Karlsruhe Institute of Technology

KIT-Campus Alpin
IMK-IFU: Atmosphärische Umweltforschung

METEOROLOGICAL ANALYSIS OF UNEXPECTED RAMPS IN ENERGY OUTPUT FROM GERMAN NORTH SEA OFFSHORE WIND PARKS

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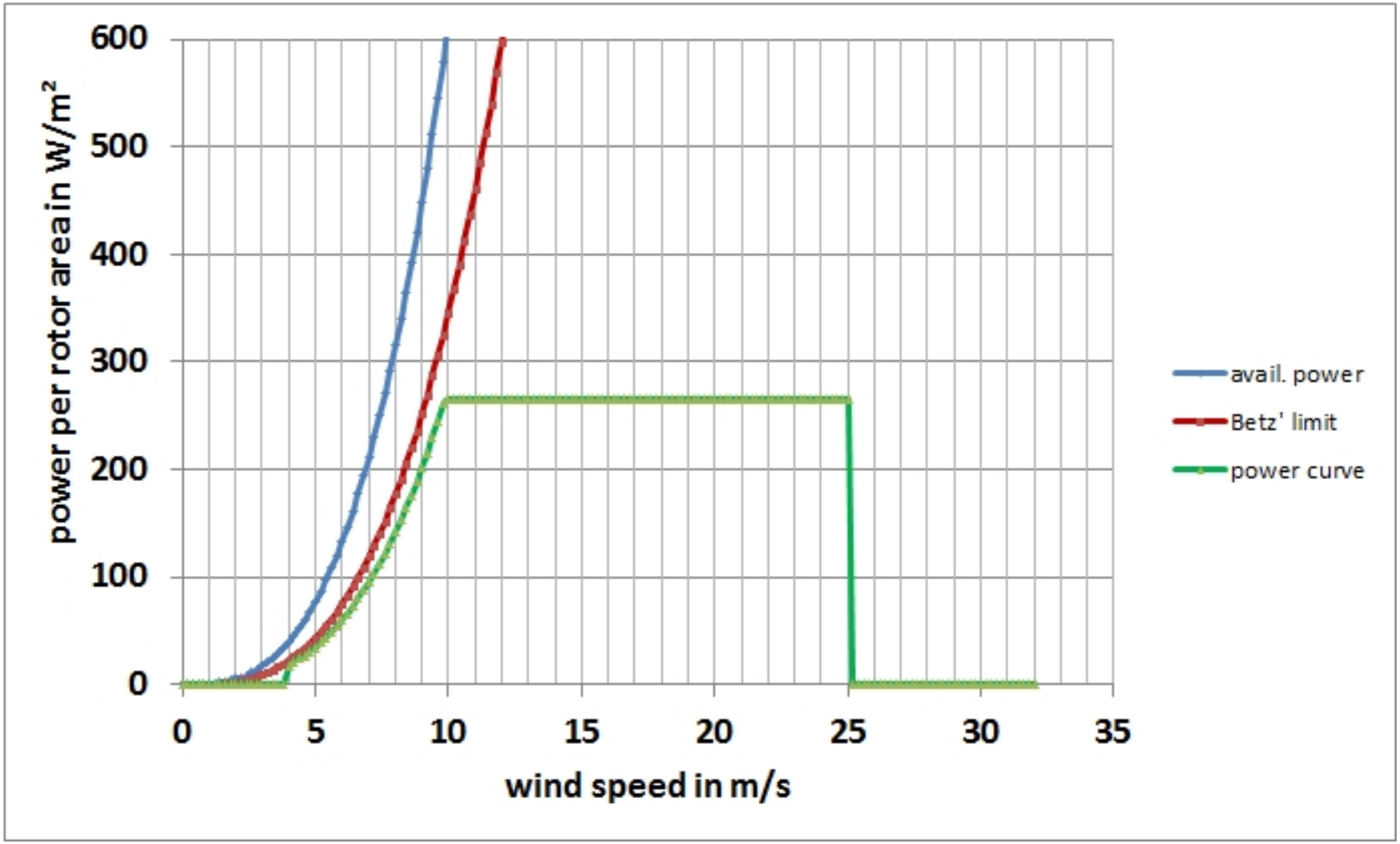
typical power curve of a wind turbine



