Winterwind 2021

Operational Icing forecast with a probabilistic approach

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Background

Weather is the main driver of renewables, but also the biggest uncertainty and exposure to trading and balancing in renewables - especially to wind and solar power.

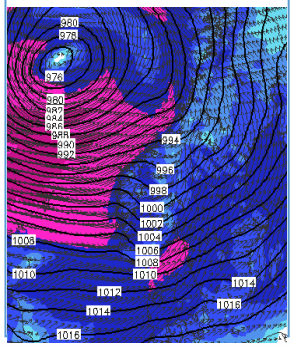
- ConWx in Brief
- Forecasting icing with NWP
- Icing forecast with Bayesian Network
- Results
- Summary

Niels Bohr: ”Prediction is very difficult, especially if it’s about the future”

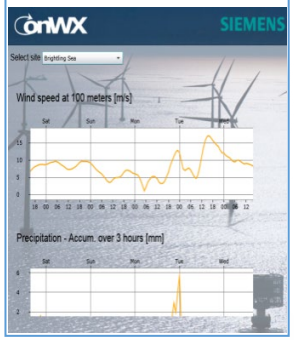
ConWx – A Global Forecasting Partner

Wind & PV Power Forecasts

Numerical Weather Models



Metocean Services and Analysis



- *ConWx have direct portfolio short-term forecasting responsibility for +110GW and 7GW PV in Europe and 50 GW in Asia*
- ***First mover** on cloud technolgies since 2009 with +30 servers on AWS today*
- *Uses daily **Machine Learning** and **AI***
- *Working with LiDAR and **IoT** for **offshore** optimization*
- *ConWx has the largest portfolio of offshore wind power and hybrid plants*
- *Part of **Volaris Group Ltd.***

Our Numerical Weather Models

ConWx blends the state of the art weather models in order to lower errors and risks in renewables forecasting

In-house modelling team adjusts models towards wind and solar forecasts

Having access to the full model grids gives us the opportunity to do local calibration

Our NWP setup:

1) **IRIE_EC (7km)**
2) **IRIE_GFS (7km)**
3) **ECMWF (9km) External**
4) **UK_Metoffice (4km)**
5) **DWD (5 km)External**

In test:
WRF_EC (3 km)
NNMB_EC (3km) (exposed)

Icing – More uncertainty to the forecasting

Three sources to build up ice on the blades:

- Wet snow (wide spread in high wind situations) **Good forecasted**

- Freezing rain (sub cooled rain- Glaze) **Good/poor forecasted**

- In-cloud icing (sub cooled droplets in clouds- soft and hard rime) **Poor forecasted**

- 24% of total currently installed capacity are in cold and icing climate
- Icing mainly between -10 and 1 degree Celsius
- Very difficult to forecast

Icing deforms the aerodynamics on the blades -> Less production

Icing WTG is closed due to vibrations/detection -> No production

What do we use from the weather models?

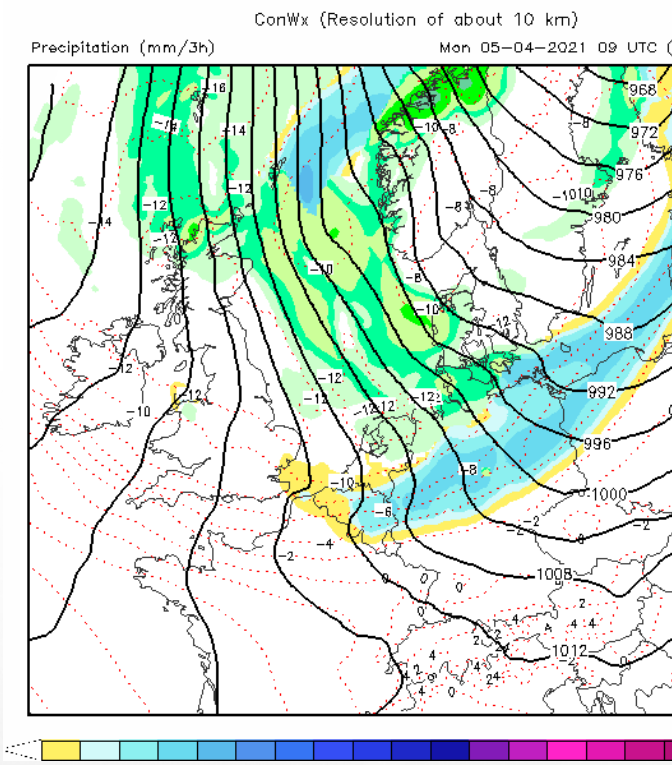
From the weather models we use:

