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2nd Grid Integration of Offshore Wind Energy

Designing and Operating Wind Farm Clusters

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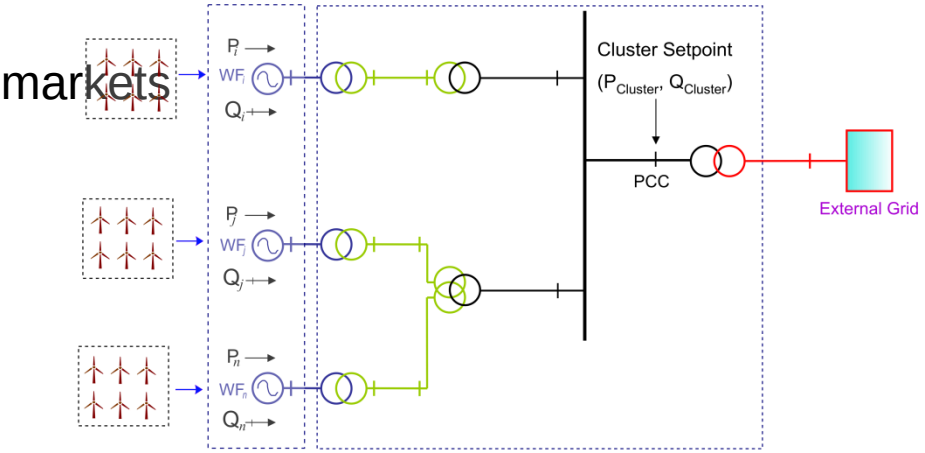
Content

- Clustering Offshore Wind Farms
- Ancillary Services Provided by Wind Farm Clusters
- Software Tools
- Conclusions

Clustering Offshore Wind Farms

- High availability of Ancillary Services due to:
  - Smoothing effect over large areas
  - Higher predictability (in case of reduced variability)
- Higher opportunities to participate in markets
- Higher complexity for optimizations



$$P_{Cluster}, Q_{Cluster} = (\sum_{i=1}^{n} P_i) + P_{Losses} + (\sum_{i=1}^{n} Q_i) + Q_{Losses}$$

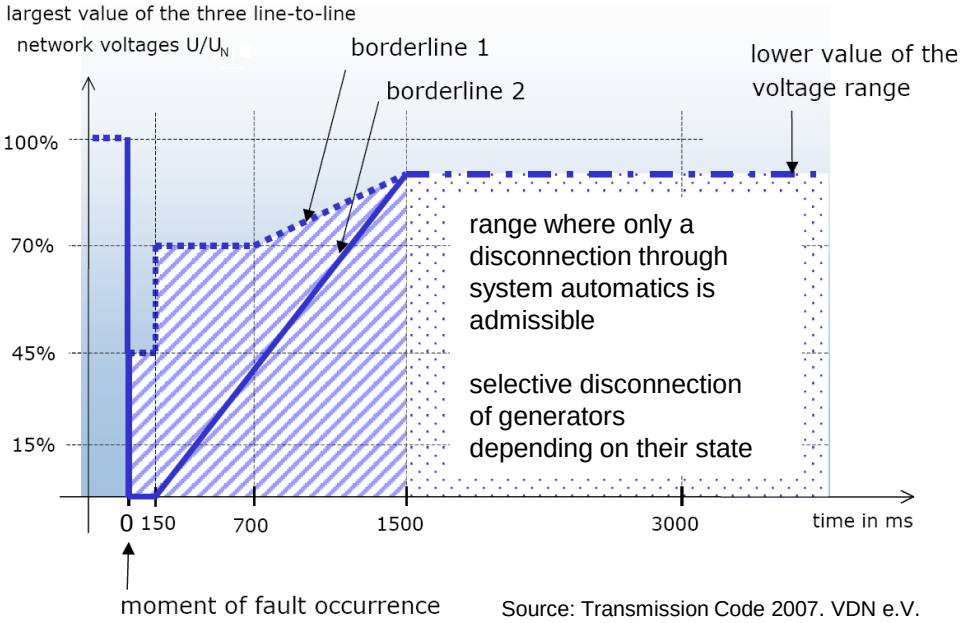
Voltage Problems

Grid Code Requirements

Fault-Ride Through (LVRT-HVRT)

