Turbine dynamics and power curve performance

26. Windenergietage

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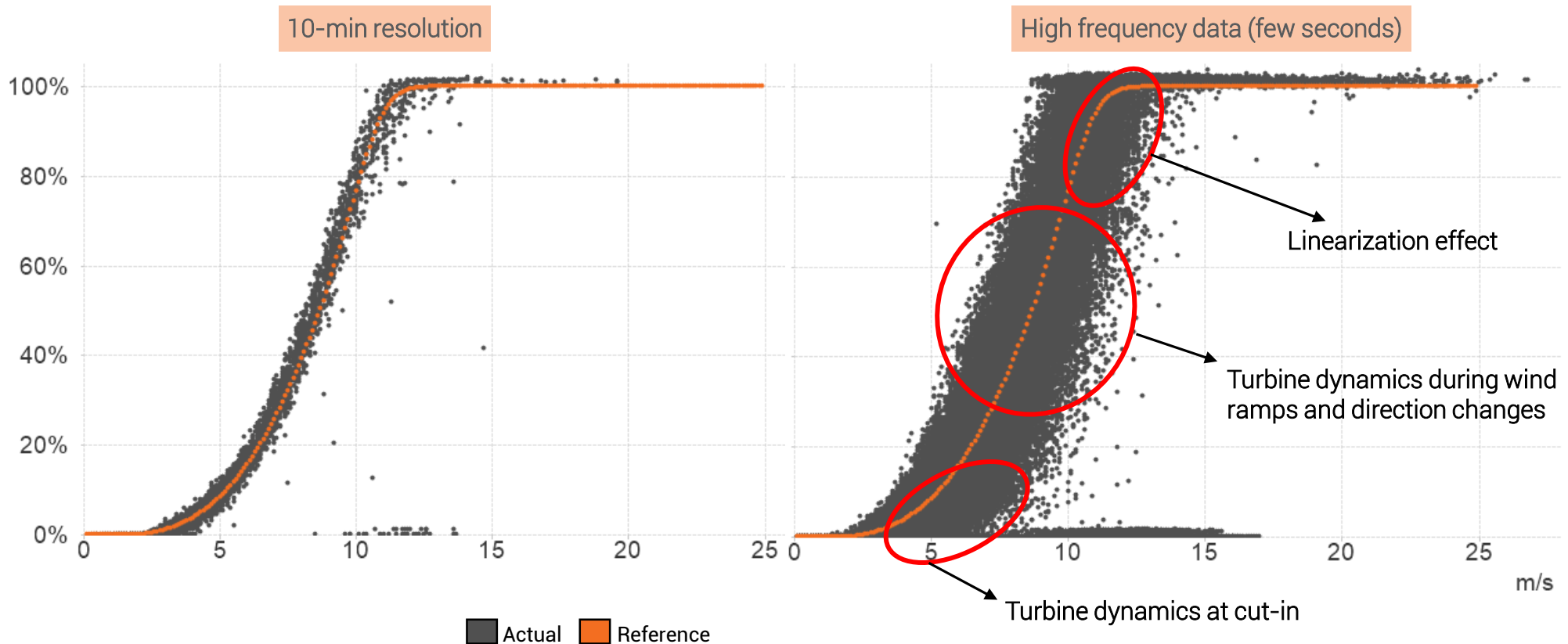
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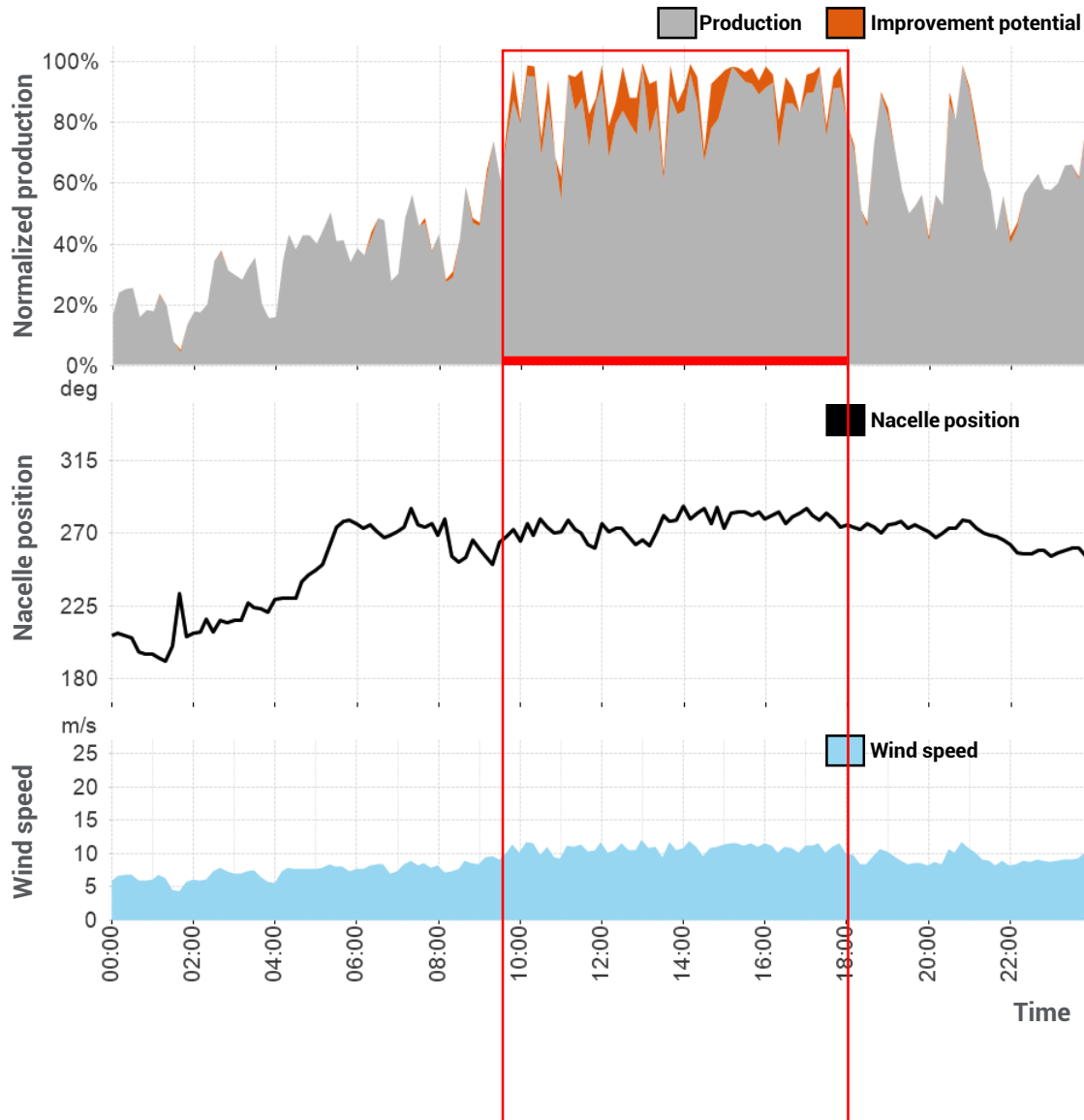# Content