German North Sea wind parks form a large cluster on 200 km by 130 km

High wind speed areas of large low-pressure areas can be even larger

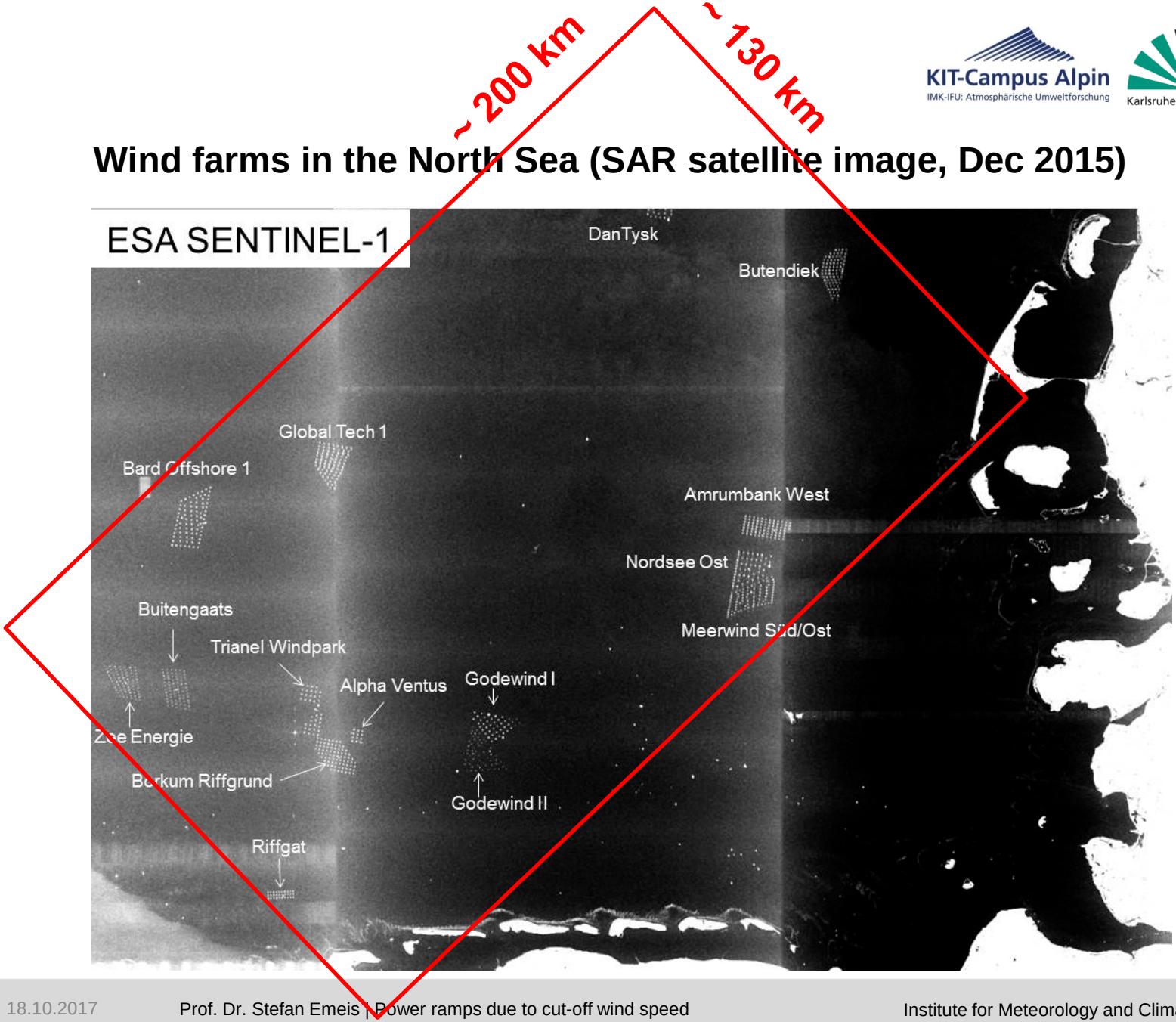
Wind speeds above 25 m/s lead to a sudden shutdown of wind turbines

Presently, installed power in the North Sea is already larger than 4 GW

Primary balancing power in the ENTSO-E grid is about 3 GW

➔ **unexpected/unpredicted surpassing of the cut-off wind speed over the North Sea can lead to large negative power ramps in the order of the primary balancing power**

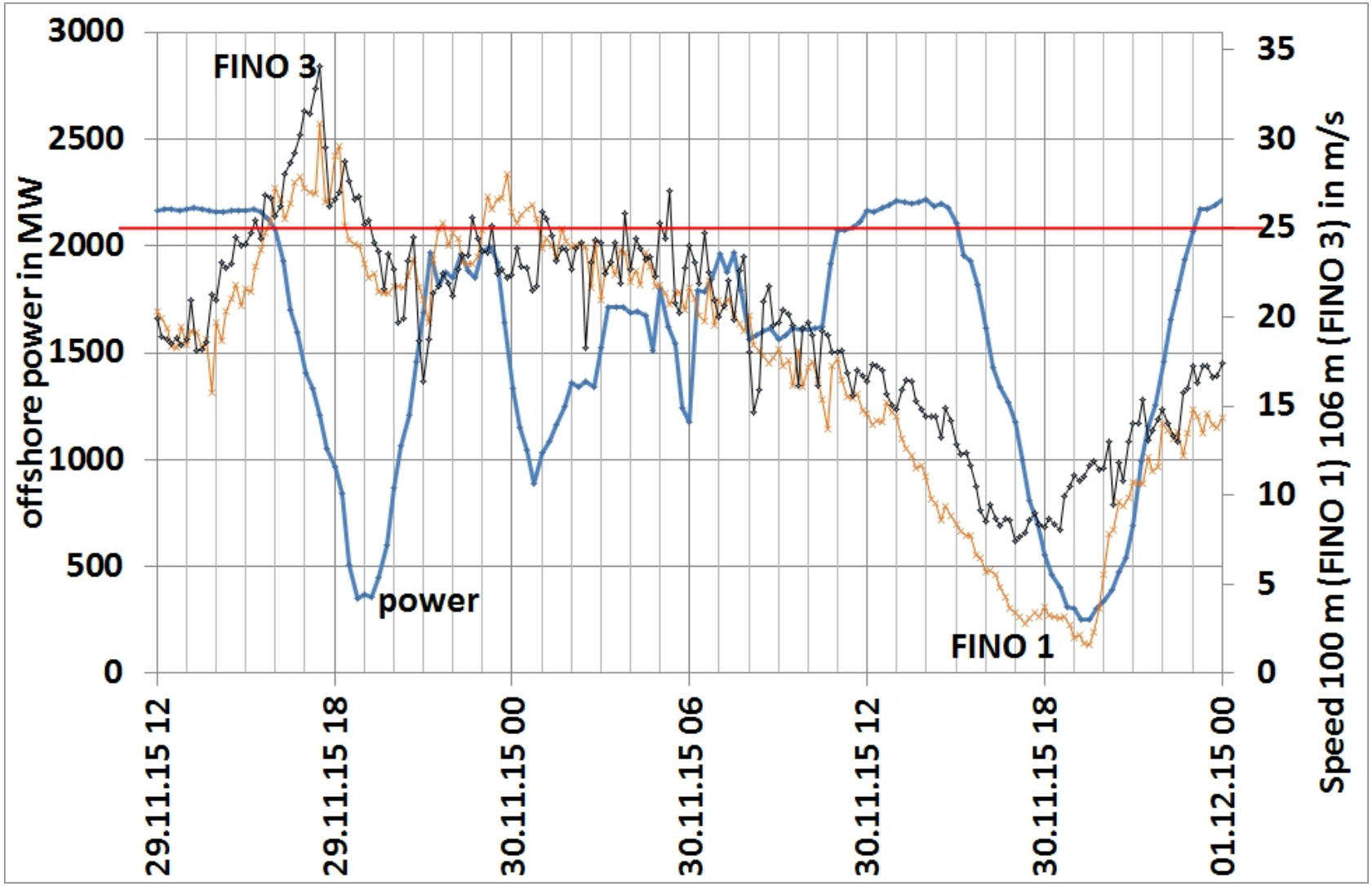
Wind farms in the North Sea (SAR satellite image, Dec 2015)



