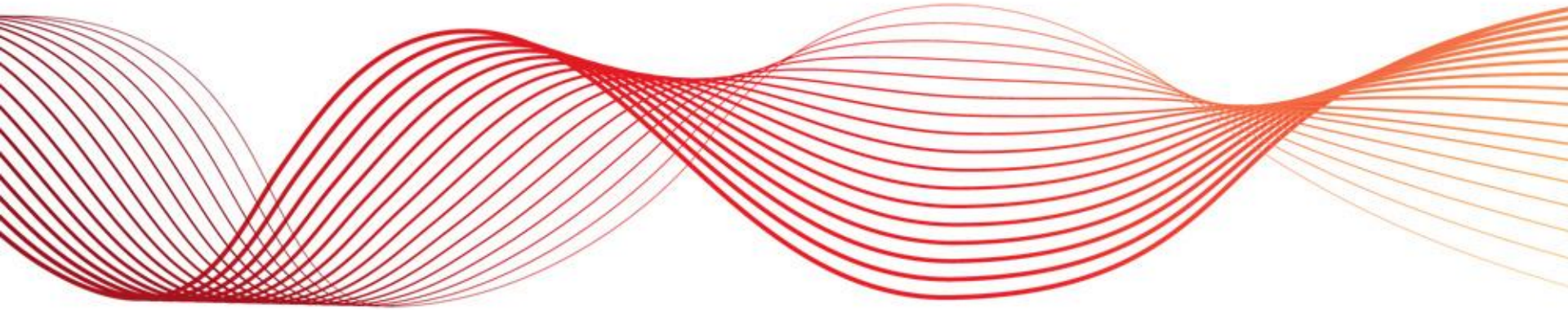
AWEFS/ASEFS VENDOR WORKSHOP

21 February 2017



PRESENTED BY FELIX DIERICH (OVERSPEED), MARCELLE GANNON (AEMO)

AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

AGENDA

- Welcome
- Introductions & roll call
- Overspeed introduction
- AWEFS/ASEFS dispatch forecasting process
- Turbines Available SCADA signal
- Estimated Power SCADA signal

----- Break

- Wind speed SCADA measurement
- Emerging forecasting technologies
- Next steps & open for questions

WELCOME & PURPOSE

- Introduction to AWEFS/ASEFS Vendors – Overspeed
- Education on AWEFS/ASEFS Dispatch forecasting process
- Follow-up to recent Consultation on ECM Guidelines

http://aemo.com.au/Stakeholder-Consultation/Consultations/Energy-Conversion-Model-Guidelines-Consultation---Wind-and-Solar-Farms

- Key consultation topics for discussion:
  - Local Limit SCADA
  - Wind Speed SCADA
  - Handling of high-speed cut-out
  - Estimated Power SCADA (Generator's own dispatch forecast)
- Status of Local Limit and Power Curve software updates
  - Anticipating both by early April 2017

TOPICS TO DISCUSS ANOTHER TIME

- Bidding of Availability
- Frequency Control Ancillary Services (FCAS)
  - External engagement on ancillary services is soon to commence
- Improvements to Intermittent Generation EMMS Portal
- Handling of low wind speed situations

- Further engagement will follow
- Please advise of other topics of interest

Overspeed: 25plus Years of Experience

- Core: Consulting for investors, banks, project developers

- R&D as background
- System development

- Main areas:

Dr. Hans-Peter Waldl

Thomas Pahlke

overspeed GmbH & Co. KG

Windenergy Consulting

Assessments

System and Software Development

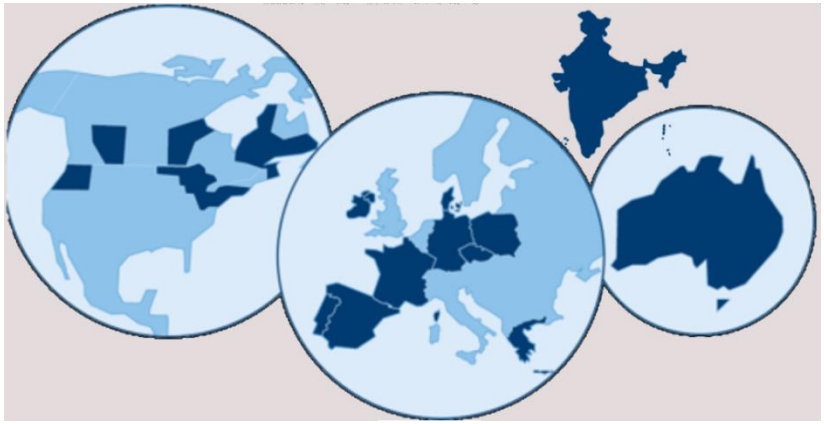
Wind and Solar Power Predictions

overspeed.de

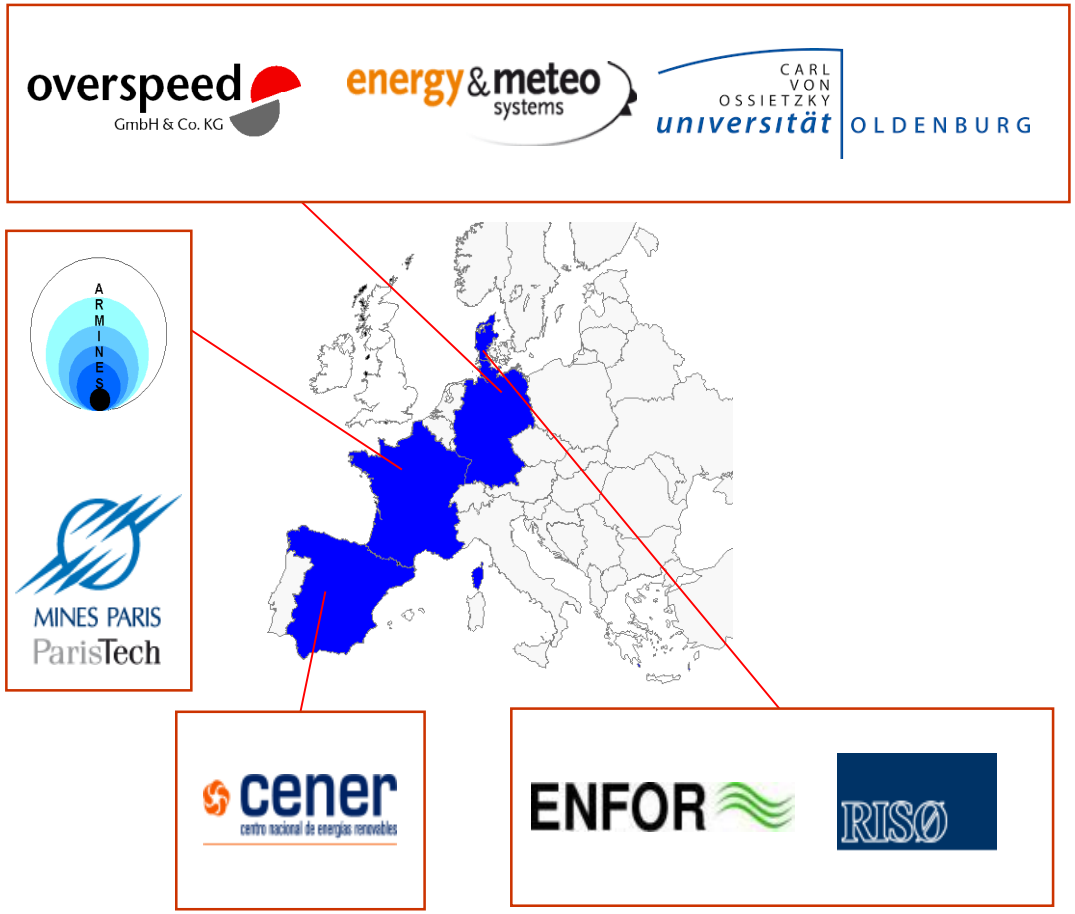
overspeed GmbH & Co. KG

What is Anemos?

