Impacts of extreme weather events on wind and solar forecasts

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and how we mitigate the problem

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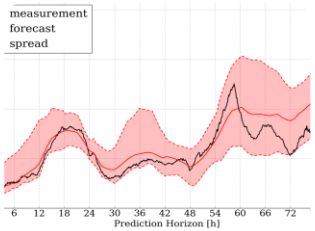
About energy & meteo systems

Company

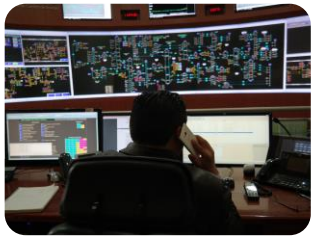
- Owner-managed since its founding in 2004
- Located in Oldenburg, Germany
- 100 employees (software developers, physicists, meteorologists and industrial engineers)

Services



- 420 GW of wind and solar power forecasting, Behind-the-Meter PV estimation and forecasting
- Market-leading Virtual Power Plant (SaaS)
- Grid Load forecasting
- Consultancy and R&D

Customers



- Transmission, Distribution and Independent System Operators
- Energy trading companies
- Plant operators (IPPs, utilities etc.)

Different extreme weather events

High-wind cutoff

Shallow fog

Smoke / Dust

Icing

Thunderstorms

Snow

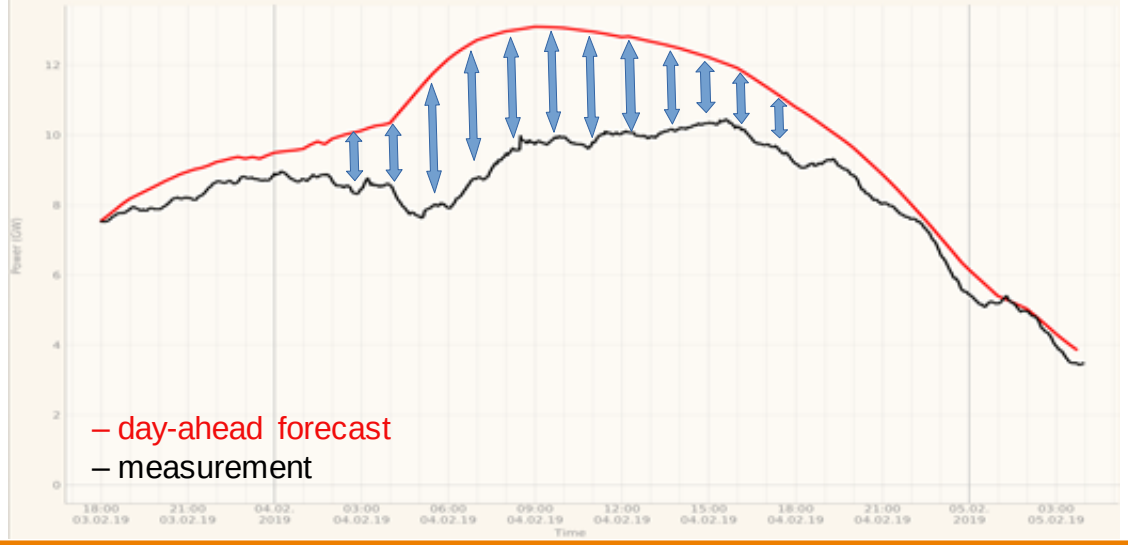
Low / high temperature cutoffs

Icing of wind turbines

- Rain falls on wind plants at temperatures below freezing level
- Freezing rain
  - wind farms (partially) get iced and shut down
  - is commonly observed in precipitation regions of winter storms
- Wind farms often **stay iced** even a long time **after the freezing rain**
- Icing of wind plants depends on several parameters:
  - Temperature in different heights
  - Temporal temperature changes (is getting warmer/colder?)
  - Spatio-temporal distribution of precipitation/freezing rain
  - Possible winter packages (e.g. heating systems)