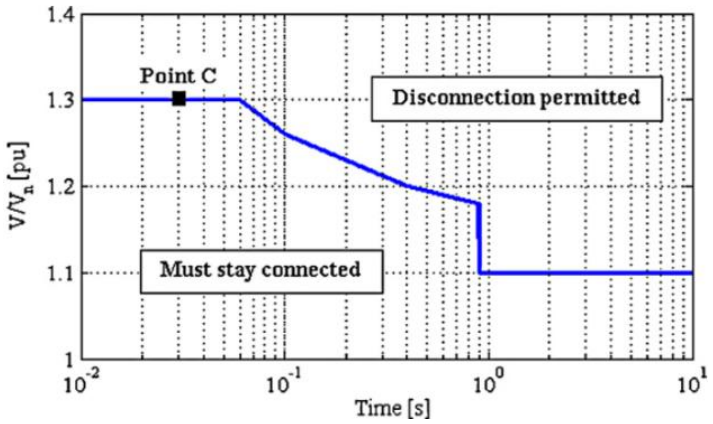
- WTG should **stay connected** in case of a grid fault

LVRT:



Source: Transmission Code 2007. VDN e.V.

HVRT:



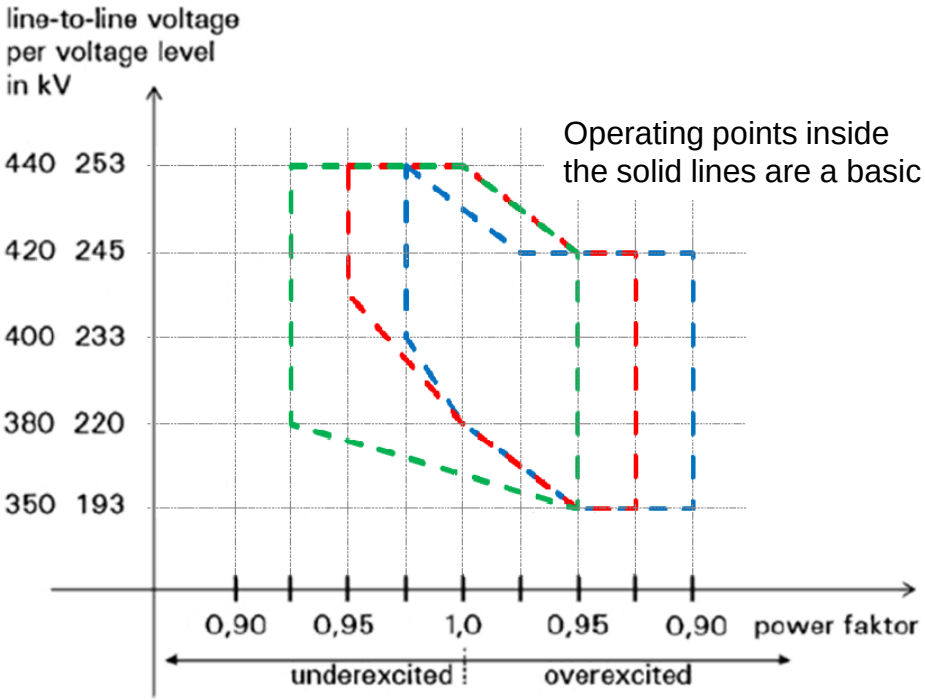
Source: Australian HVRT requirement

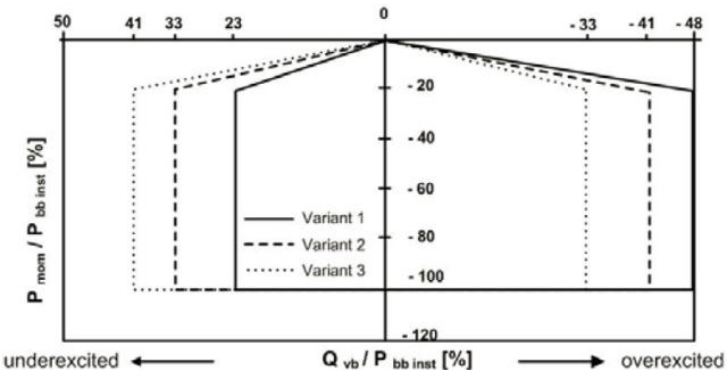
Voltage Support

Grid Code Requirements

Voltage support in case of a normal grid operation

- defining possible operational ranges