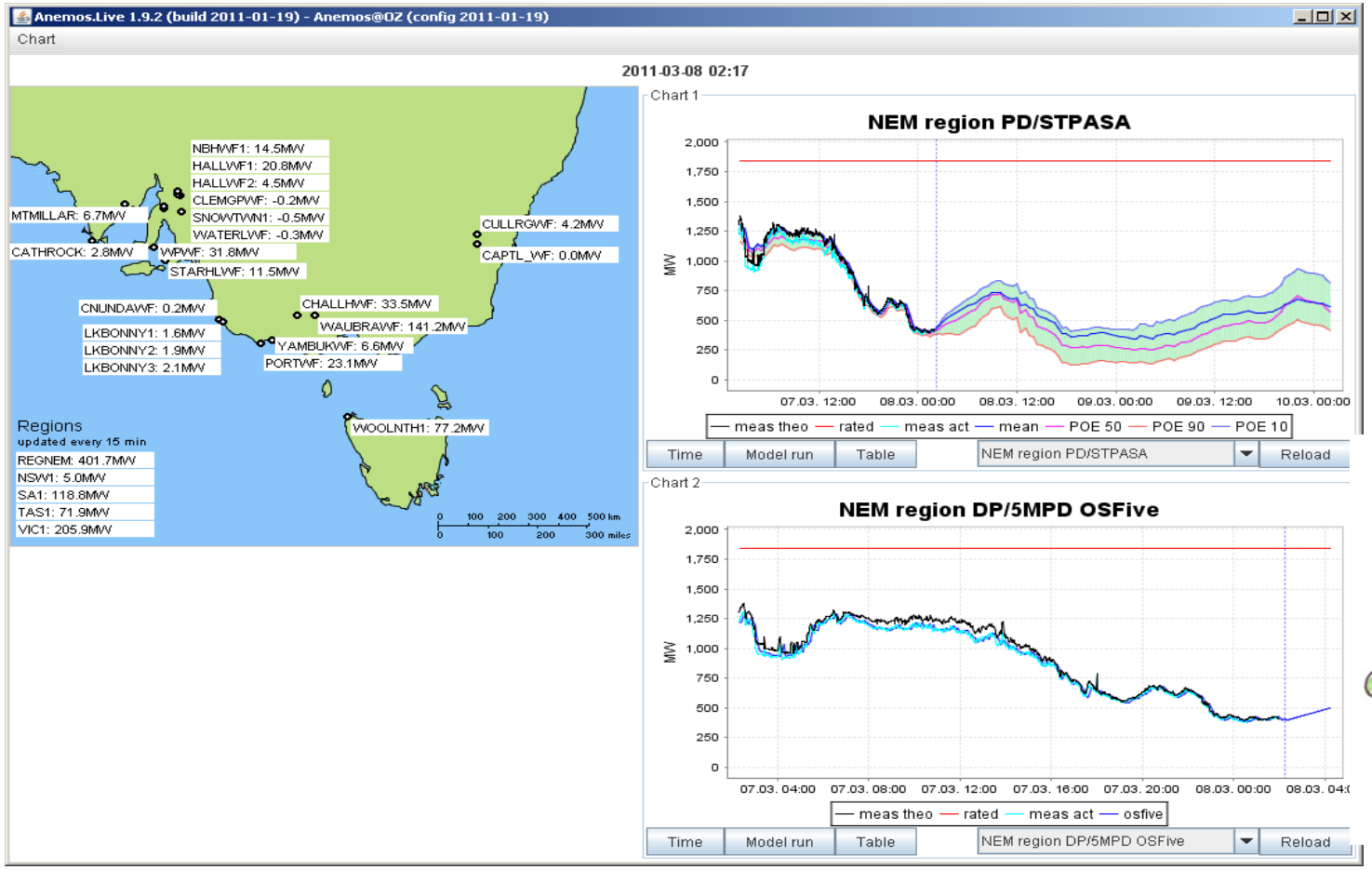
- Leading edge research and development
- Prediction models and modules
- Wind and Solar Power Prediction System
- World-wide 70plus GW



Anemos Wind/Solar Power Predictions: Partners



Australian Wind Energy Forecasting System



overspeed GmbH & Co. KG

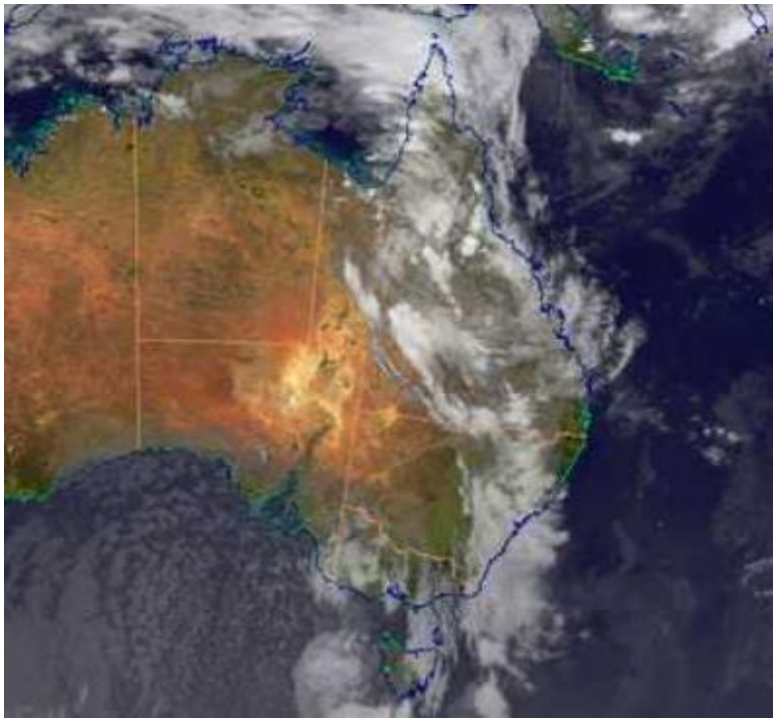
Australian Wind Energy Forecasting System

- Fully integrated into market system
- Running locally at dispatch centres

- “Market-system-proof“
- High-availability design
- 24/7 operation

Anemos for Australia

- AWEFS: Wind farms
  - Online since 2008
  - 100.00 % availability
- ASEFS 1: Solar farms
- ASEFS 2: Solar roof-top
- Helios: Satellite-based solar predictions