The following topics are investigated:

- Turbine dynamics during changes of wind speed and wind direction

- Turbine dynamics at cut-in

- Effect of 10-minutes linearisation close to rated wind speed

# The data used in this study

- The data comes from a modern pitch-controlled multi-megawatt wind turbine with more than 100 meters rotor diameter
- SCADA data in high resolution is used (few seconds) obtained from OPC server
- 10-minutes averaged signals are also considered in this study

10-min resolution

High frequency data (few seconds)

Linearization effect

Turbine dynamics during wind ramps and direction changes

Turbine dynamics at cut-in

Actual   Reference

Wind ramps: 10-min data

- Fast changing wind speed and wind direction
- The points on the power curve are below the reference (red arrow)

➢ Is this underperformance?
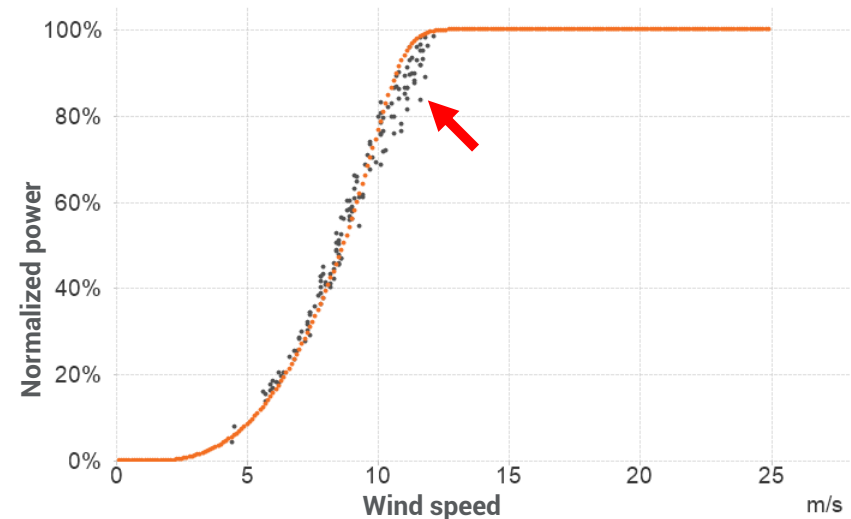
Wind ramps: high-freq data
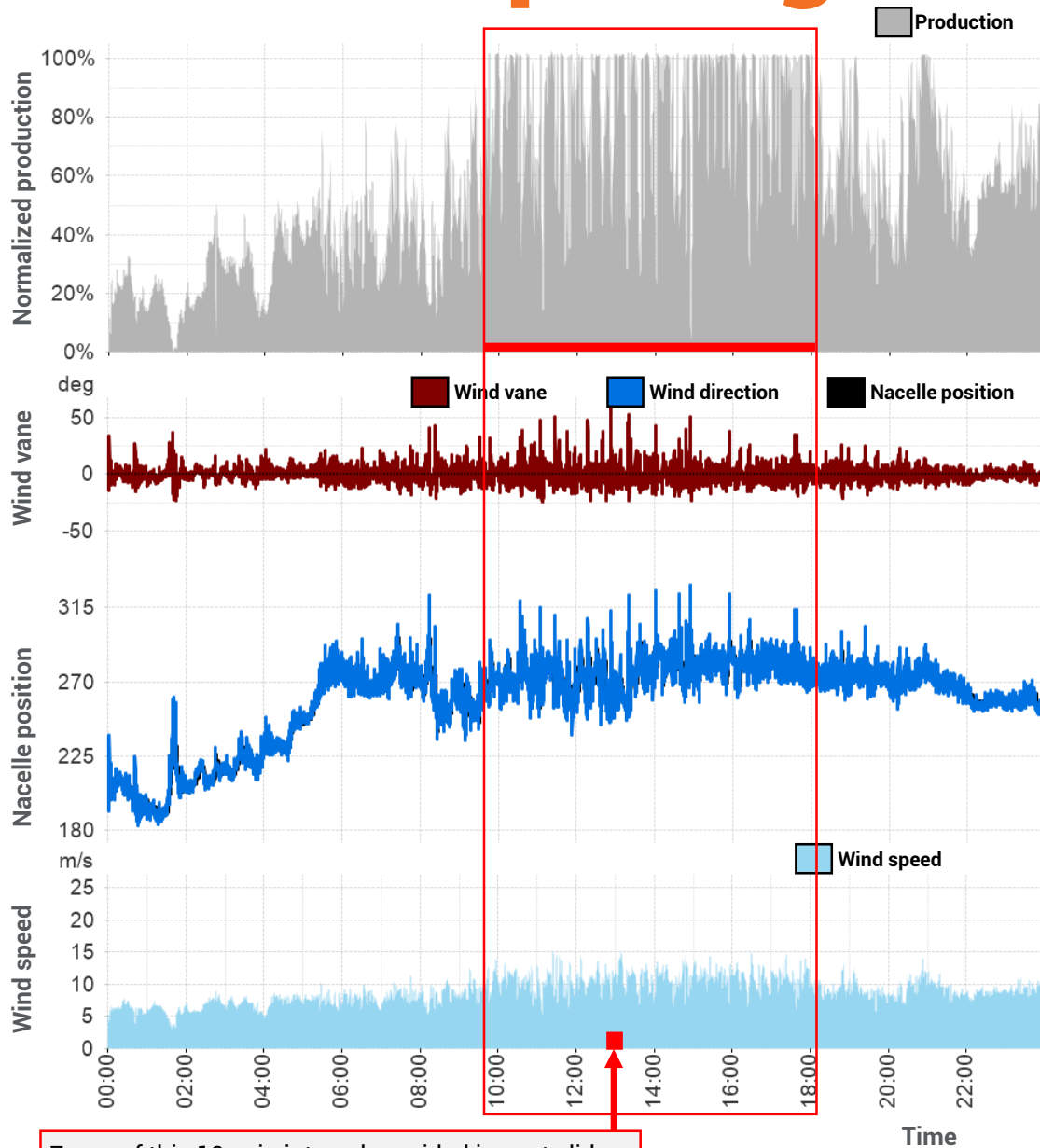
- The same time interval as shown in the previous slide with 10-min data is presented here using high frequency data