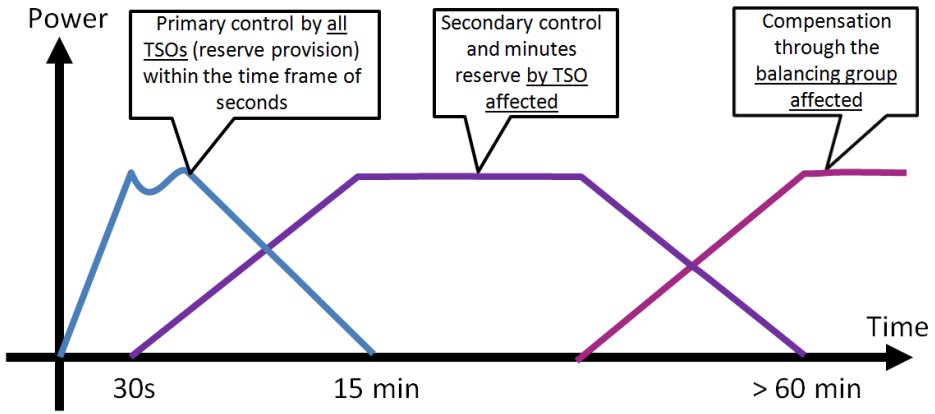
Source: TransmissionCode 2007. VDN e.V.

Frequency Control

Grid Code Requirements

- Continuous balancing of power

- Different types of control reserve



Positive and negative reserve is necessary

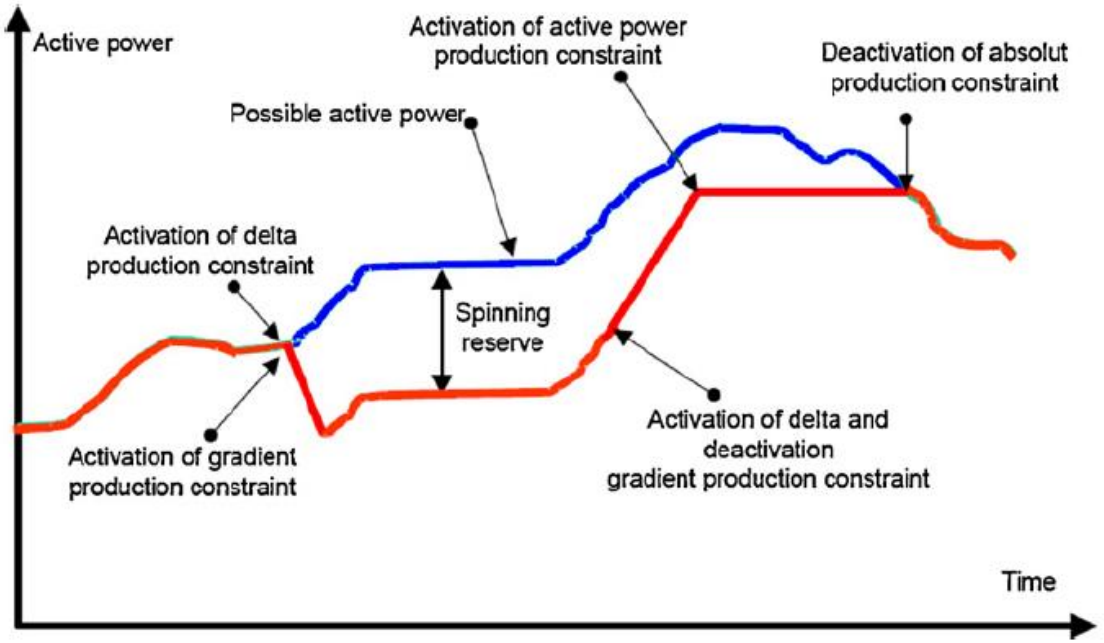
Sources: ENTSO-E NCfG/ ENTSO Balance Management Harmonisation and Integration; Amprion GmbH (http://www.amprion.net/en/control-energy)