AWEFS
Participant Meeting

Dispatch Forecasting and Wind-based Power Estimate

2017-02

Dr. Igor Waldl, Felix Dierich,
Overspeed GmbH & Co. KG, Germany

overspeed
GmbH & Co. KG

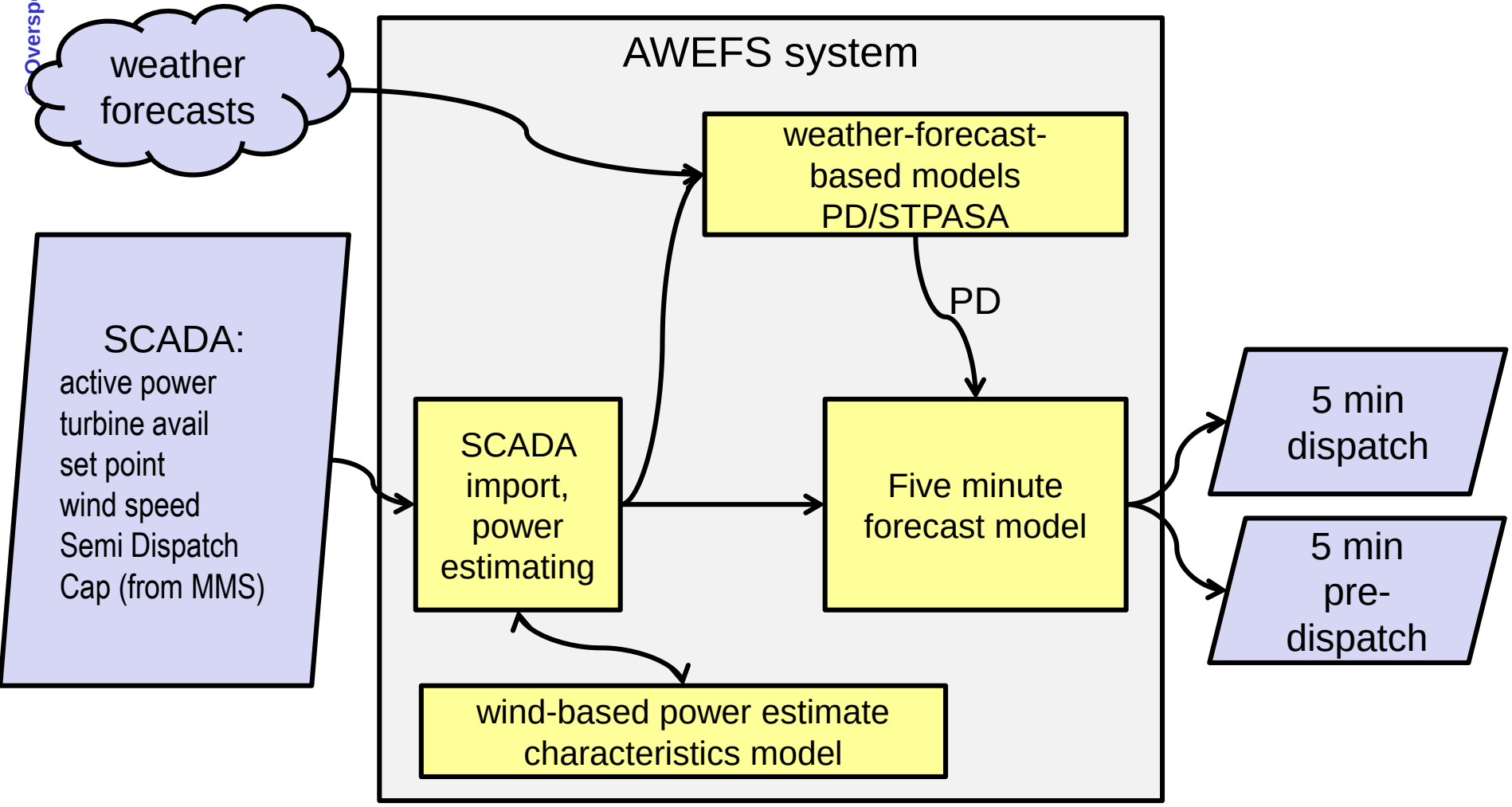
Topics

AWEFS/ASEFS 5 min dispatch forecasting

- High level overview
- UIGF in curtailment situations
- SCADA channel usage for Dispatch
- Wind-based Power Estimate Characteristics Tuning

5 min Forecast Creation Overview

AWEFS 5 min Forecasts: Overview



UIGF in Curtailment Situations

UIGF in Curtailment Situations

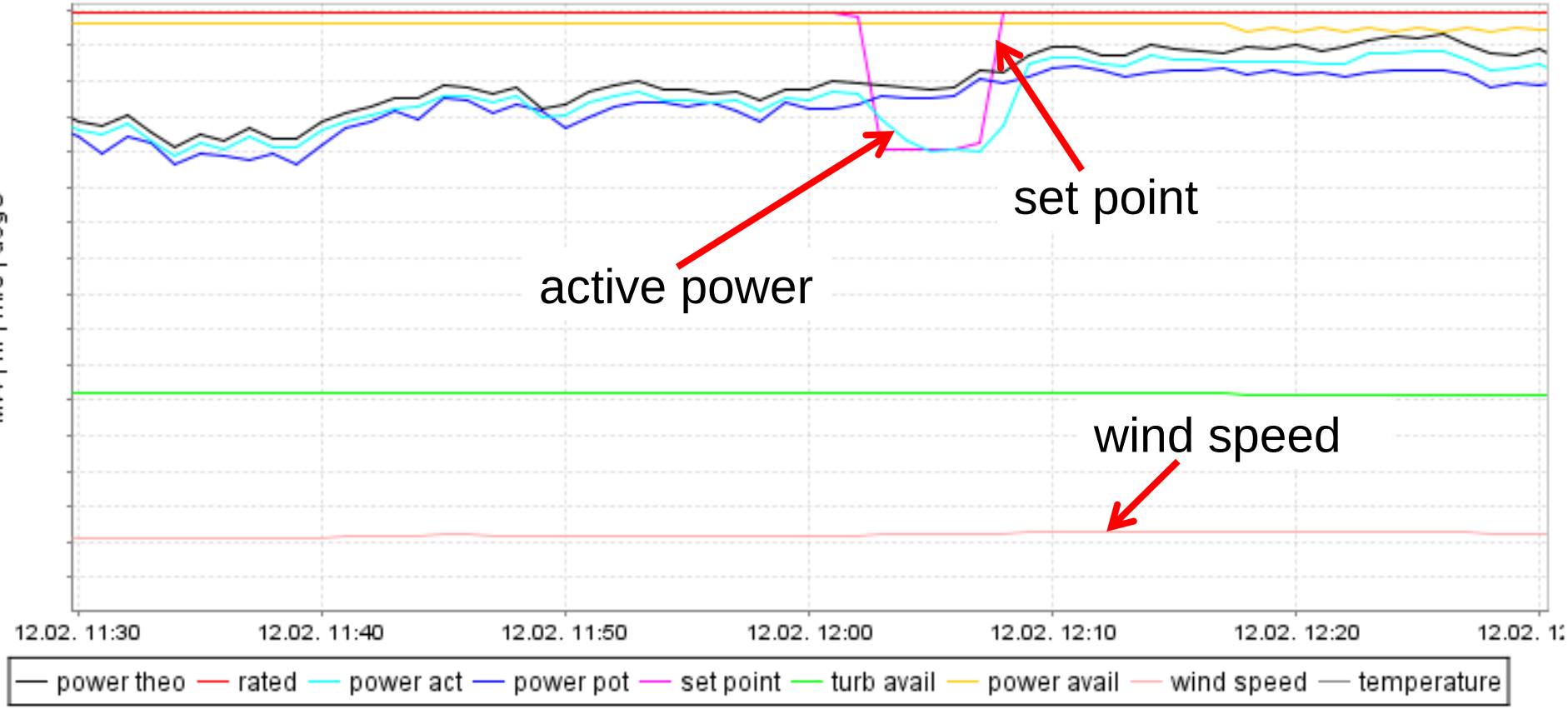
- AWEFS/ASEFS required to produce an "Unconstrained Intermittent Generation Forecast" (UIGF), also in curtailment situations
- precise 5 min forecasts are only possible based on latest SCADA measurements

➢ "potential power" estimate calculated internally by AWEFS from wind measurements / irradiation for solar

Creation and Use of Potential Power: Example

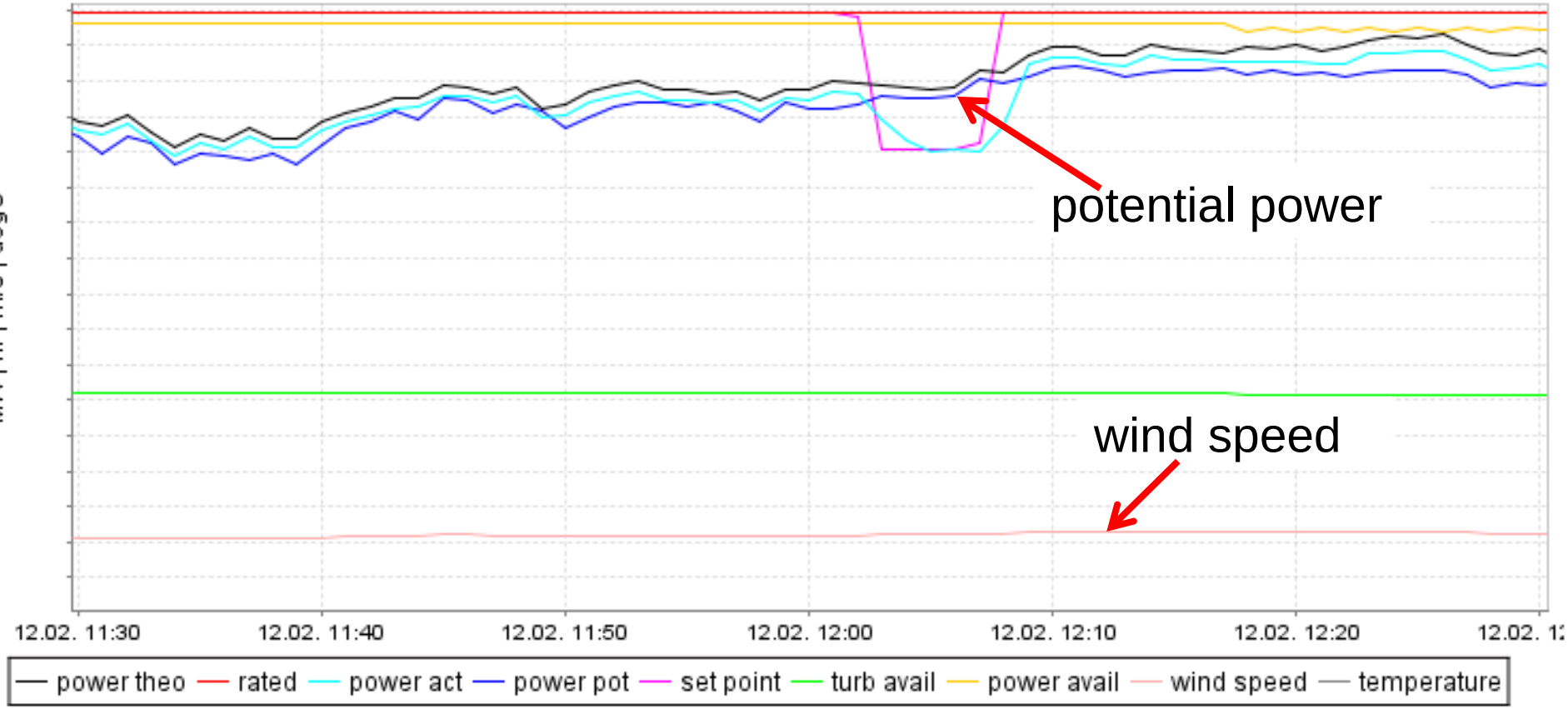
SCADA and Potential Power

Example SCADA and potential power in curtailment situation:



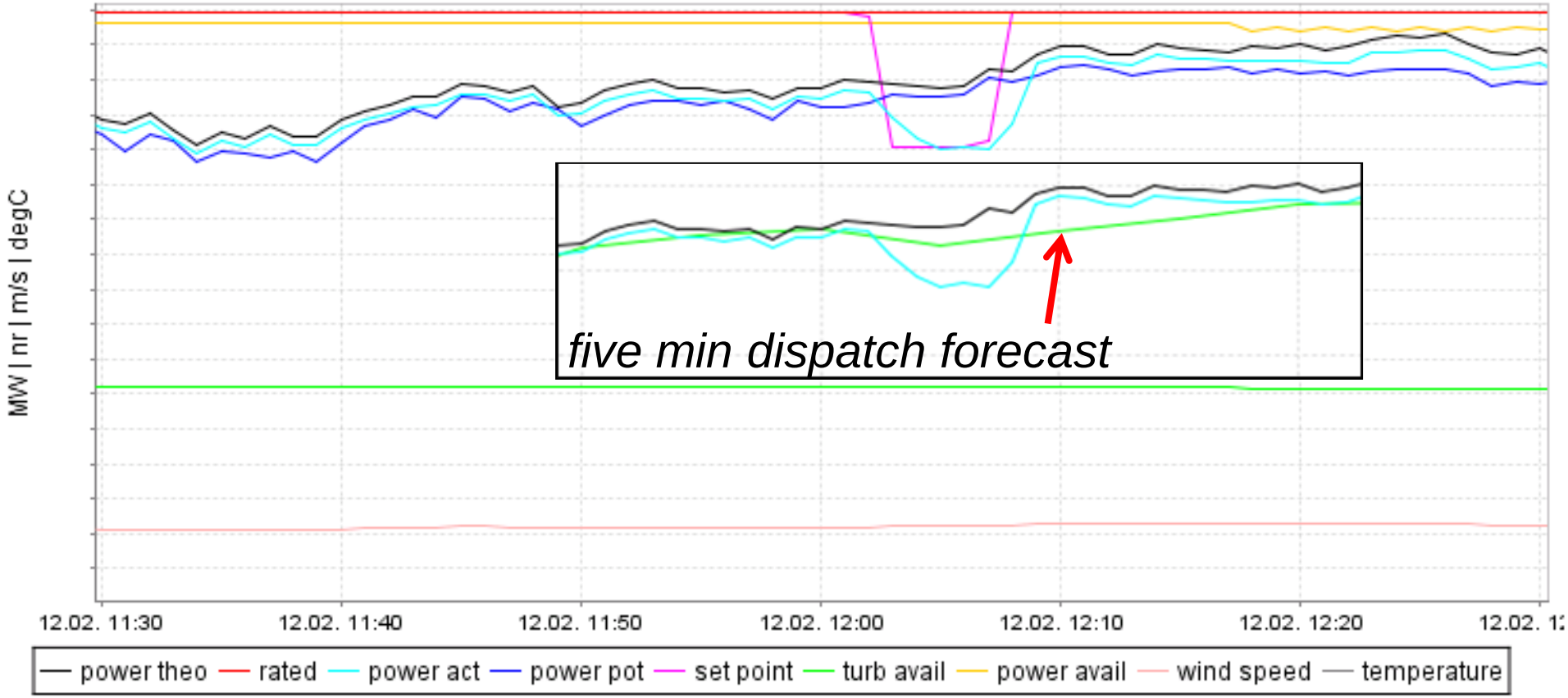
SCADA and Potential Power

Example SCADA and potential power in curtailment situation:



SCADA, Potential Power and Forecast

Example SCADA, potential power and forecast:



SCADA Channel Use for Dispatch

SCADA Channel Use for Dispatch

AWEFS SCADA channel use relevant for five min forecasts:

- Active Power: basis for forecasts in unconstrained situations
- Turbines Available:
  - to calculate potential power
  - to scale power to 100% available farm conditions
- Set point: to detect down-regulation conditions
- Semi Dispatch Cap flag (from MMS): to detect down-regulation conditions
- Wind Speed: to calculate potential power estimate
  - wind speed on wind farm level

AWEFS SCADA Channel Use

AWEFS SCADA channel use relevant for five min forecasts:

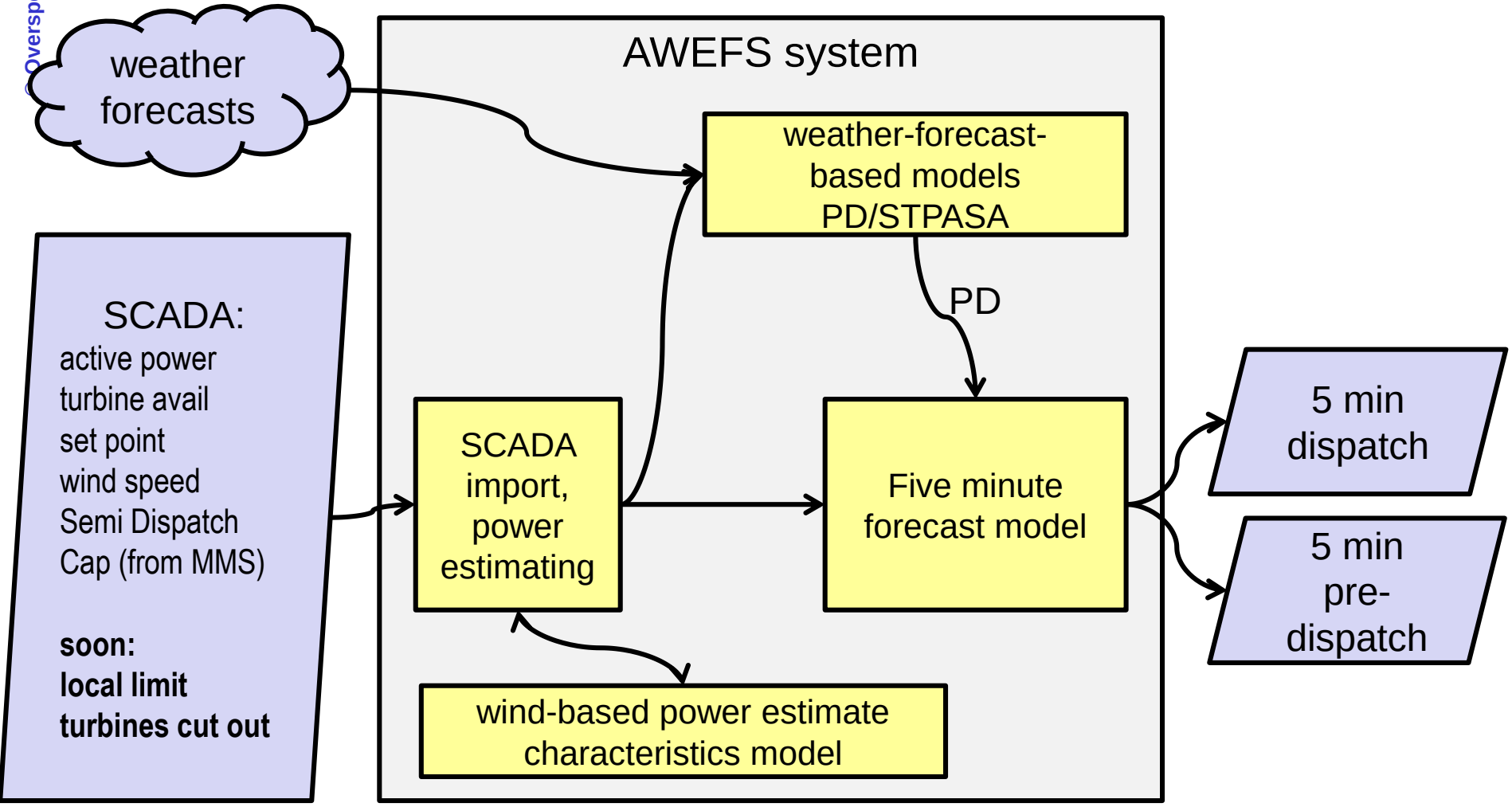
soon:

- Local Limits: limit dispatch forecast
- Turbines in [extreme wind] cut-out: for “Net Turbine Capacity Available”

other channels currently not [yet] used for 5 min forecasts:

- Wind Direction
- Temperature
- soon: Estimated Power

AWEFS 5 min Forecasts: Overview



Wind-based Power Estimate Characteristics Tuning

Wind-based Power Estimate Tuning

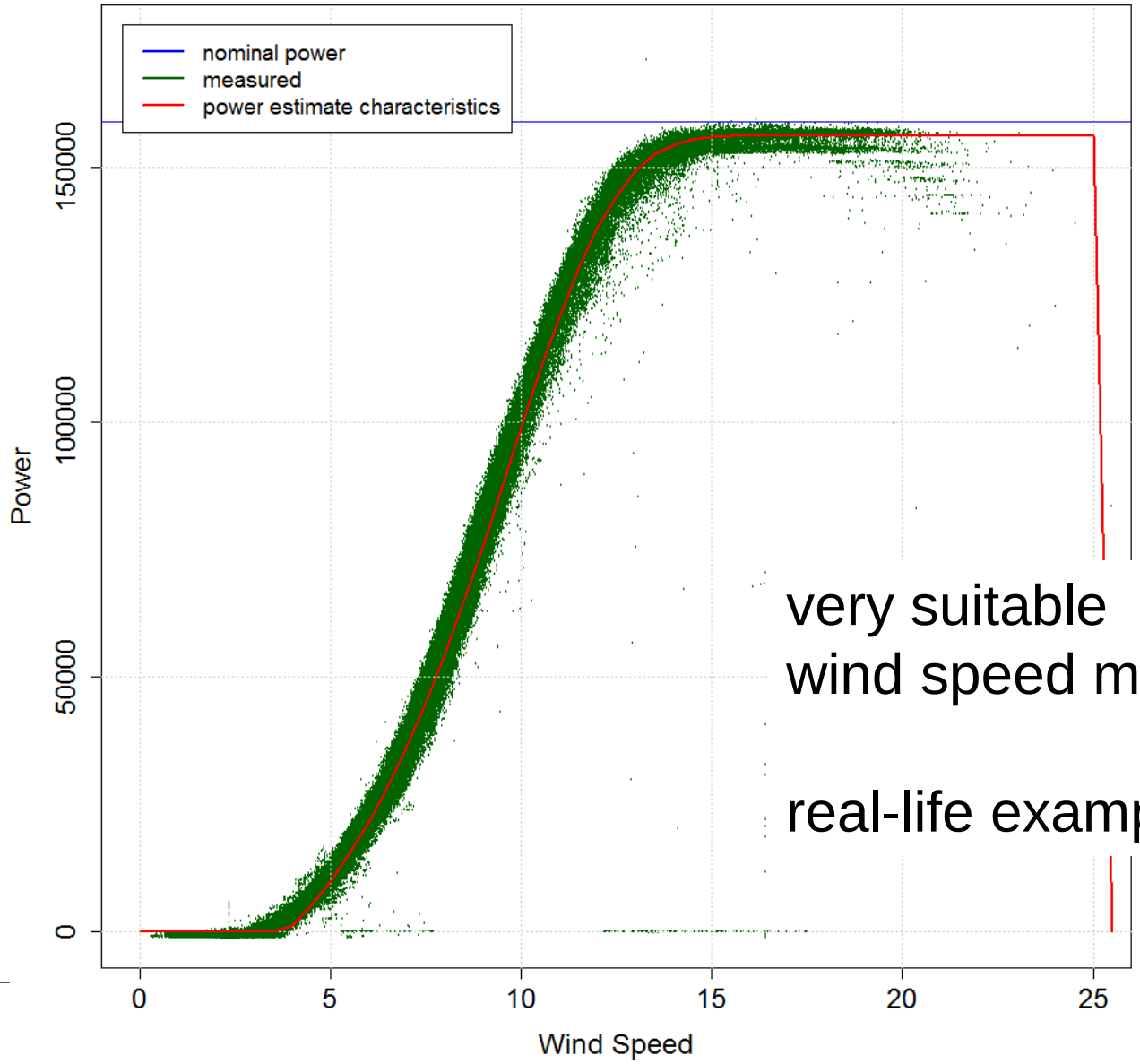
Wind-based Power Estimate Characteristics Model

- creates tuned wind farm power characteristics
- these reflect the past average “wind speed to power conversion”
- not maximum power