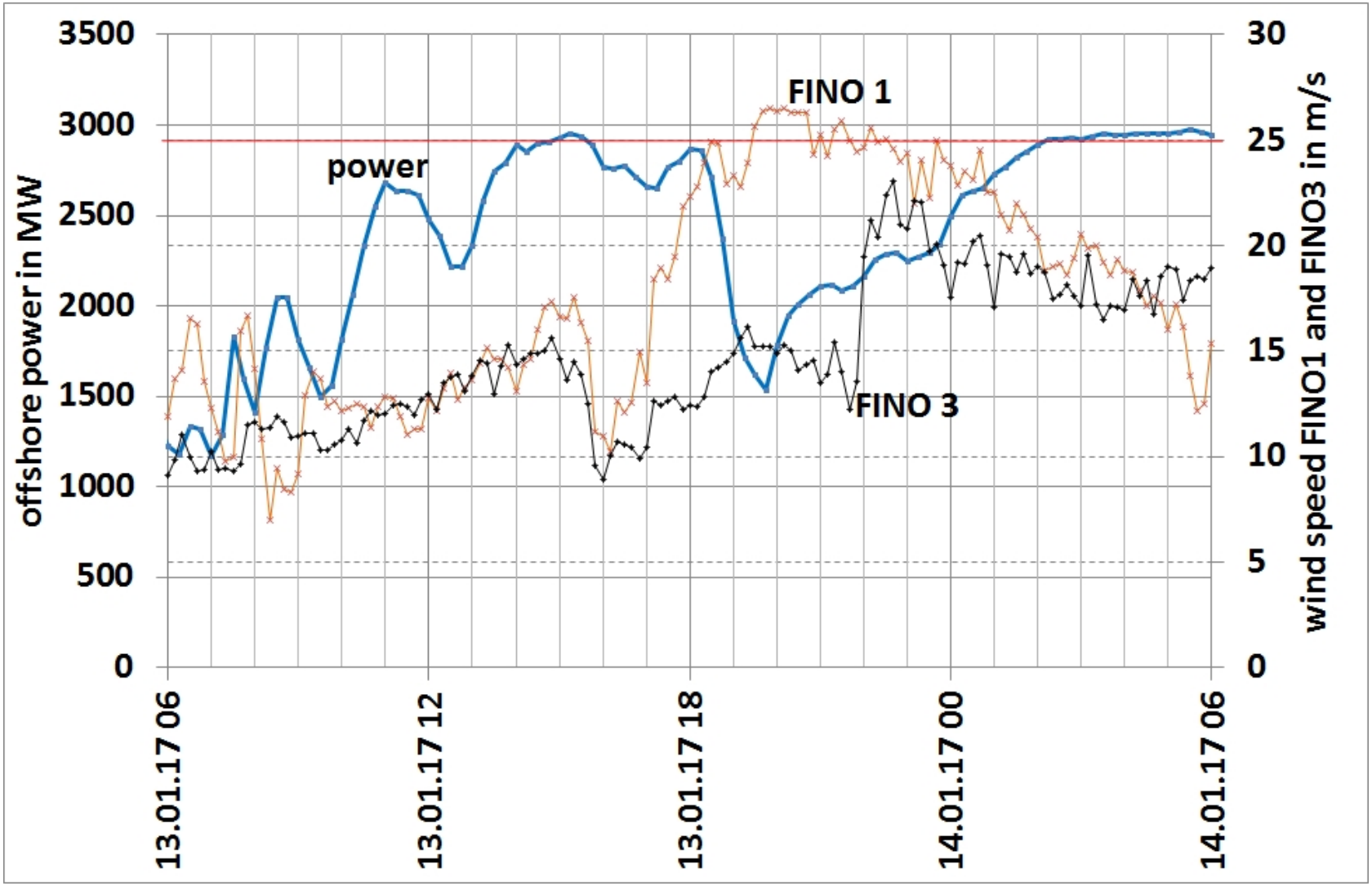
Dez. 2015 , produced from ESA remote sensing data

(@) European Space Agency – ESA

negative ramp event November 2015

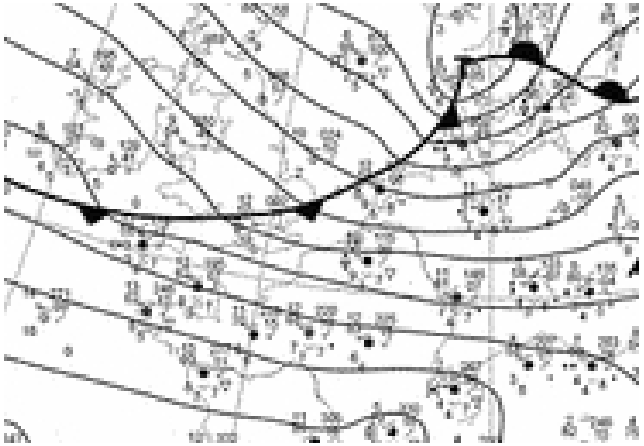


negative ramp event January 2017



surface weather maps (DWD, http://www2.wetter3.de/Archiv/)