Frequency Support

Grid Code Requirements

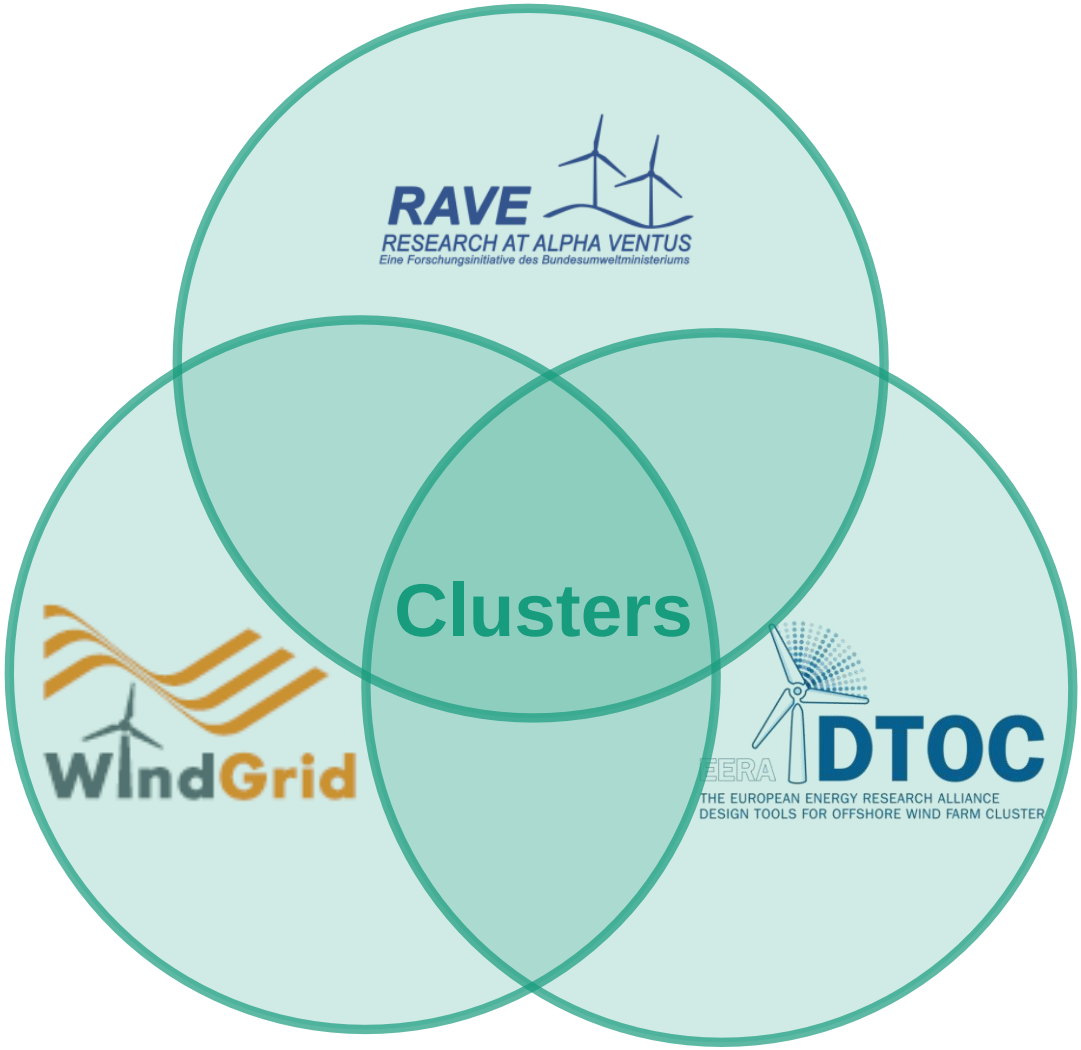
Frequency support in case of a normal grid operation

- decreasing active power output of the WTGs in order to offer a positive contribution to the control reserve



Sources: Wind Turbines Connected to Grids with Voltages above 100 kV (Energienet.dk)

Technical Research and Solutions: Fraunhofer IWES



Research: Wind on the Grid

Operational Tool

- Objective → preparation of European electricity system for large-scale integration of wind energy.
- Design, development & validation of new tools.
- Wind Farm Cluster Management System (WCMS).
- Development of control strategies.
- Associated methodology for providing power reserve with wind power.