- tuning runs daily and keeps a history of measurements

- correlation wind speed and power is essential

Example: Ideal for Power Estimate



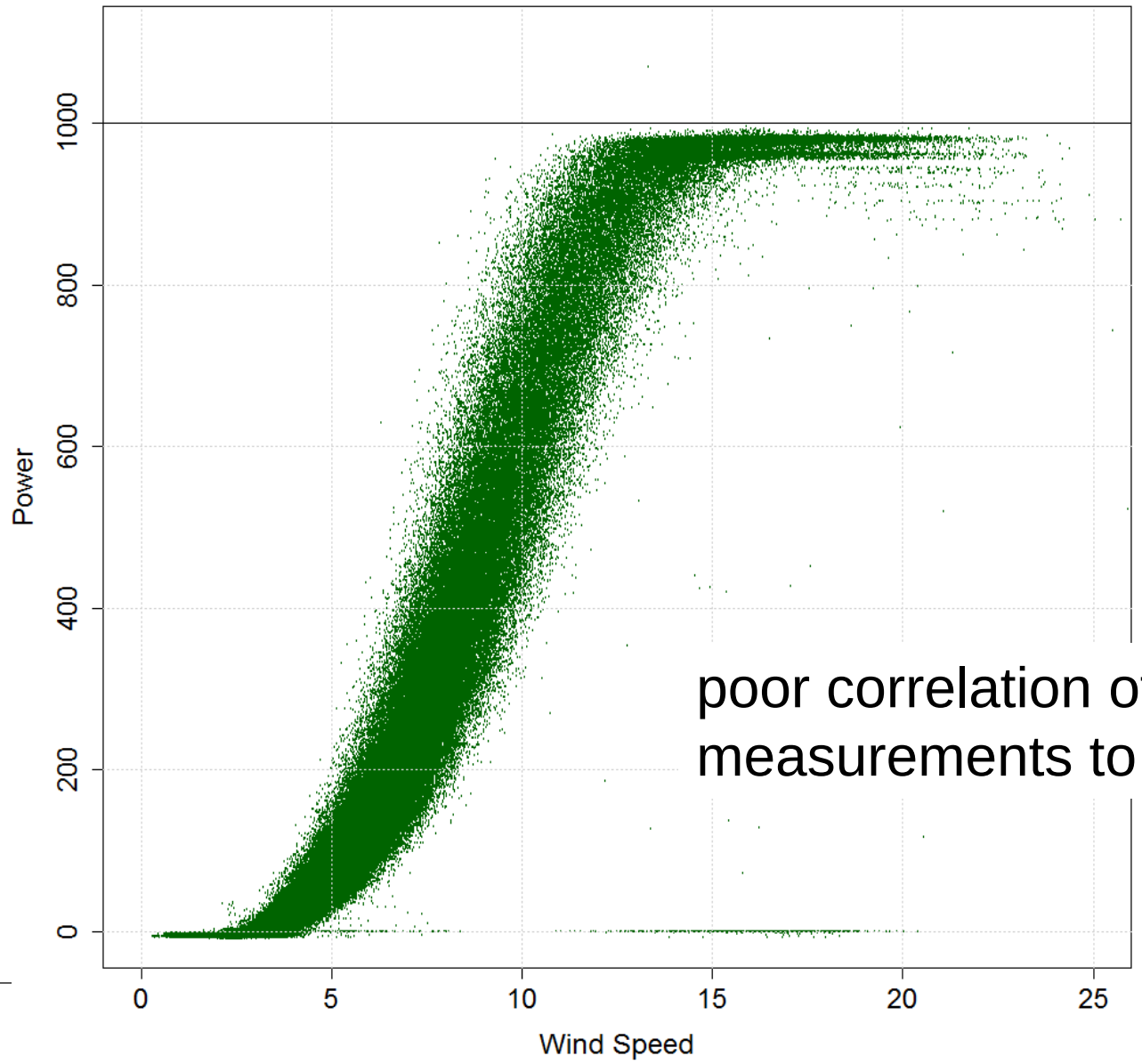
very suitable
wind speed measurements

real-life example

Examples: Problematic for Power Estimate

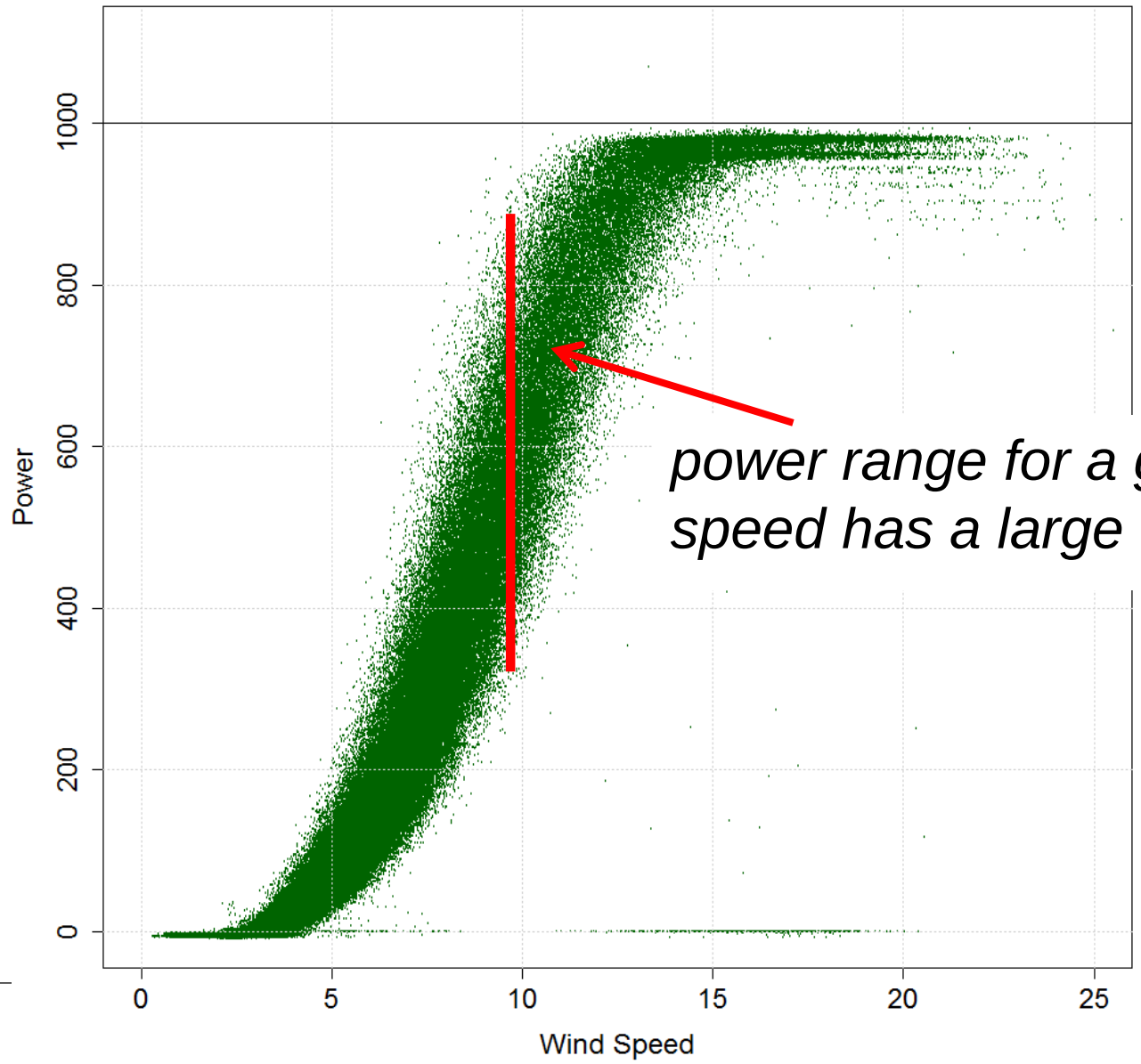
- Many real-world wind farms show non-ideal behaviour
  - unsuitable wind speed measurements
  - disturbed wind speed measurements
  - changes in power characteristics

Example: Poor Correlation Wind to Power



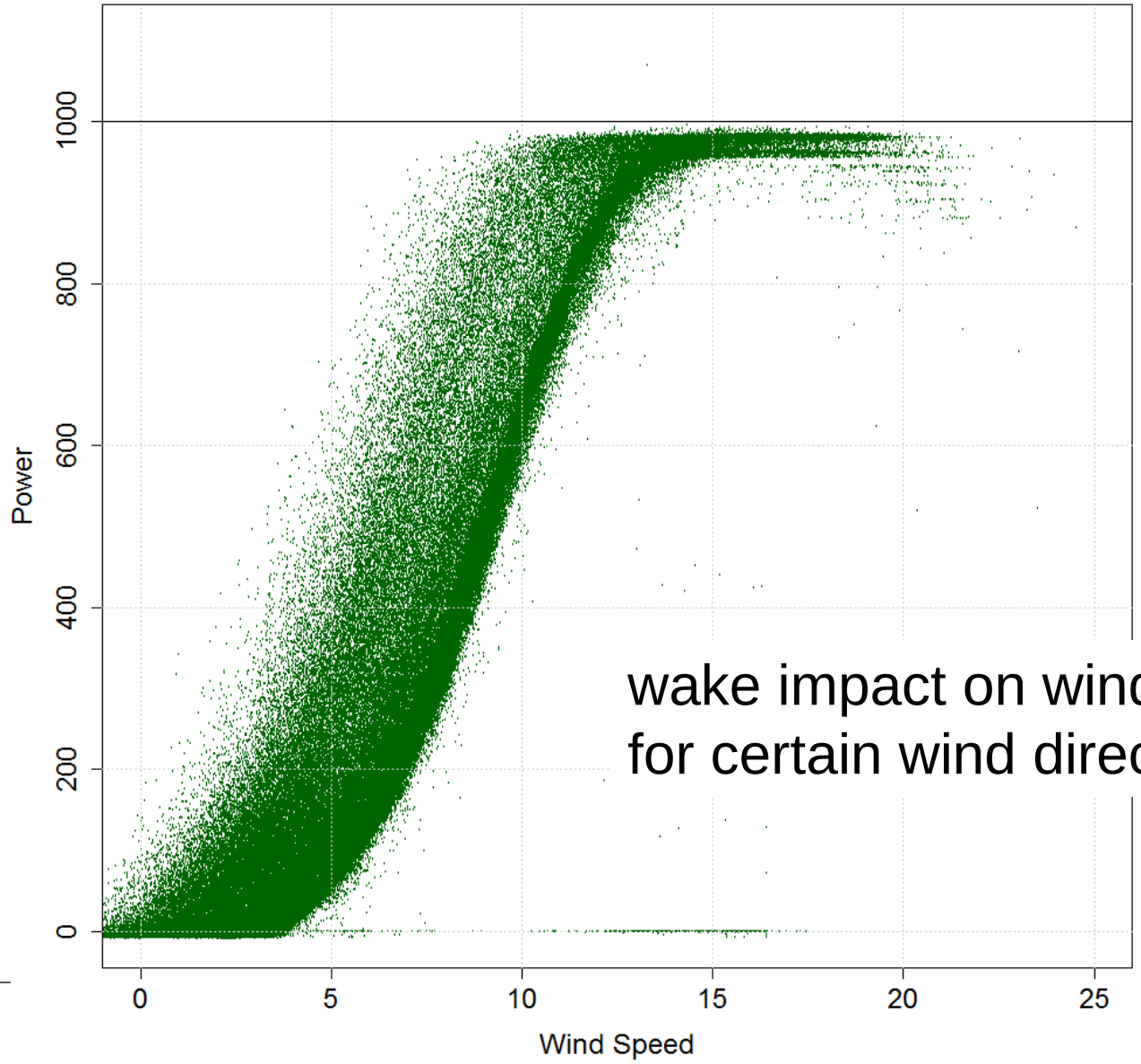
poor correlation of wind measurements to power