Icing Scenarios

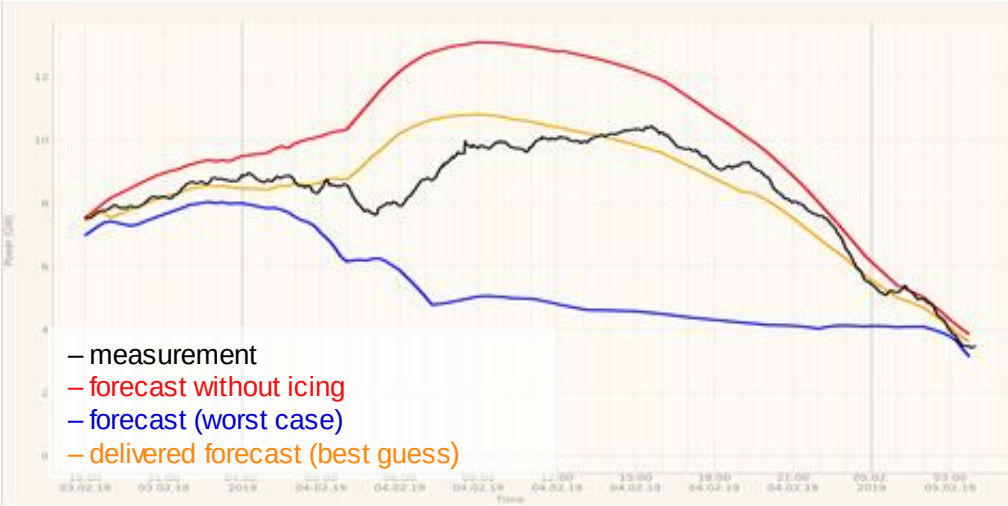
Icing on Single Plant



Icing on Portfolio

Icing: Consideration in the Forecasts

- **Icing-scenarios** (kind of confidence band)
  - no-ice scenario: forecast without consideration of icing
  - worst case: forecast with maximum possible icing reduction
  - best-guess: most likely forecast scenario considering icing



- **Situational awareness:**
  - **Icing reports** with worst-case affected power, a list of potentially affected parks and a map showing affected park locations
  - **Weather warnings** with regular updates from our meteorologists
- Possible additional **manual adaption of the forecasts** in case the icing was not predicted by the NWP models

Icing Report

Icing report
2020-04-01 22:00 EST

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Summary and definitions

Installed capacity of portfolio: 23243.403 MW

Largest icing risk is predicted to occur at 2020-04-03 12:00 EST reducing power production by 8,673 MW (37.31% of installed capacity)

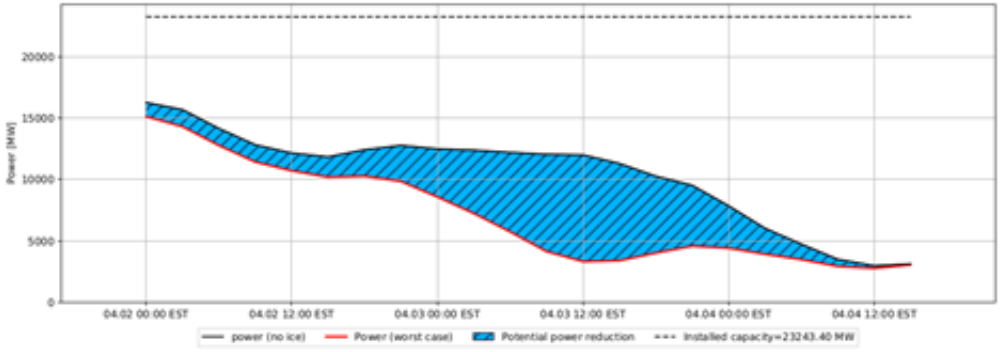
The icing forecast is based on the numerical weather model predictions and represents the worst case scenario, i.e. each wind farm affected by icing is assumed to produce no energy.