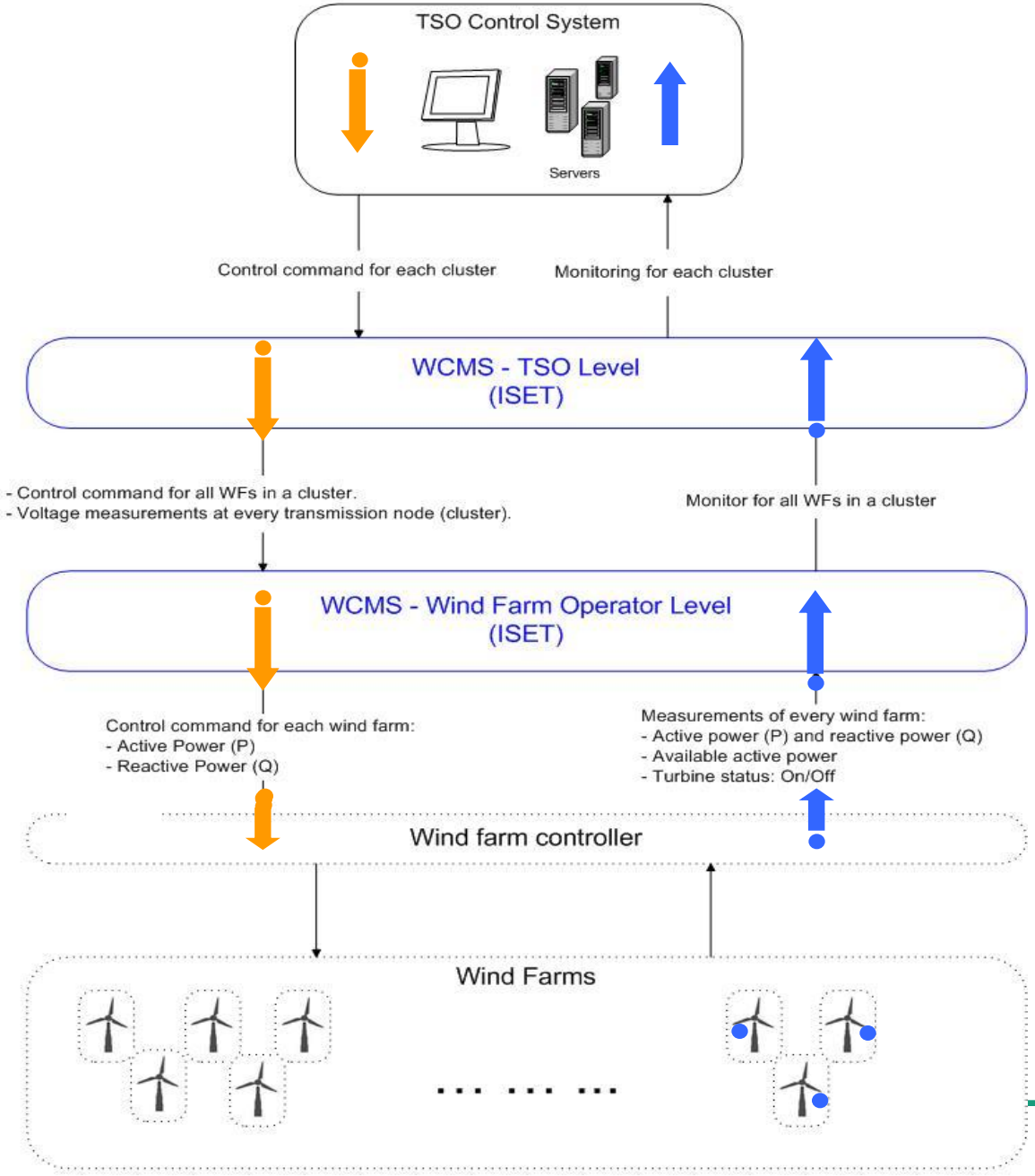


Figure: Monitoring and command control flow for the WCMS i

TSO → Wind Farms

1 - WCMS TSO Level

2 - WCMS WF operator level

3 - WF controller

4 - Wind Farms

Wind Farms → TSO