29 November 2015 18:00



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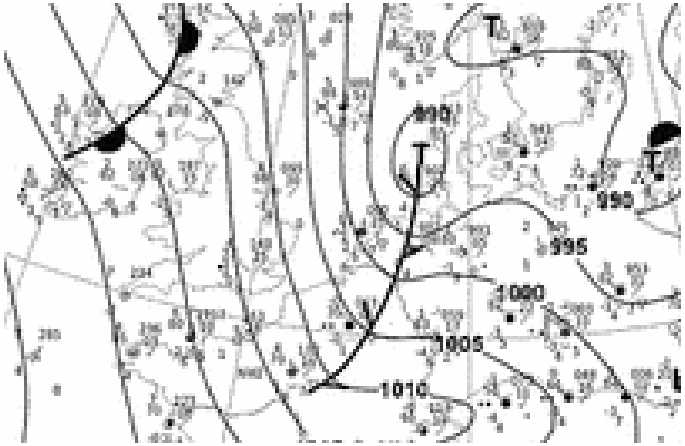
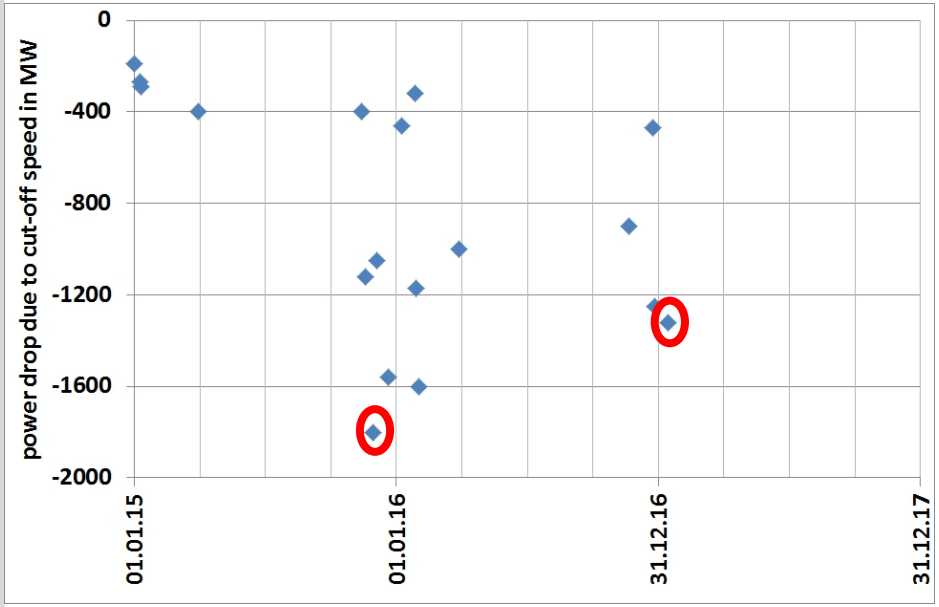
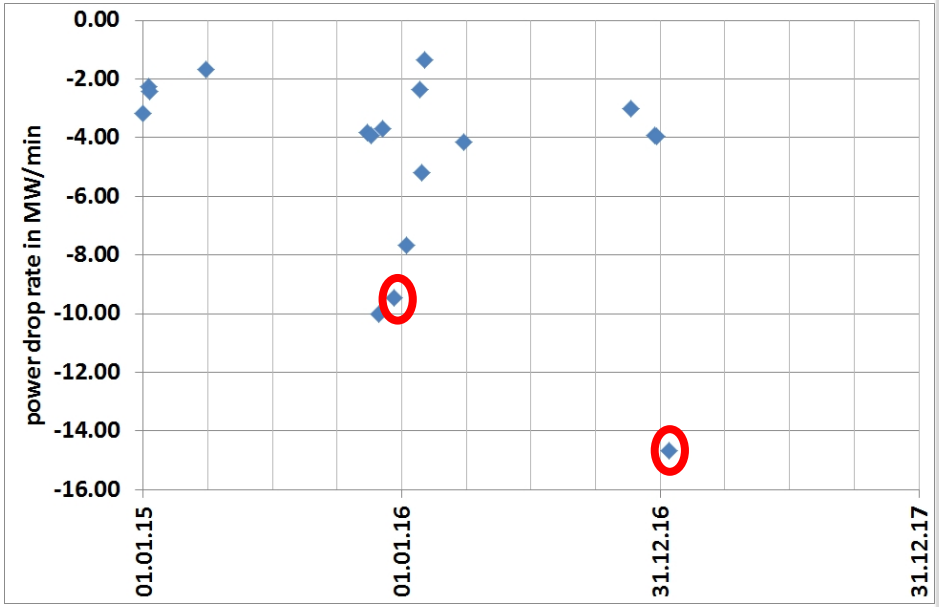