Example: Poor Correlation Wind to Power



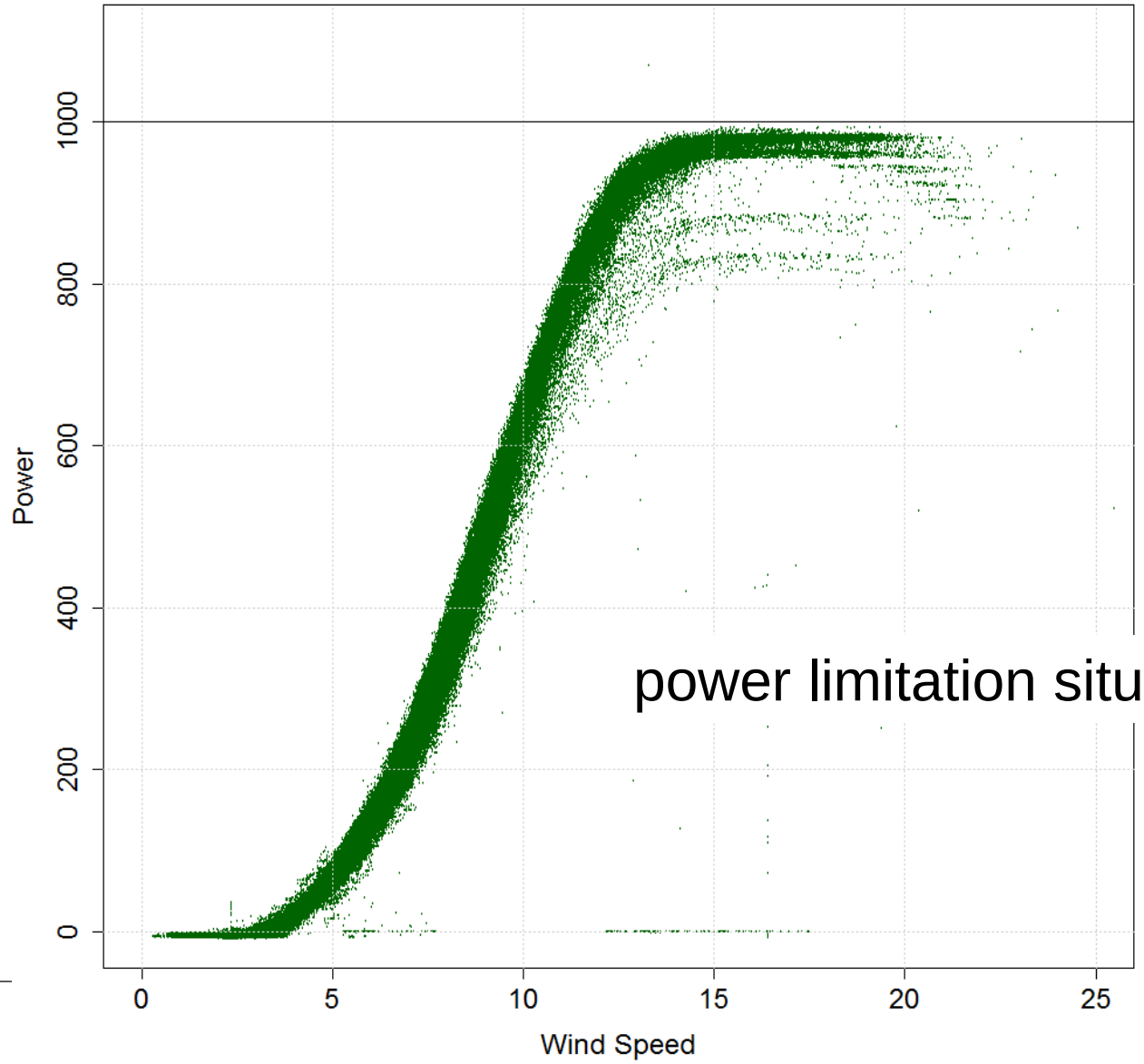
power range for a given wind speed has a large uncertainty

Example: Wake Impact on Measurement



wake impact on wind measurements for certain wind directions

Example: Power Limitation



power limitation situations

Power Estimate Tuning Improvements

Wind-based power estimate characteristics tuning - improvements implemented Q1 2017:

- Improved filtering of data used in tuning
  - improved automatic detection of unflagged curtailment situations
- Improved robustness
  - against prolonged periods with bad data
  - against unsuitable wind speed data
  - less impact from outliers

HIGH-WIND CUT-OUT

- As discussed in ECM Consultation – we need a solution for handling High-Wind Cut-out in Dispatch
- A modification to or additional signal about turbine availability is one approach.

- Current status:
  - Turbines Available represents turbines “available” to generate
    - including those cut-out due to high wind speed
    - effectively those that are not out of service
    - broadly aligns with scheduled turbine availability in portal

  - AWEFS currently uses Turbines Available SCADA to:
    - calculate wind-based dispatch forecast
    - tune pre-dispatch and STPASA models, including capturing the effect of high-wind cut-out

HIGH WIND CUT-OUT

- Issue: High Wind Cut-out in Dispatch forecast
  - Turbines in cut-out shown as available
  - AWEFS wind-based forecast assumes they will all run
  - AWEFS needs better information to improve the accuracy of the dispatch forecast

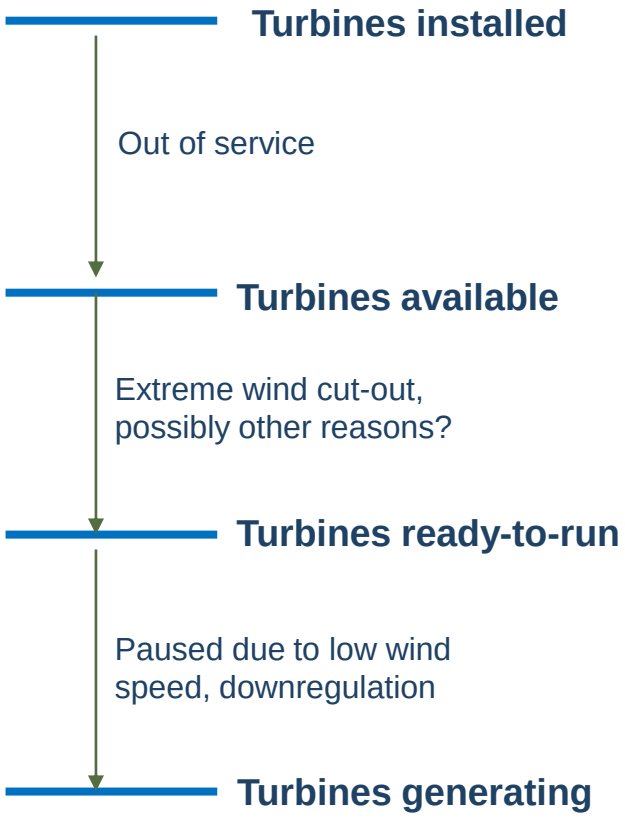
- **Core Question**
  - **How to most accurately represent the turbines that are able to produce power in the next dispatch interval?**

HIGH WIND CUT-OUT

- Solution Ideas:
  - Current Turbines Generating SCADA
    - Too low in low wind speeds or downregulation
  - Estimated Power SCADA
    - Complete MW estimate
    - Requires a sophisticated implementation on-site
  - Turbines Extreme Wind Cut-Out
    - Covers only extreme wind cut-out
    - May be difficult for some farms to implement for extreme wind only (feedback received during consultation)
    - Implemented as Optional in revised ECM Guidelines

TURBINES READY-TO-RUN SCADA

- New solution ideas:
  - Define a “Turbines Ready-to-Run” SCADA
    - For input into the dispatch forecast calculation
    - Turbines that are actually able to run
      - In service
      - Not currently paused due to cut-out
  - Extra value of a “Future Turbines Ready-to-Run” SCADA
    - To give even more dispatch accuracy with a 5-7 min ahead view



TURBINES READY-TO-RUN SCADA

- Questions:
  - How to define “ready-to-run”
    - Name?
    - Meaning?
  - What is something that can be easily and consistently implemented?
  - Is there value in a forward turbine count?
  - Alternative approaches?