- As can be seen, the fluctuations are even higher

- Power curve: now the points are more equally distributed around the reference curve. What about underperformance?


Zoom of this 10-min interval provided in next slide
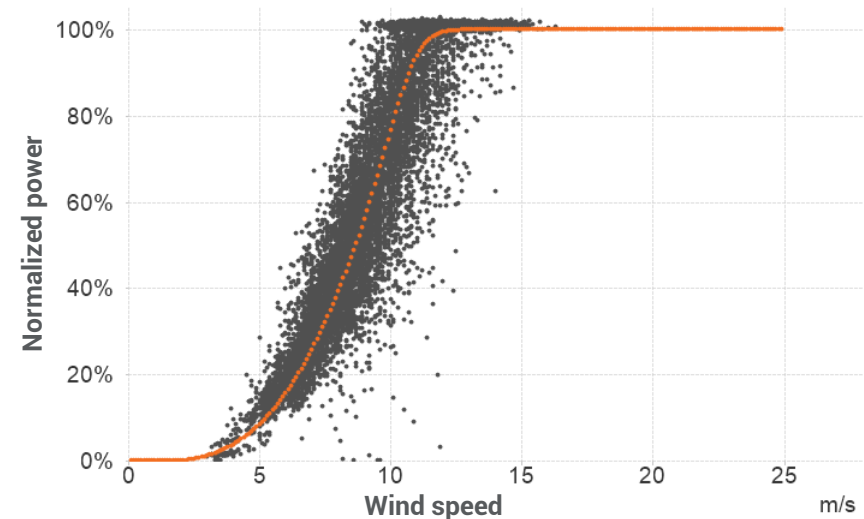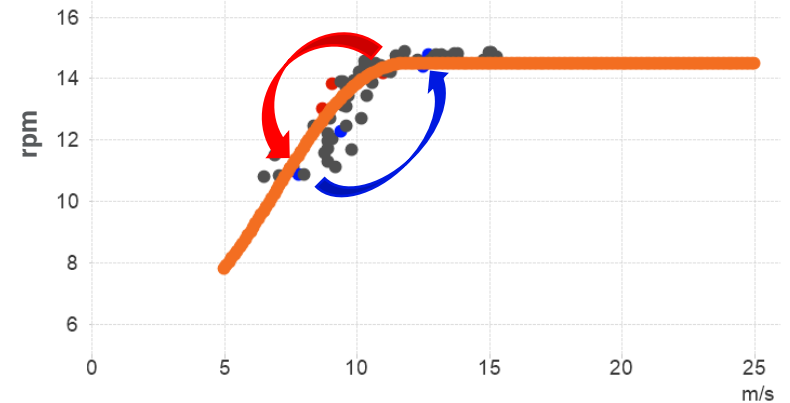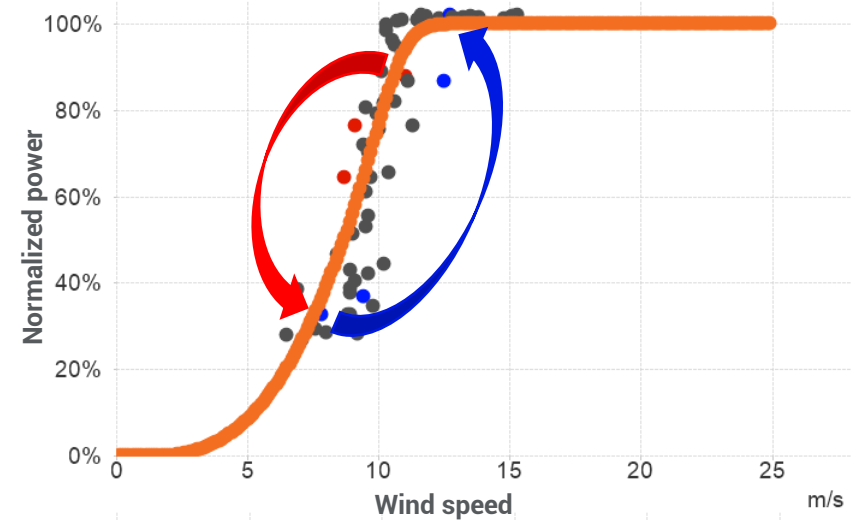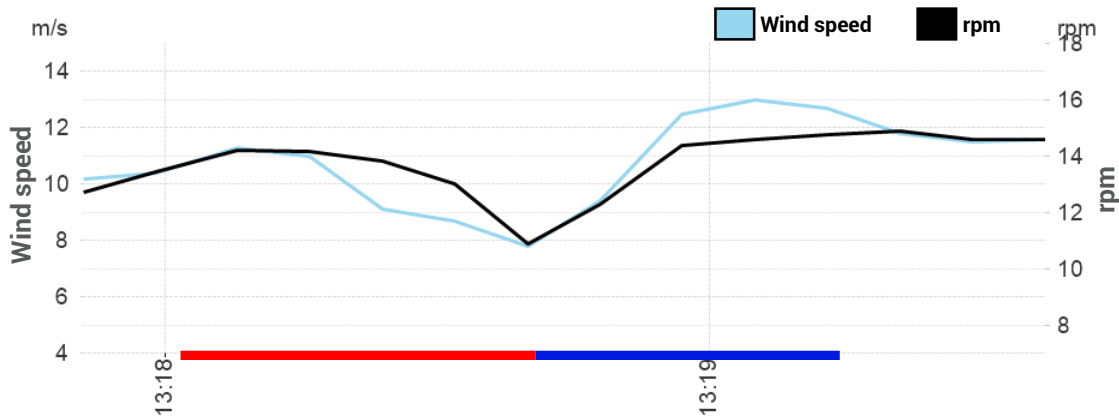
Wind ramps