statistics for the North Sea wind park cluster

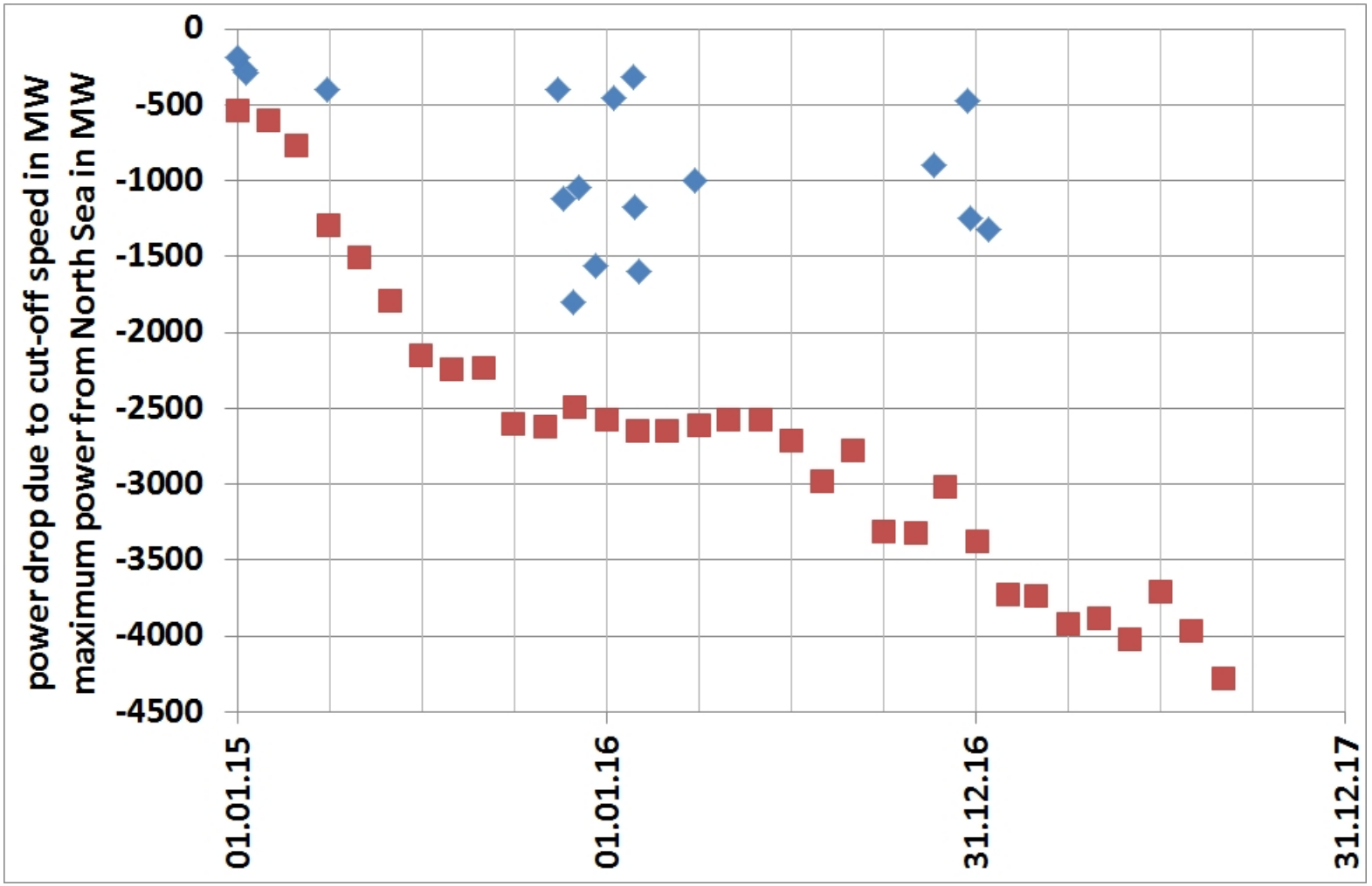




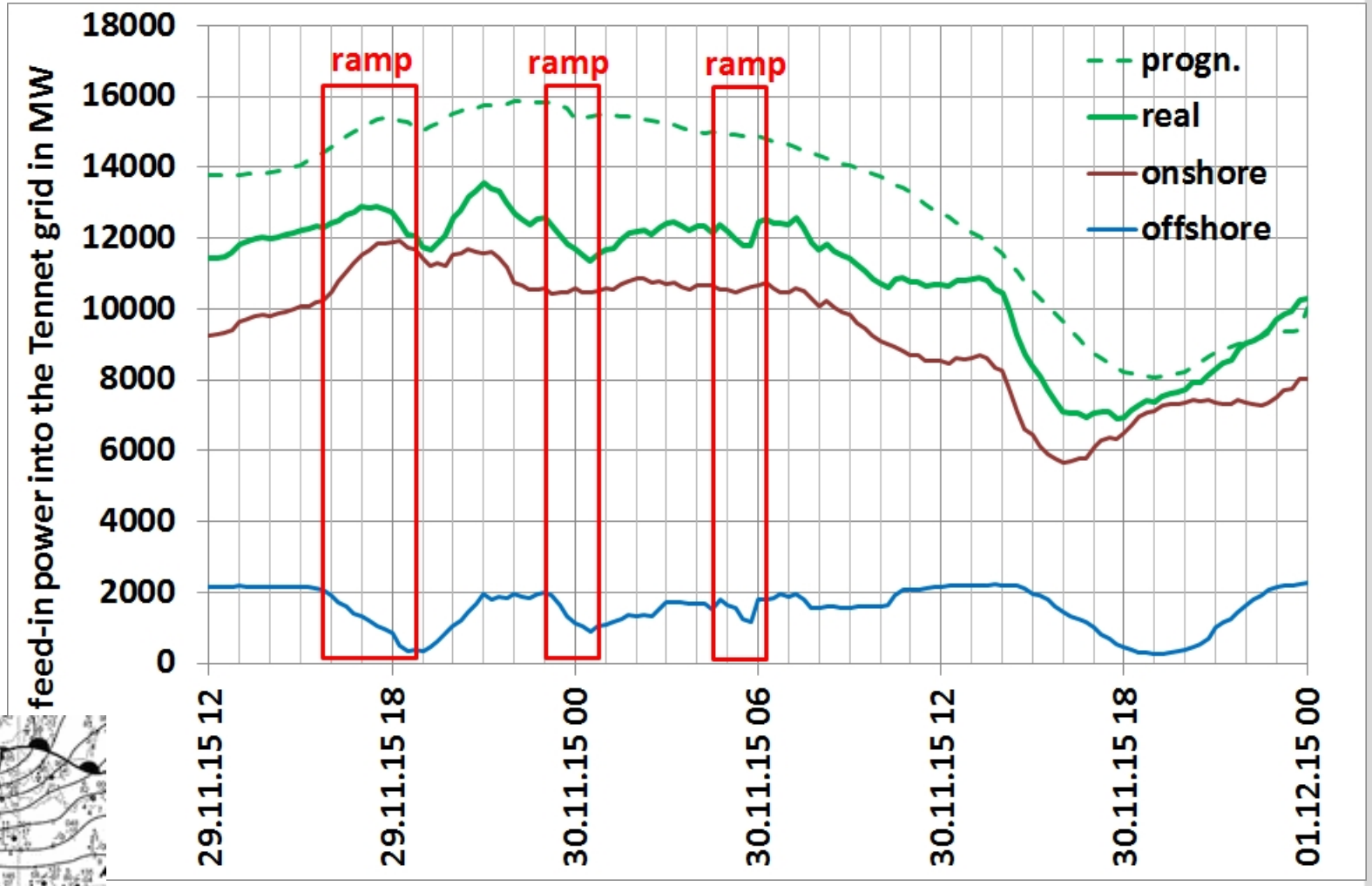
absolute drop in offshore power feed-in into the Tennet grid in MW