ESTIMATED POWER SCADA

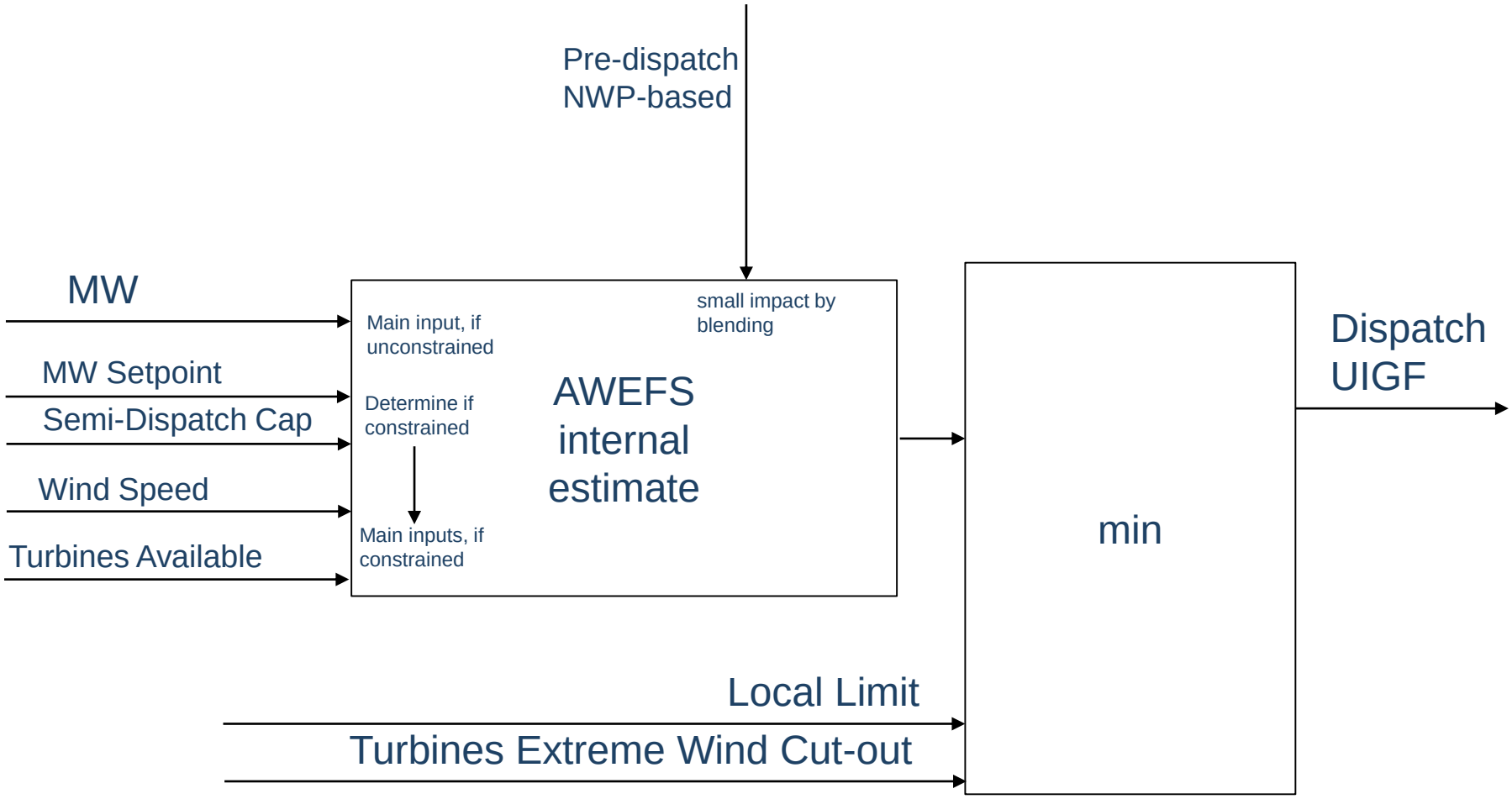
- As discussed in Consultation on ECM Guidelines

- New optional SCADA signal: wind or solar generator's estimate of active power generation at the end of the next dispatch interval, assuming no network constraints

- To discuss:
  - Requirements
  - A proposed approach
  - Way forward

CURRENT STATE OF AWEFS & INPUTS

This is an approximation of the logical behaviour – not to be taken as the actual design



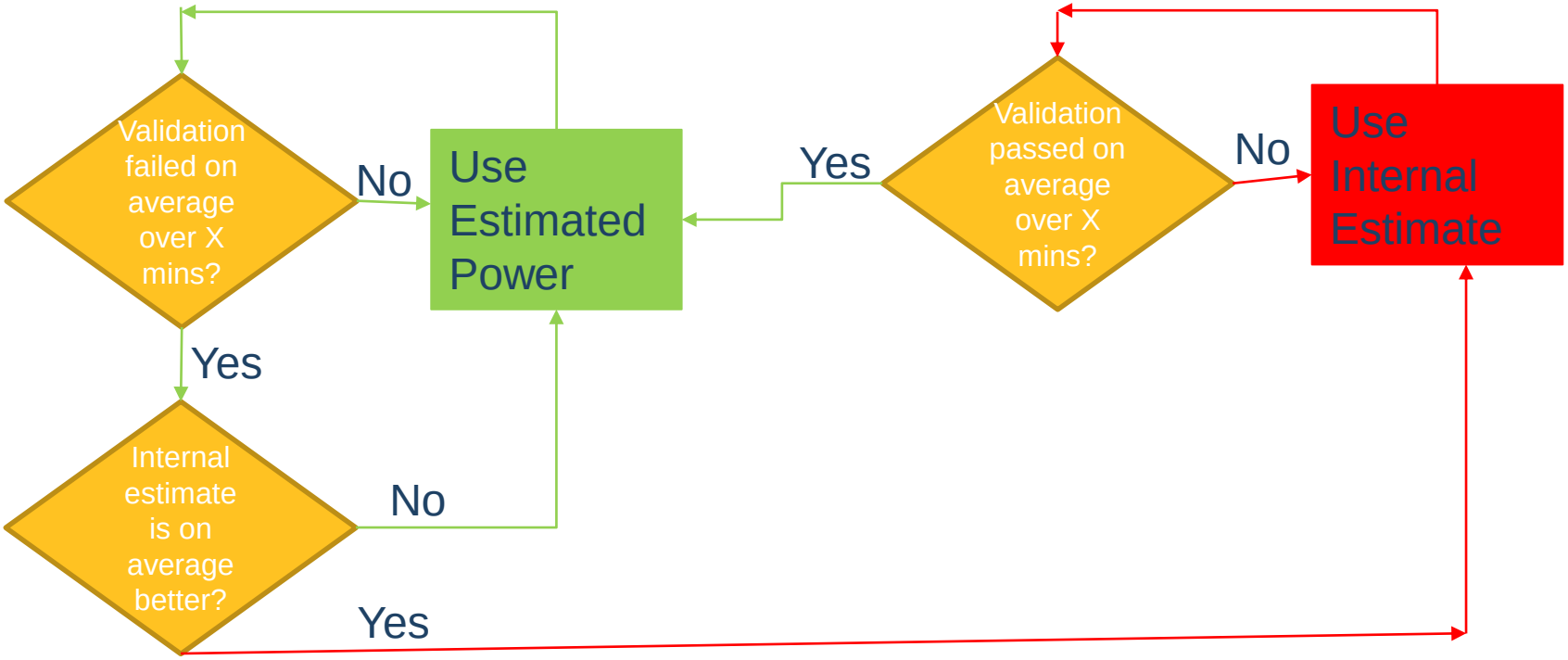
HOW TO USE ESTIMATED POWER SIGNAL?

- AEMO requirements:
  - We have to validate it to protect dispatch accuracy and for Rules compliance.

- Participants:
  - It’s our best forecast for dispatch.
  - We want to improve our dispatch accuracy to manage causer-pays liability.

POSSIBLE APPROACH – OVERVIEW FLOW CHART

Possible approach: Use Estimated Power unless it's performing badly. Validate Estimated Power against Actual MW.



ESTIMATED POWER - IMPLEMENTATION

- Performance metrics of Estimated Power and internal AWEFS/ASEFS estimate to be logged

- **Critical implementation requirements:**
  - When generator is constrained (e.g. by Semi-Dispatch Cap), Estimated Power represents the **unconstrained forecast**.
  - When turbines are in **high-wind cut-out** and not coming back next dispatch interval, the Estimated Power reflects this.

QUESTIONS

- What do you think of the possible approach?
  - Concerns?
  - Alternative suggestions?
- How precise will Estimated Power be – sub-MW?
- What information do you need to start implementing your Estimated Power signal?

ESTIMATED POWER NEXT STEPS

- AEMO to further refine proposed implementation
- Wind/solar farms to provide spreadsheet and/or SCADA data for operational and accuracy assessment
- AEMO to work with individual farms on performance
- AEMO to report back to all stakeholders on outcomes of performance assessment
- Further meetings on this topic to discuss details

WIND SPEED SCADA IMPROVEMENT

- ECM consultation refined definition of farm-wide “Wind Speed” SCADA signal
  - This drives the dispatch forecast when output is constrained through the tuned power curve
  - Wind speed signal better correlated with output gives more accurate dispatch forecast.
- Recommendation: provide an average wind speed from all nacelles.
- Any questions on implementation?

EMERGING FORECASTING TECHNOLOGIES

- New technologies to improve forward forecasting of wind and solar farm output
  - Discuss with AEMO and the vendors of AWEFS and ASEFS the emerging technologies around forward forecasting of wind and solar.
  - We would like to be informed about any technologies you have come across, to provide AEMO the opportunity to potentially integrate or facilitate use of these technologies in future.
- AEMO encourages you to review AEMC work on the future power system and make a submission if appropriate.

NEXT STEPS

- Please send follow-up questions and ideas by email to op.forecasting@aemo.com.au

- AEMO is looking forward to receiving Estimated Power spreadsheets and SCADA.

- Further meetings will be organised to discuss:
  - details of Estimated Power implementation and progress in assessing candidate signals
  - other issues, including a broader review of AWEFS & ASEFS
  - implementation of any change or addition to Turbines Available