Power curve with 10-min data
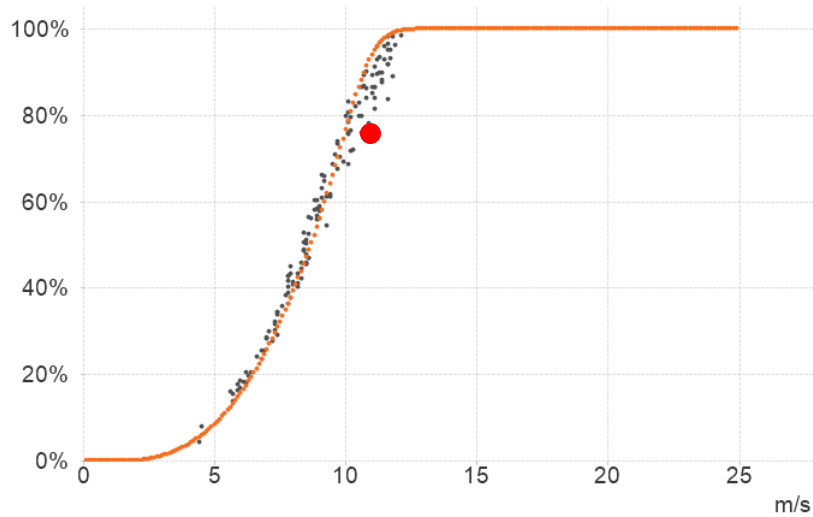
- The red point in the power curve above represents the 10 min interval marked with a red filled rectangle in the previous slide.

- The graphs on the right-hand side of this slide show the turbine dynamics during the 10-min interval specified above.

- As one can see, the turbine behavior during this 10-min interval was far from being stationary.