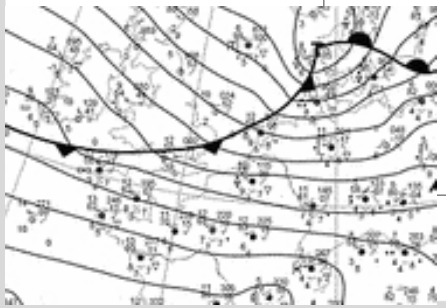
drop rate in offshore power feed-in into the Tennet grid in MW/min

statistics for the North Sea wind park cluster comparison of negative power ramps and monthly maximum feed-in in MW



prognosis vs. reality





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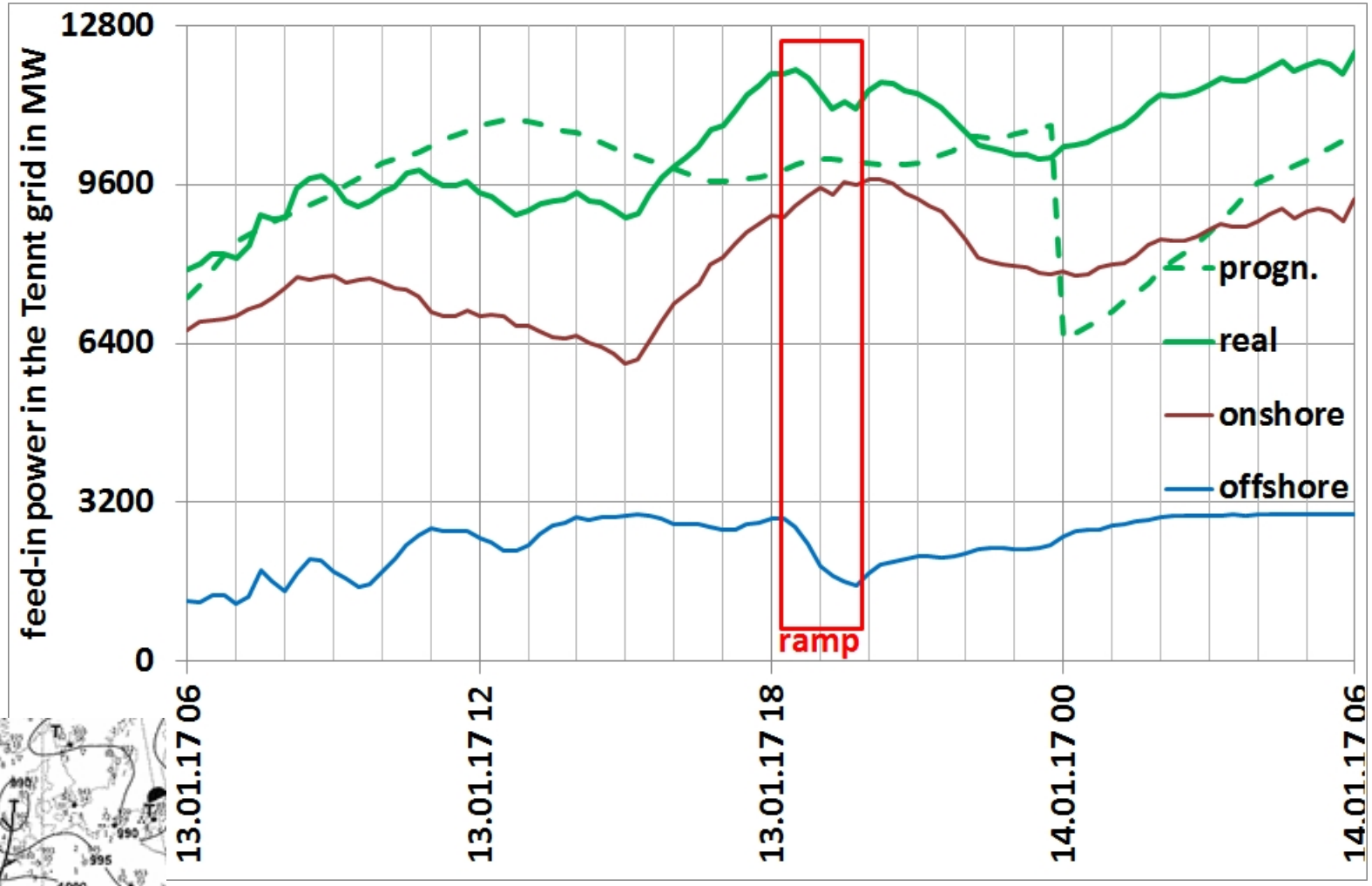
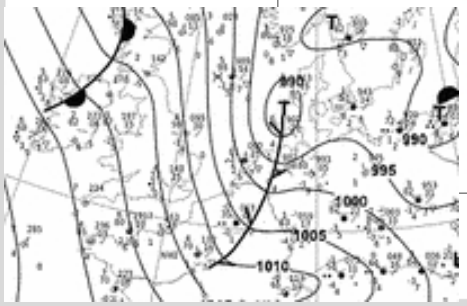
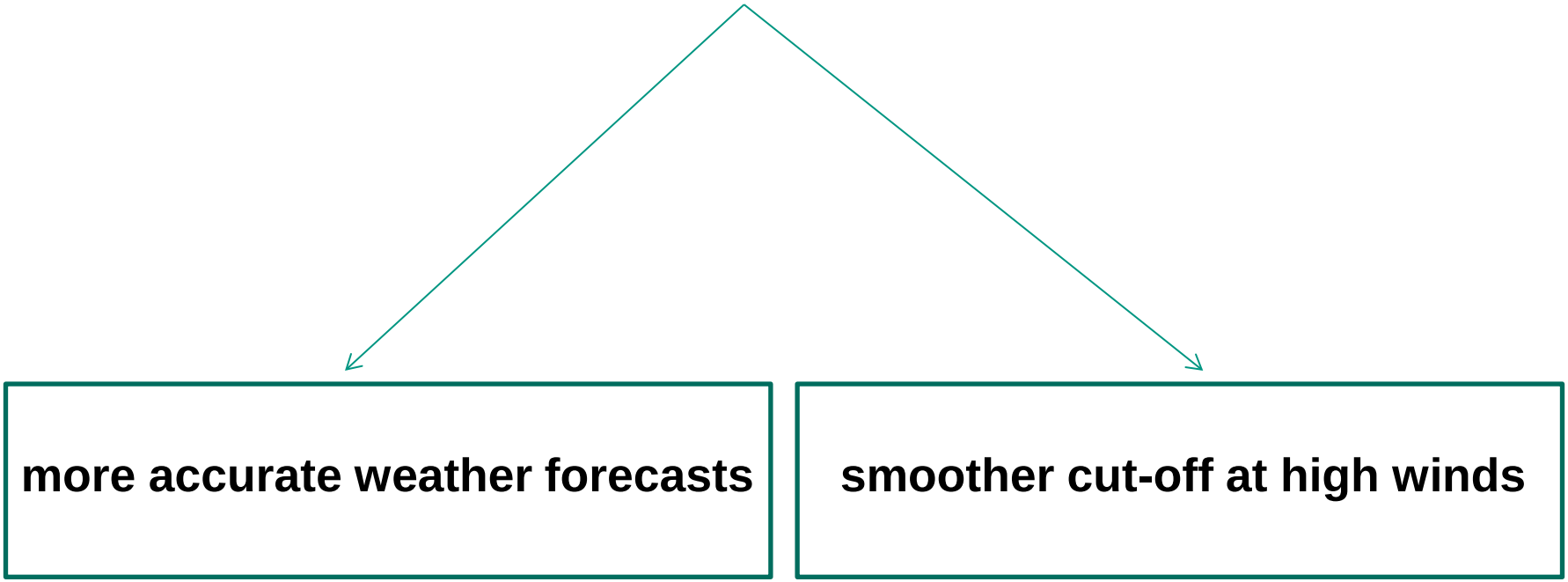
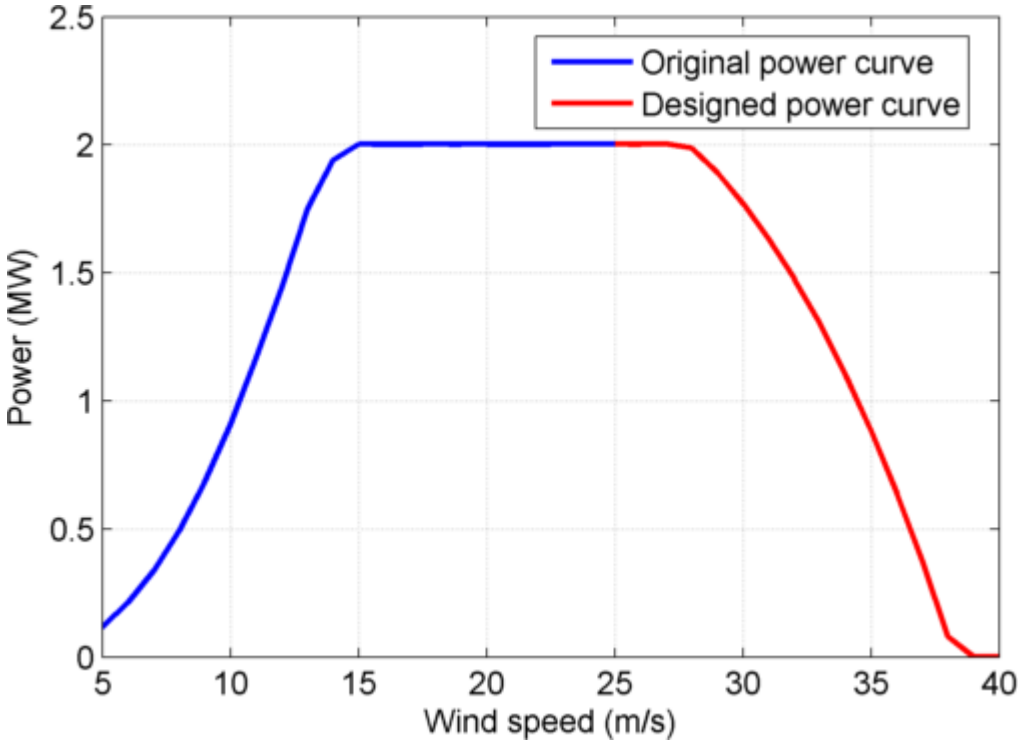