- Temperature (surface and hub height)
- Dew point (humidity)
- Precipitation (type and amount)
- Wind speed (hub height)
- **Visibility a proxy for the droplet's concentration**

The NWP very good for wet snow and freezing rain.
But difficult to handle the drizzle and in-cloud icing

Why is it challenging?

- Errors in the forecast
- Local topographical forcing
- Icing formation on the blades is complex
- The impact on the production is complex
- Sublimation
- Heating makes it more complex for the forecasting



Fig; Heavy icing from show showers in NL/BE 5-6 April 21

ConWX Icing Forecasting

ConWX Icing Forecasting

- Bayesian Networks have an advantage for rare events (binary events)
- Advanced Machine Learning method
- Developed in-house
- Robust towards data fall out

Supervised learning

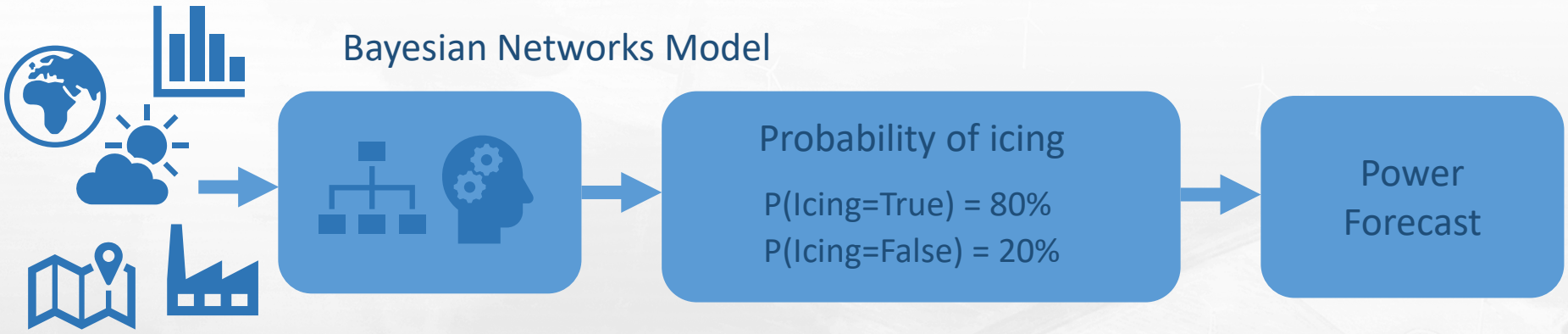
- Historical data for training
- Model adapted to park characteristics