Wind ramps

Production
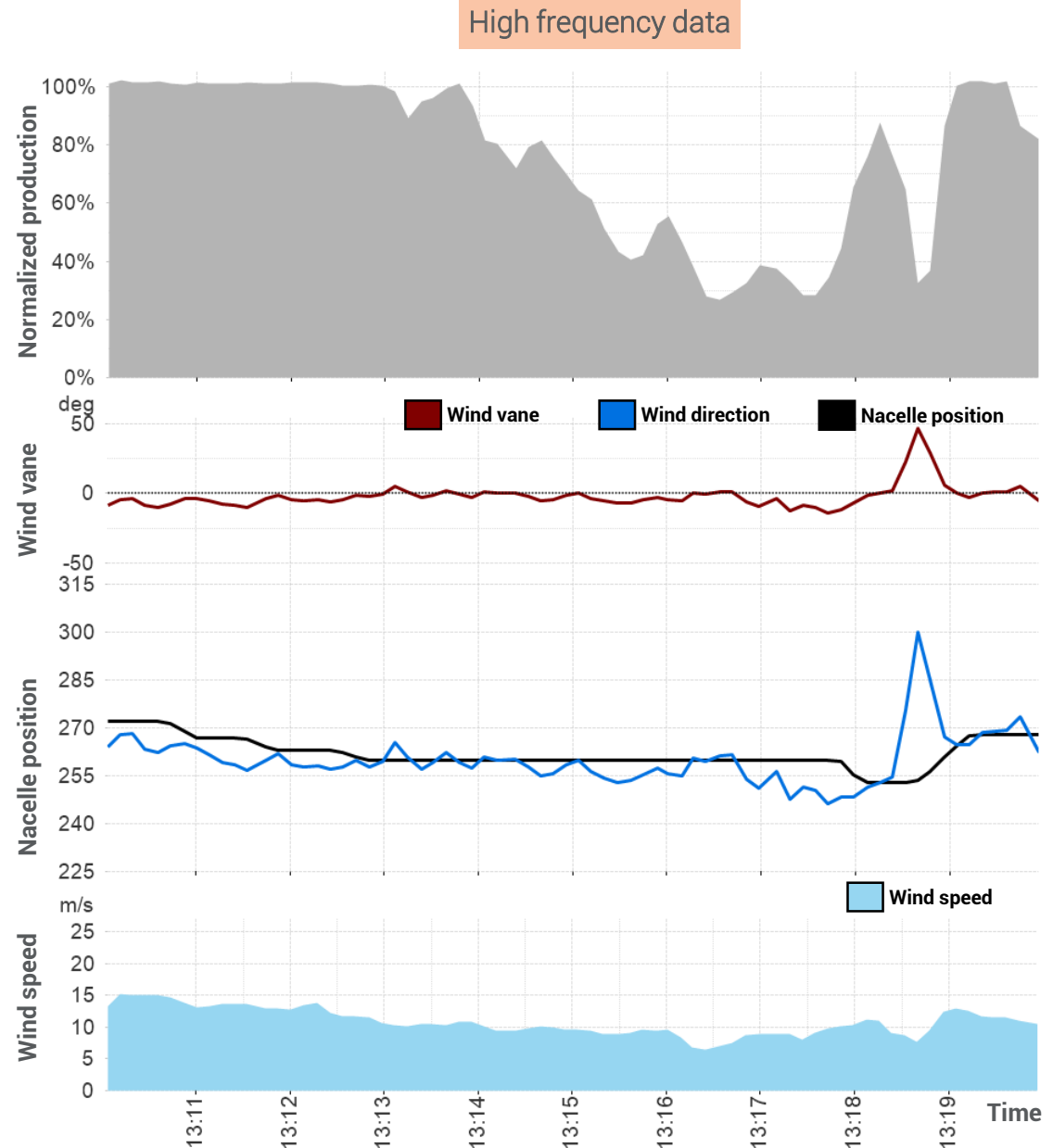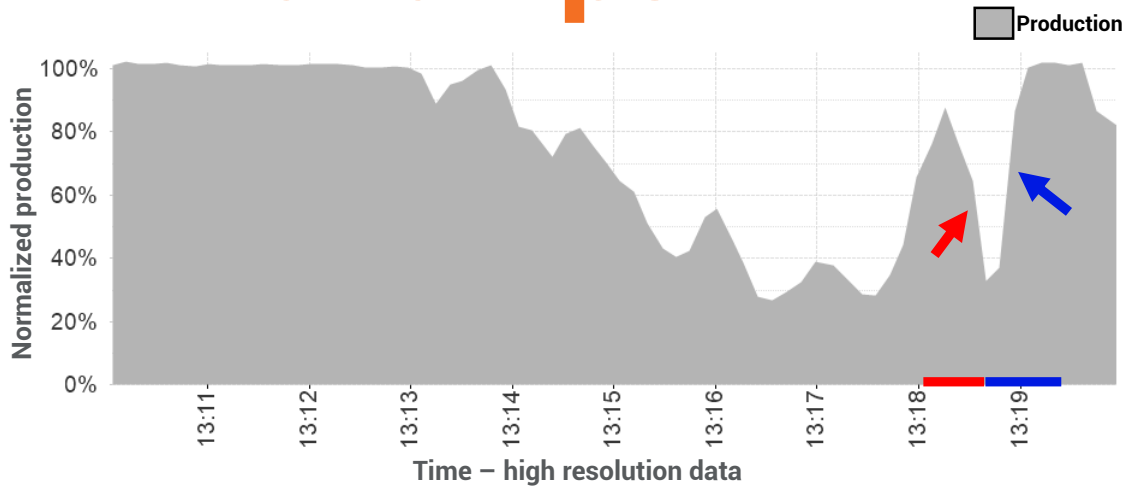
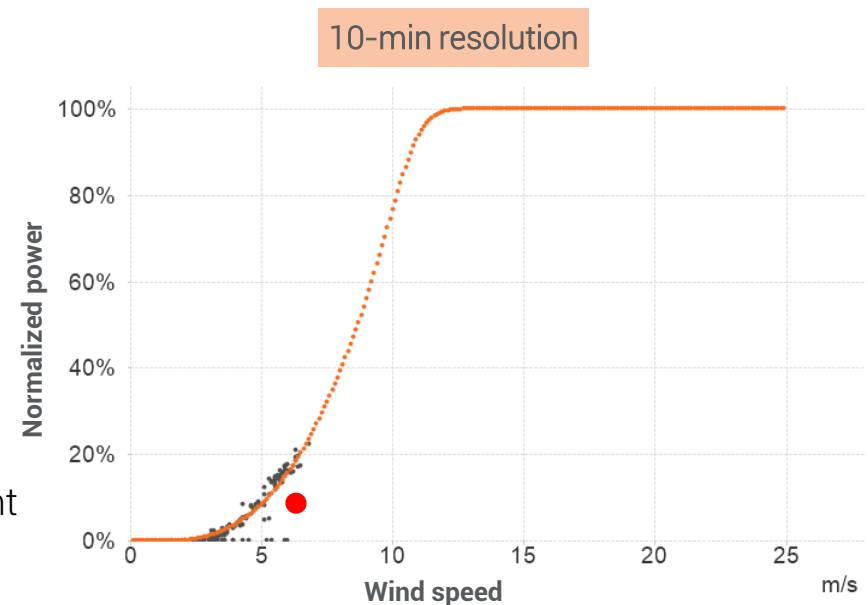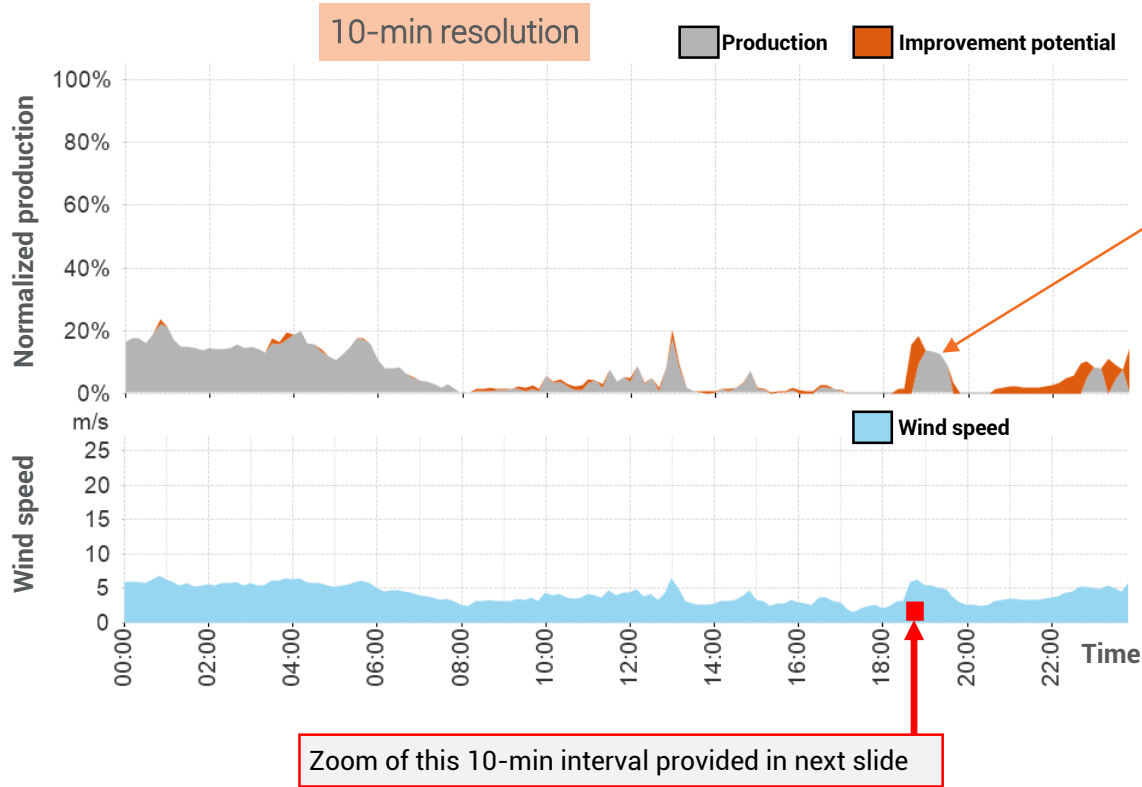- In this slide two wind speed ramps are investigated closer:
  o A decreasing wind speed ramp (marked in red)
  o An increasing wind speed ramp (marked in blue)

