-inspired heuristic model and combine “the best of both worlds” to perform a **hybrid model**.
- **Sensitivity analysis** of existing input streams to estimate the most important input one as well as advices regarding additional or missing data sources respectively measurement equipment.
- **Real-time** implementation of the algorithms on the **edge device**.

Q18: Who was talking?

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