1 - WCMS TSO Level

2 - WCMS WF operator level

3 - WF controller

4 - Wind Farms

Research: Wind on the Grid

Operational Tool

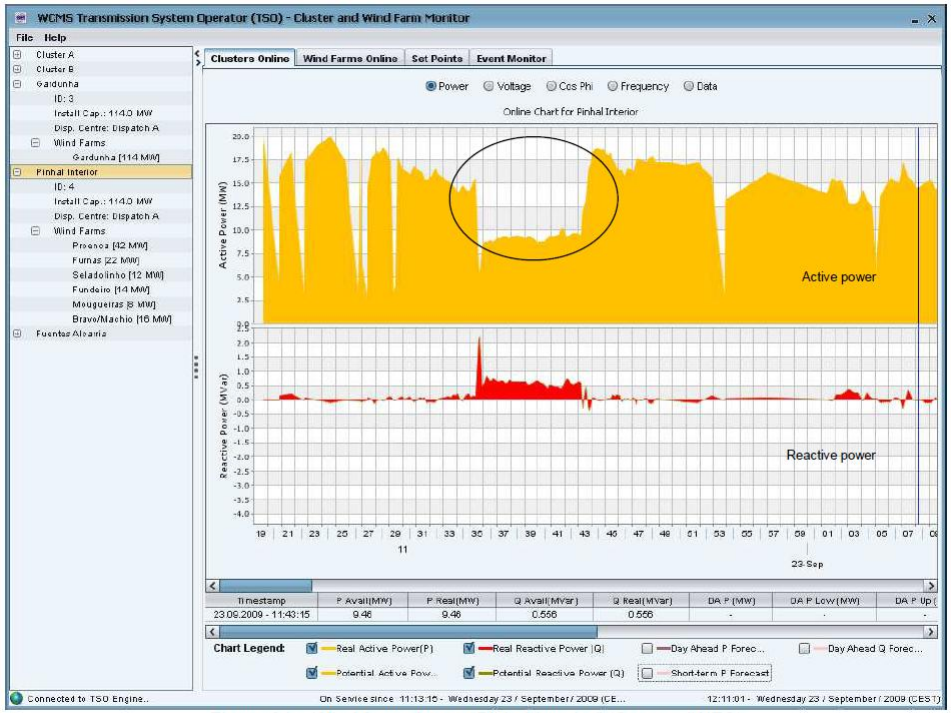


Figure 64 – Wind farm cluster "Pinhal Interior" (Source: IWES)