As one can see, during a decreasing wind speed ramp, the points are laying above the reference power curve, due to the time lag of the turbine response (mainly rotor speed). The opposite occurs for increasing wind speed ramps.

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Turbine dynamics at cut-in

10-min resolution
Production
Improvement potential
situation of turbine cut-in
Wind speed

Zoom of this 10-min interval provided in next slide

10-min resolution

- In the 10-min power curve on the right hand side, the red point represents the 10-min interval corresponding to the cut-in event shown in the graphs above.

- Is this underperformance?

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Turbine dynamics at cut-in

Normalized production
100%
80%
60%
40%
20%
0%
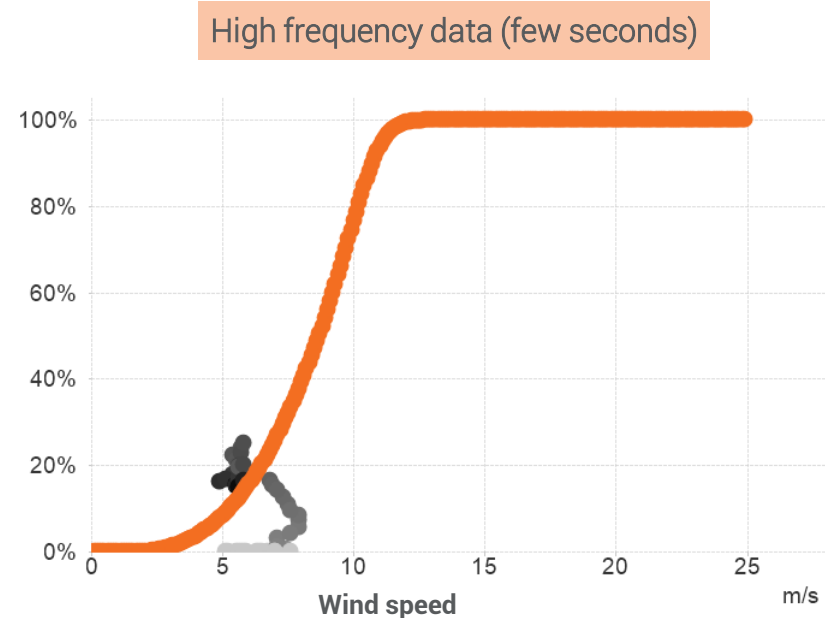
Wind speed
m/s
25
20
15
10
5
0