how to solve this issue?

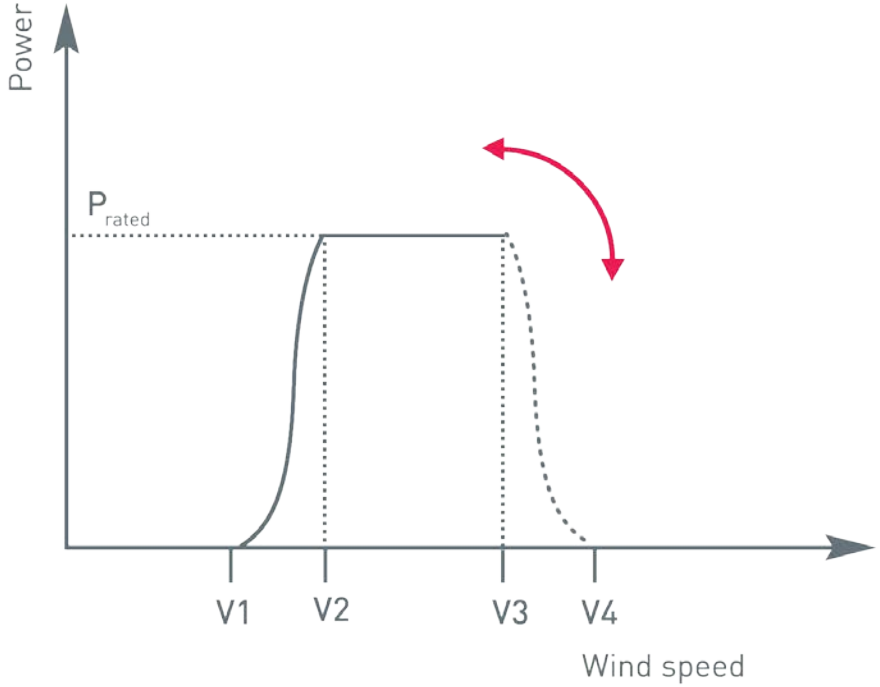


smoother cut-off at high winds



Source: Feng, J., W.Z. Sheng, 2014: Operating wind turbines in strong wind conditions by using feedforward-feedback control *J. Phys.: Conf. Ser.* 555 012035

smoother cut-off at high winds

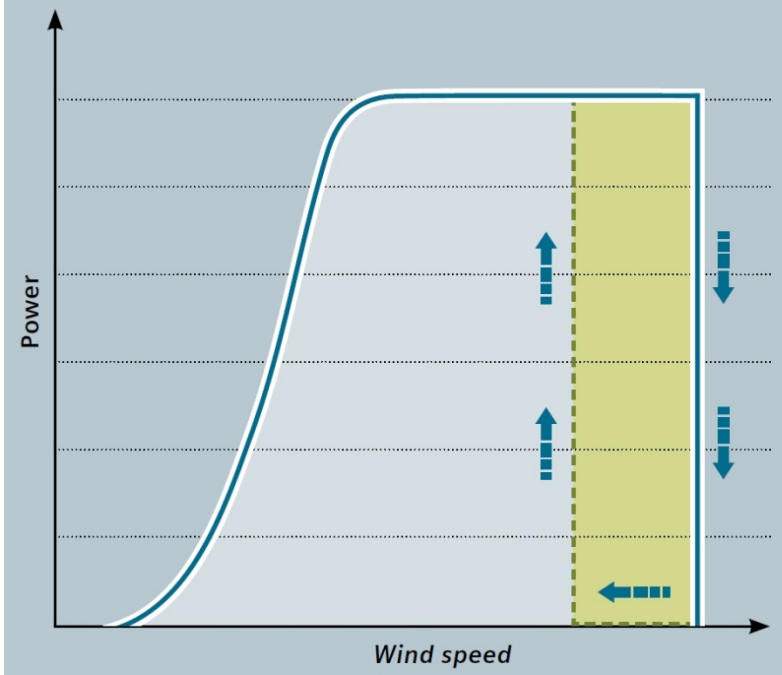


V1 = Cut-in wind speed
V2 = Rated wind speed
V3 = Beginning of power reduction
V4 = Cut-out wind speed with activated storm control

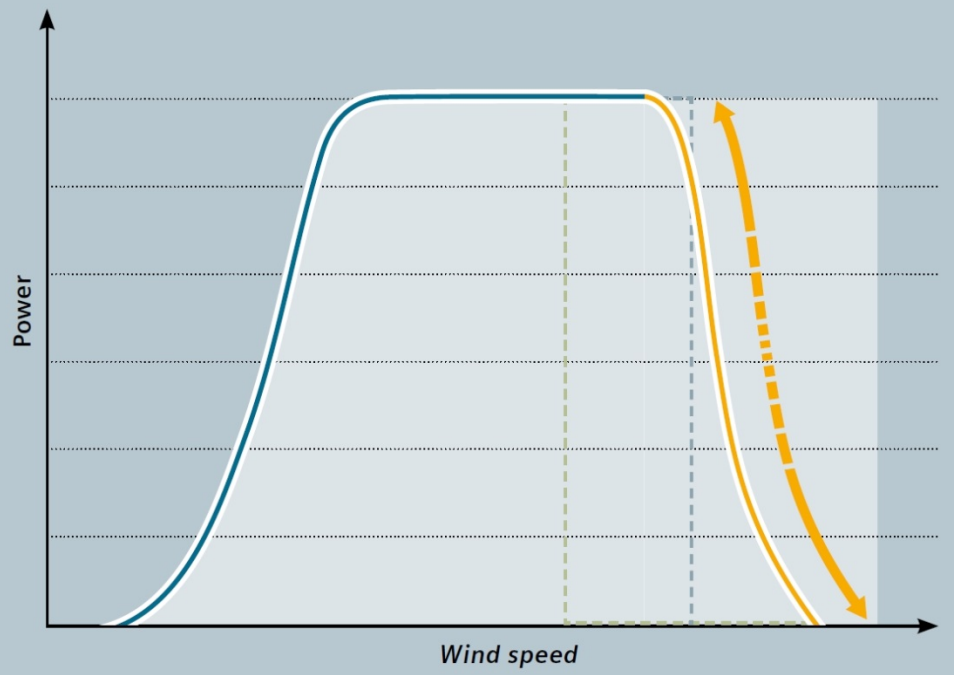
Source: Enercon storm control: https://www.enercon.de/en/technology/wec-features/

smoother cut-off at high winds

Fig. 1: Power curve without and with High Wind Ride Through



The green dotted line shows the hysteresis loop



The orange line shows the extension in operation at high wind speeds

Source: Siemens High Wind Ride Through
https://www.energy.siemens.com/us/pool/hq/power-generation/renewables/wind-power/Flyer-WindPower.pdf

Outlook:

Larger offshore wind park cluster in relatively small areas may lead to problems for grid operators (negative power ramps) in case the wind speed exceeds the cut-off wind speed.

Accurate weather forecasts will be helpful, but are difficult to achieve. Predicting the exact wind speed and position of low-pressure systems will remain challenging.

Technical solutions such like a smooth cut-off could be helpful to run electrical grids more resiliently.

European grid integration and large electrical or chemical storage facilities would be helpful either.

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Thank You for your attention