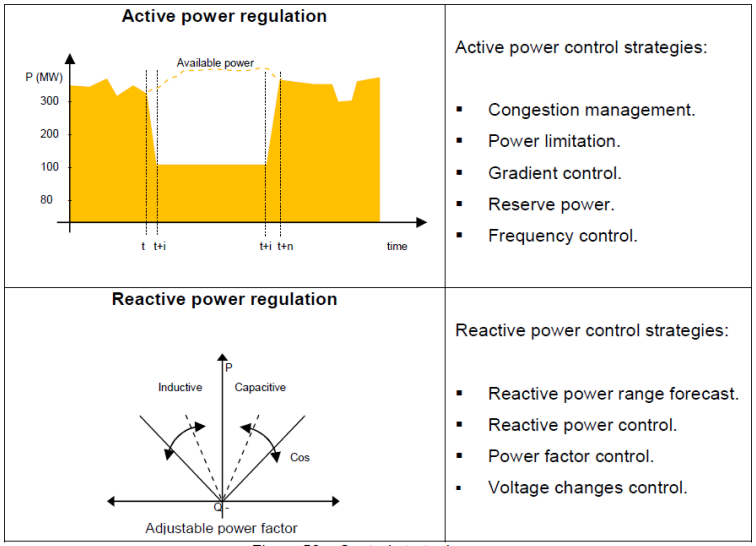


Figure 59 – Control strategies

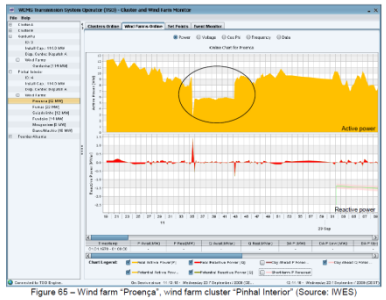


Figure 65 – Wind farm "Proença", wind farm cluster "Pinhal Interior" (Source: IWES)

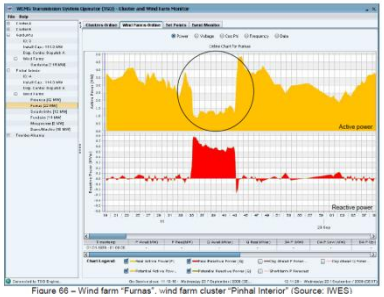


Figure 66 – Wind farm "Furnas", wind farm cluster "Pinhal Interior" (Source: IWES)

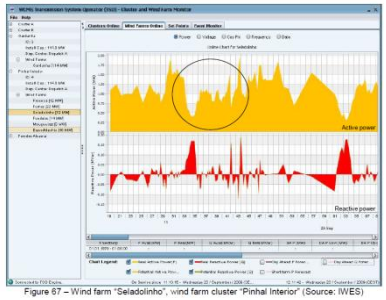


Figure 67 – Wind farm "Seladolinho", wind farm cluster "Pinhal Interior" (Source: IWES)

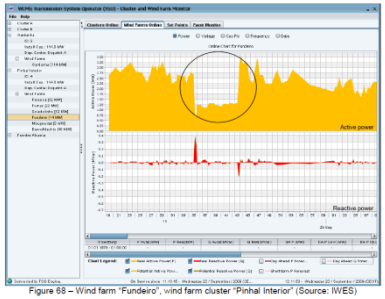


Figure 68 – Wind farm "Fundeiro", wind farm cluster "Pinhal Interior" (Source: IWES)

Source: Power Reserve Provision with Wind Farms - A. Gesino

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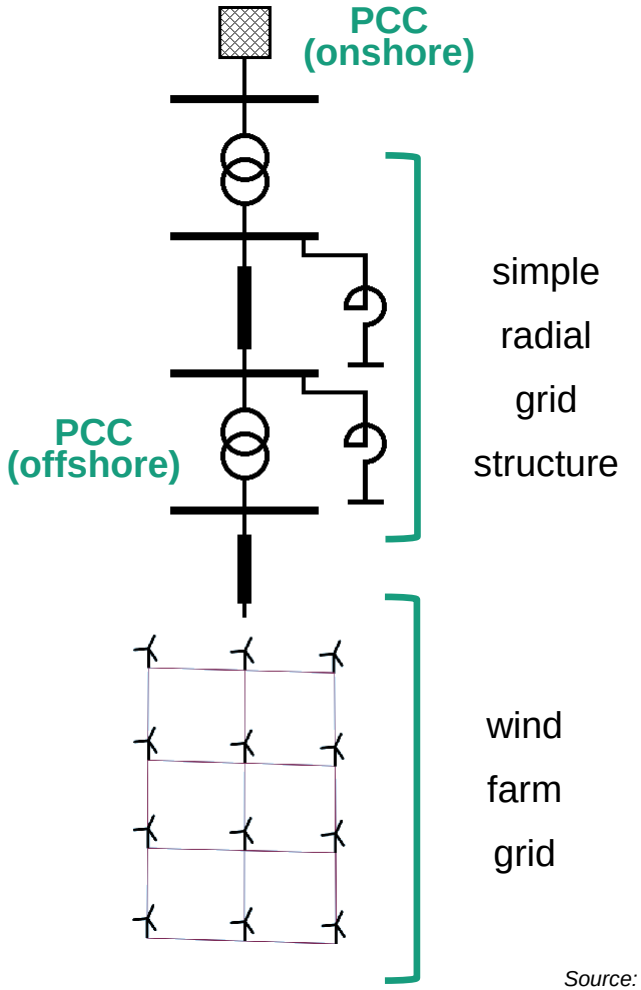
Research: RAVE Project