18:51 18:52 18:53 18:54 18:55 18:56 18:57 18:58 18:59 **Time**

- The grey scale used in the power curve below indicates the time evolution, with colour becoming darker as time increases
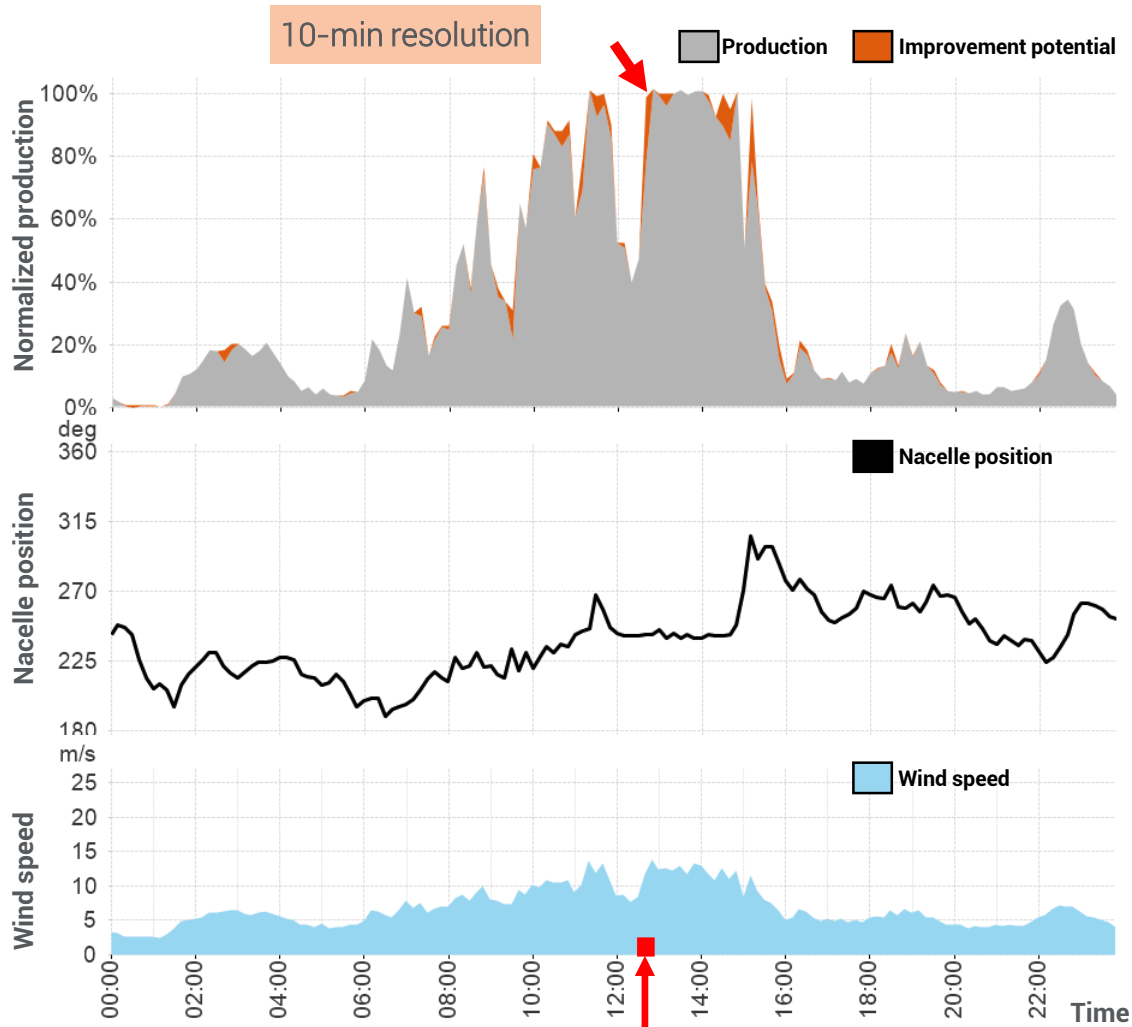
High frequency data (few seconds)

- As one can see, the turbine needs several minutes before the power output reaches the stationary value corresponding to the given wind speed.

- Therefore, the red point on the previous slide is a result of a 10-min averaging during a period of highly transient behavior