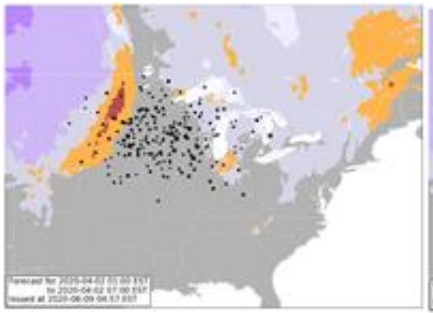
- Meteorological icing: Period during which meteorological conditions favour ice accretion (active ice formation)
- Instrumental icing: Period during which wind farms are expected to be affected by icing (remaining ice)
- Temperature cutoff: Period during which wind farms are expected to be shut down due to very low temperatures

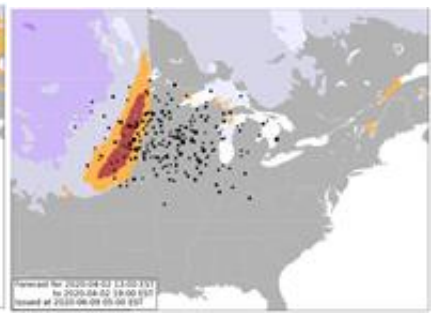
	2020-04-02 EST								2020-04-03 EST								2020-04-04 EST					
	00	03	06	09	12	15	18	21	00	03	06	09	12	15	18	21	00	03	06	09	12	15
Total																						
Absolute reduction [MW]	1130	1378	1381	1391	1455	1649	2142	2628	3907	5149	6462	7912	8673	7906	6247	4943	3447	2105	1246	570	206	65
Relative reduction [%]	5	6	6	6	6	7	9	13	17	22	28	34	37	34	27	21	15	9	5	2	1	0

Absolute power reduction represents the worst case scenario, i.e. each wind farm affected by icing is assumed to produce no energy.
Relative power reduction represents the power loss relative to the installed capacity.

Timeseries plot: Total

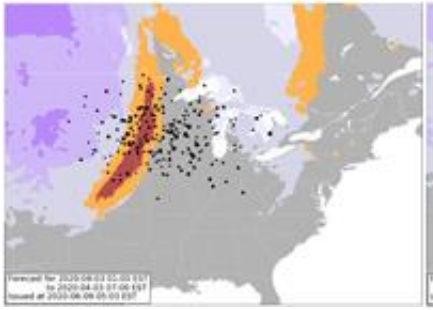


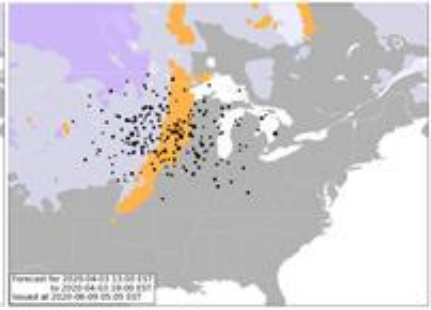




Meteorological icing likely | Meteorological icing possible

32.0 to 14.0°F | 14.0 to -4.0°F | -4.0 to -22.0°F | -22.0 to -40.0°F | below -40.0°F





Wind farm overview of largest 50 farms

Meteorological icing: Period during which meteorological conditions favour ice accretion (active ice formation)
Instrumental icing: Period during which windfarms are expected to be affected by icing (remaining ice)
Temperature cutoff: Period during which windfarms are expected to be shut down due to very low temperatures

m Meteorological icing | i Instrumental icing | t Temperature cutoff | Temperature below freezing point

Wind farm	2020-04-02 EST								2020-04-03 EST								2020-04-04 EST					
	00	03	06	09	12	15	18	21	00	03	06	09	12	15	18	21	00	03	06	09	12	15
Park 1												m	m	i	i							
Park 2								m	m	m	m	m	i	i	i	i	i	i	i	i	i	i
Park 3																						
Park 4											m	m	m	i	i	i	i	i	i	i	i	i
Park 5																						
Park 6												m	m	i								
Park 7																						
Park 8												m	m	i								
Park 9									m	m	m	m	m	i	i	i	i	i	i	i	i	i

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Icing as an extreme weather event

- **Icing** due to freezing rain is **crucial for wind power production**
- Significantly reduced power even on portfolio level
- Mitigation through:
  - Delivery of different scenarios (no ice, worst case, best case)
  - Correction algorithms
  - Manual adaption in extreme cases
  - Reports and warnings (situational awareness)

Thank you for your attention!

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