Requires input such as

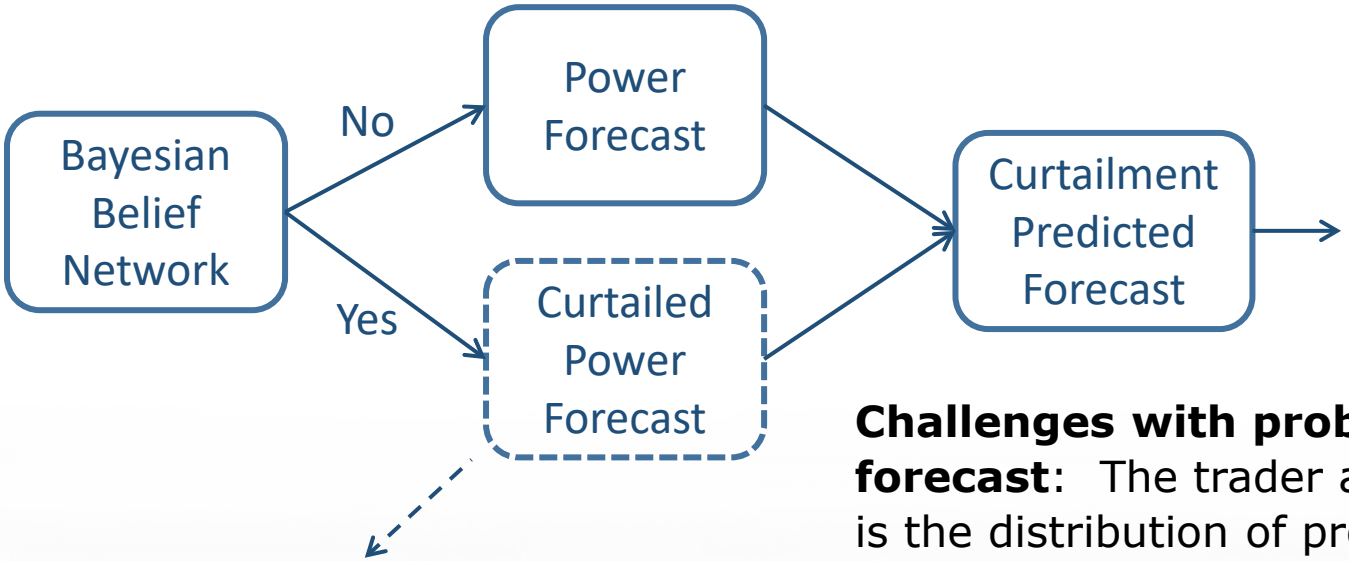
- Geographical location
- NWP data
- Power production data
- Icing information if available
- Season

Provides

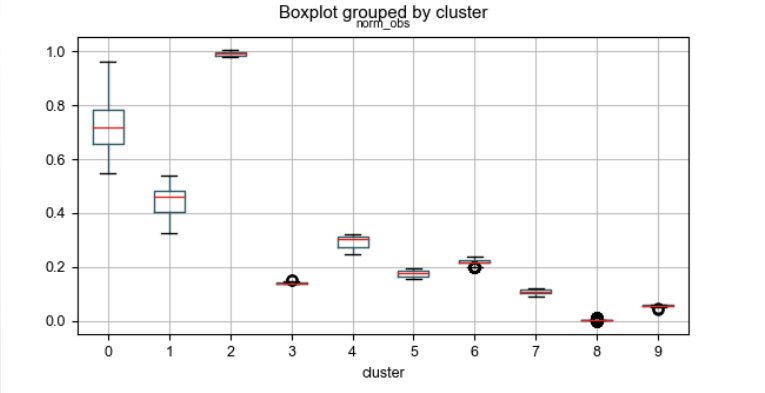
- Predicted probabilities of icing
- Most likely Power Forecast when combined with ConWx Power Forecast System (including icing)



Icing Prediction



Improvements in progress – cluster analysis



Challenges with probabilistic forecast: The trader at the Nordpool is the distribution of probabilities for a binary event, either we have icing or not. Should they in practical work with different thresholds like 50%, 60% or different thresholds?

The network gives us a probability of icing not the intensity of the icing. The intensity must be estimated with machine learning to estimate the power forecast.

Some examples from Swedish farms in SE1

	Percentage of observations iced*
SE_1	25%
SE_2	20%
SE_3	15%
SE_4	17%

Table 1 ; Icing frequency

*Where 1 or more turbines has been marked as icing from October to March.