100%
80%
60%
40%
20%
0%

0   5   10   15   20   25   m/s
Wind speed

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Linearization effect

10-min resolution

Production   Improvement potential

Nacelle position

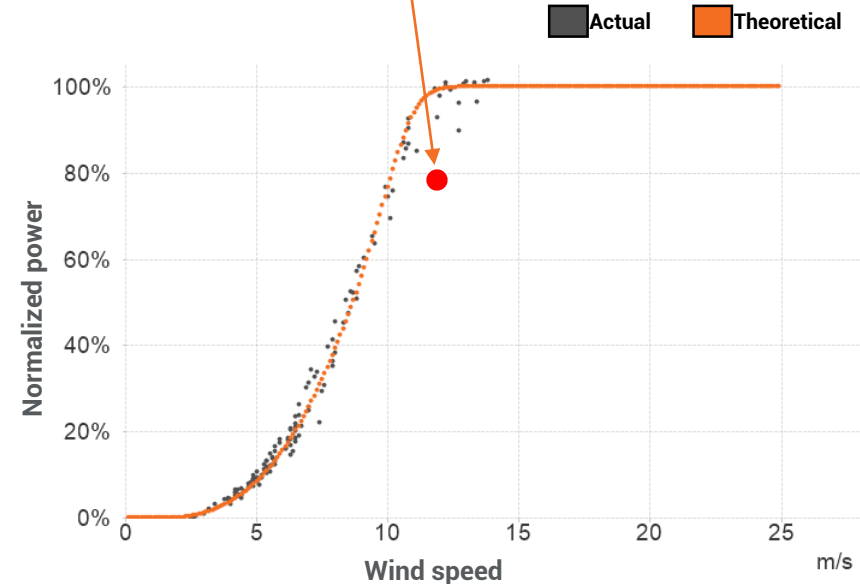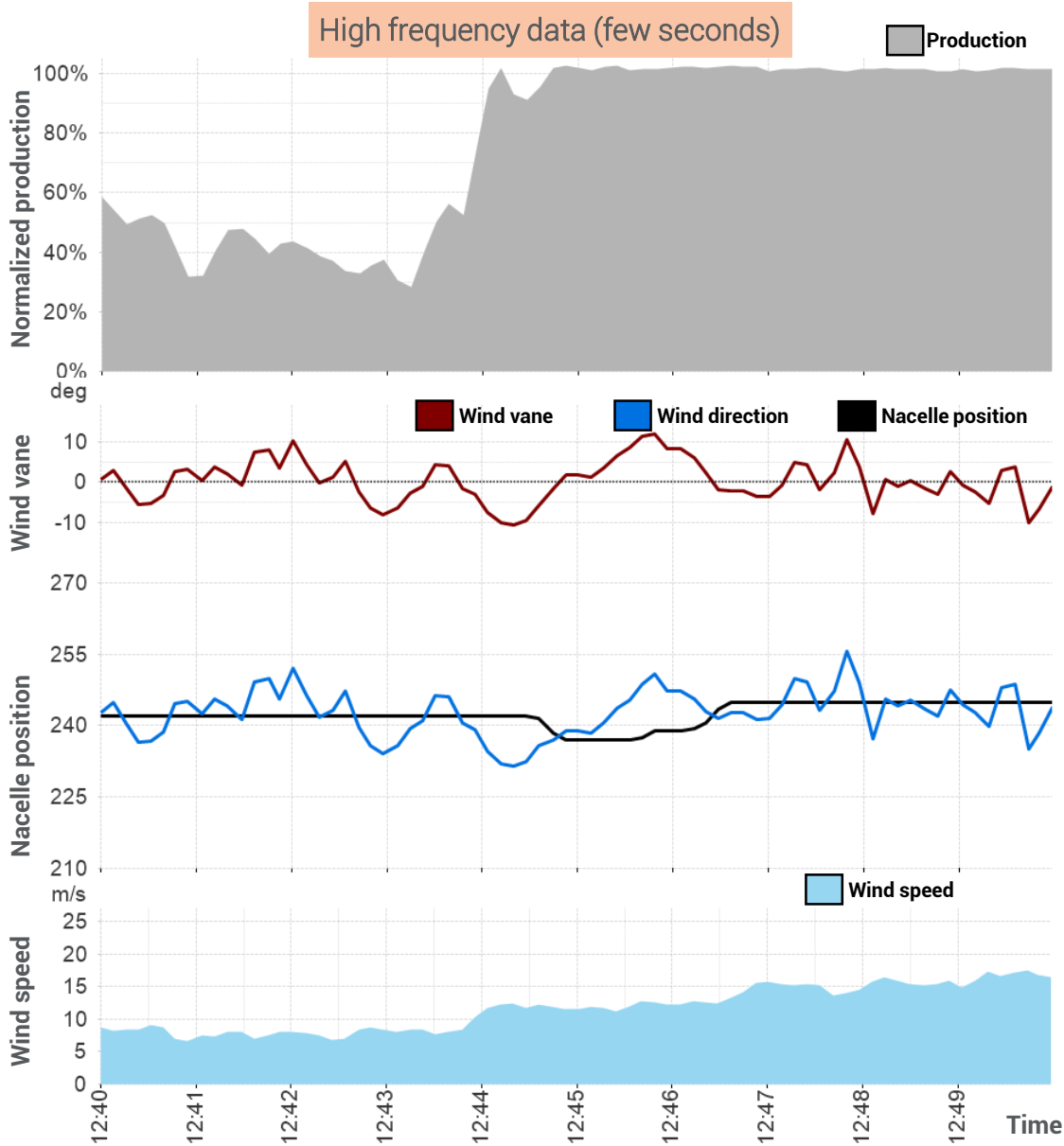Wind speed

Zoom of this 10-min interval provided in next slide

- During the 10 minute interval highlighted with the red arrow in the graph on the left hand side the nacelle position is fairly constant while the wind speed has a significant variation, changing from 8 to 13 m/s in few minutes.

- Accordingly, the power output increases from an initial condition of 40% to rated power within the same interval.

- The corresponding point on the power curve is marked with a red dot (underperformance?)

Actual   Theoretical

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Linearization effect

High frequency data (few seconds)

- All graphs in this slide are relative to the 10-min interval highlighted with the red box in the previous slide.
- It can be seen that, during the first 3 minutes of the wind speed was around 8 m/s while afterwards it increased to values higher than the rated.
- By taking the average over time of all the points in the power curve (graph below) one can easily understand that the result is a 10-min averaged point which lies below the reference line.
- The underperformance is only apparent.
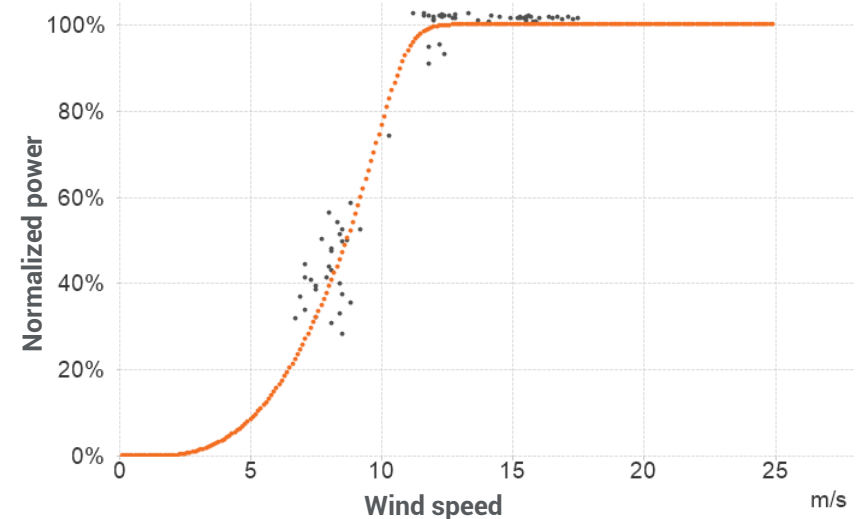
Conclusion

- Under non stationary turbine operations, like e.g. in presence of fast changing winds (in intensity and direction) or during cut-in, the 10 minutes average values typically used in the industry lead to misleading results about the real turbine performance.

- In order to better understand the real turbine performance, SCADA data in few seconds resolution shall be considered.

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