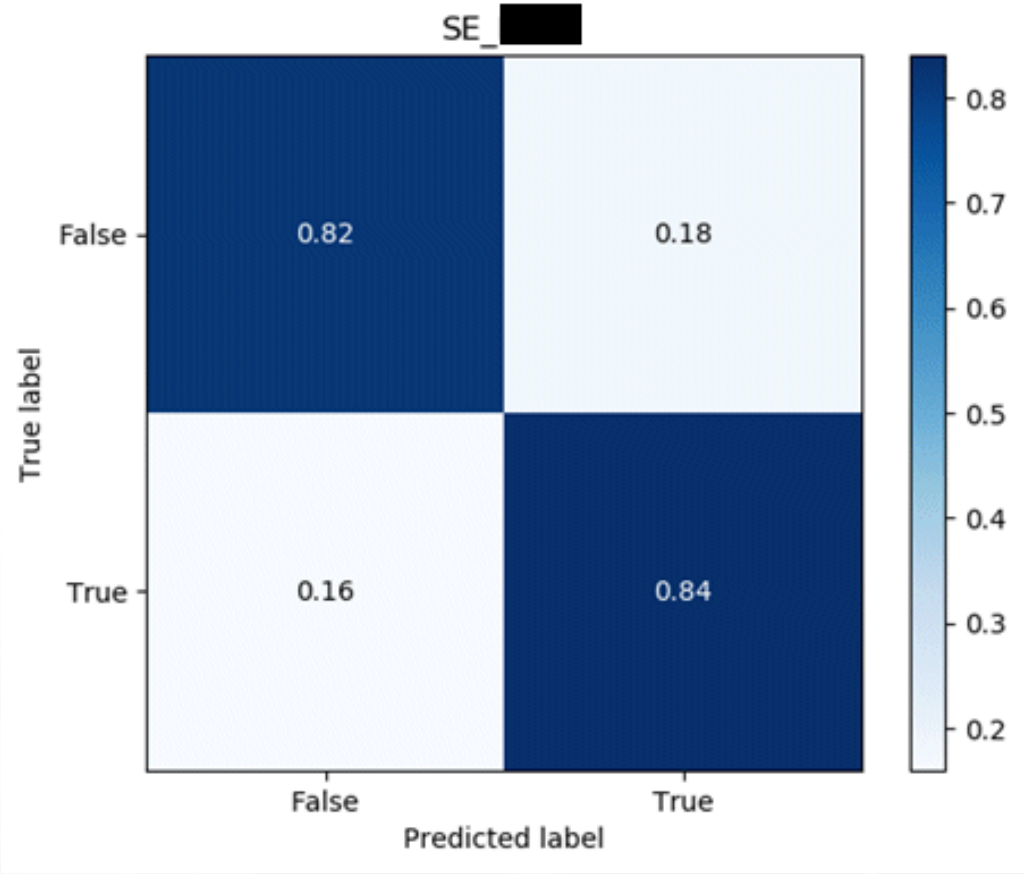
Accuracy	Predict all to FALSE	Icing Network
SE_1	0.74	0.84
SE_2	0.79	0.83
SE_3	0.84	0.87
SE_4	0.82	0.87

Table 2; Overall accuracy vs baseline

	Forecast improvement during icing
SE_1	0.50%
SE_2	9%
SE_3	6%
SE_4	17%

Table3; Improvements in the forecast on intra day

Farm in SE1 true/false predictions



Figure; Icing forecast for ID forecast for a site in SE1

Summary

- Icing is very difficult to forecast, especially the intensity
- Bayesian network can predict binary events
- The intensity of the icing could be forecasted with machine learning
- Still depending on a algorithm for snow and freezing rain
- Without historical data a generic icing profile must be used

Future improvements

- Optimize on the volume forecast with the information on heating, turbine type etc.
- More online Icing detection data

It is all about data!

Thank you!

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