Operational & Simulation Tool

Providing control possibilities
of the WF relating its onshore PCC

- Congestion or voltages problems could be detected **in advance** due to forecasts
- Operated as an expanded Wind Farm controller



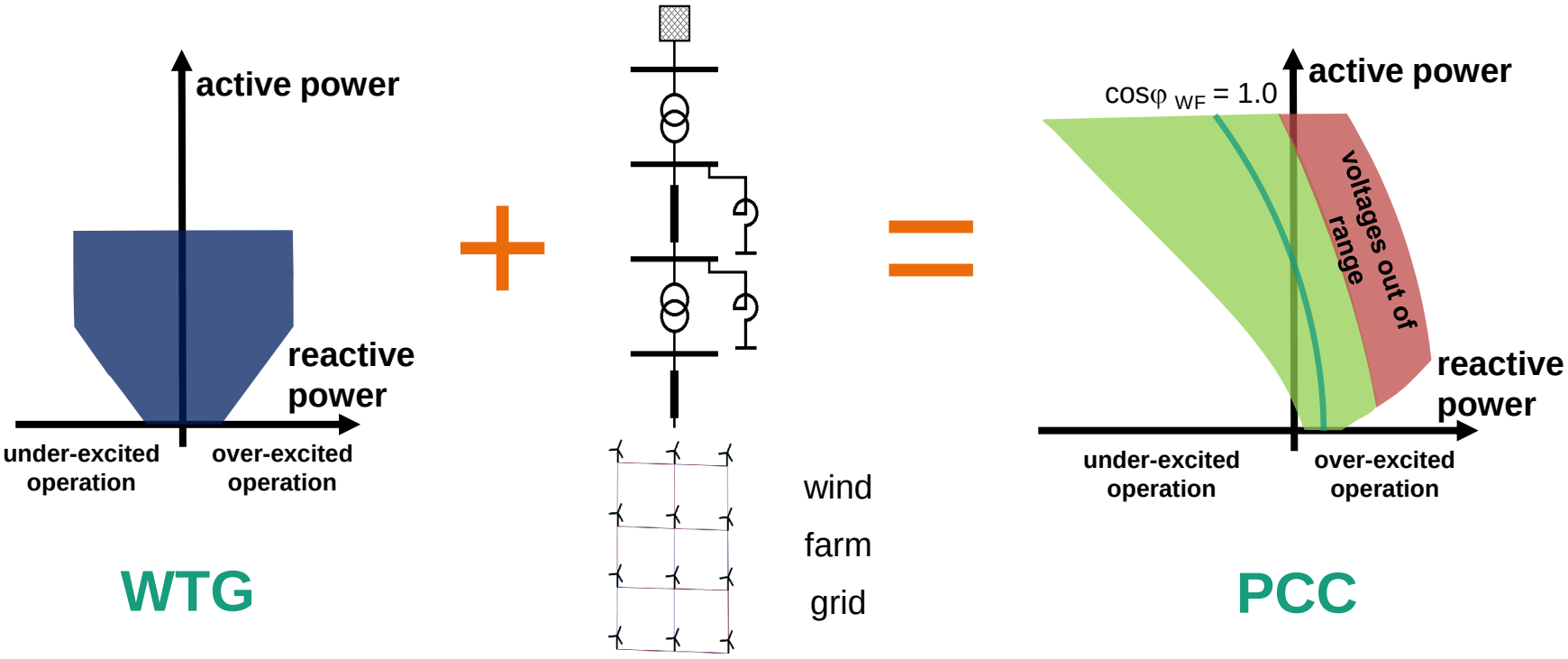
Source: RAVE Project

Research: RAVE Project

Operational & Simulation Tool

RAVE RESEARCH AT ALPHA VENTUS
Eine Forschungsinitiative des Bundesumweltministeriums

Providing control possibilities of the WF relating its onshore PCC



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Research: RAVE Project

Operational & Simulation Tool

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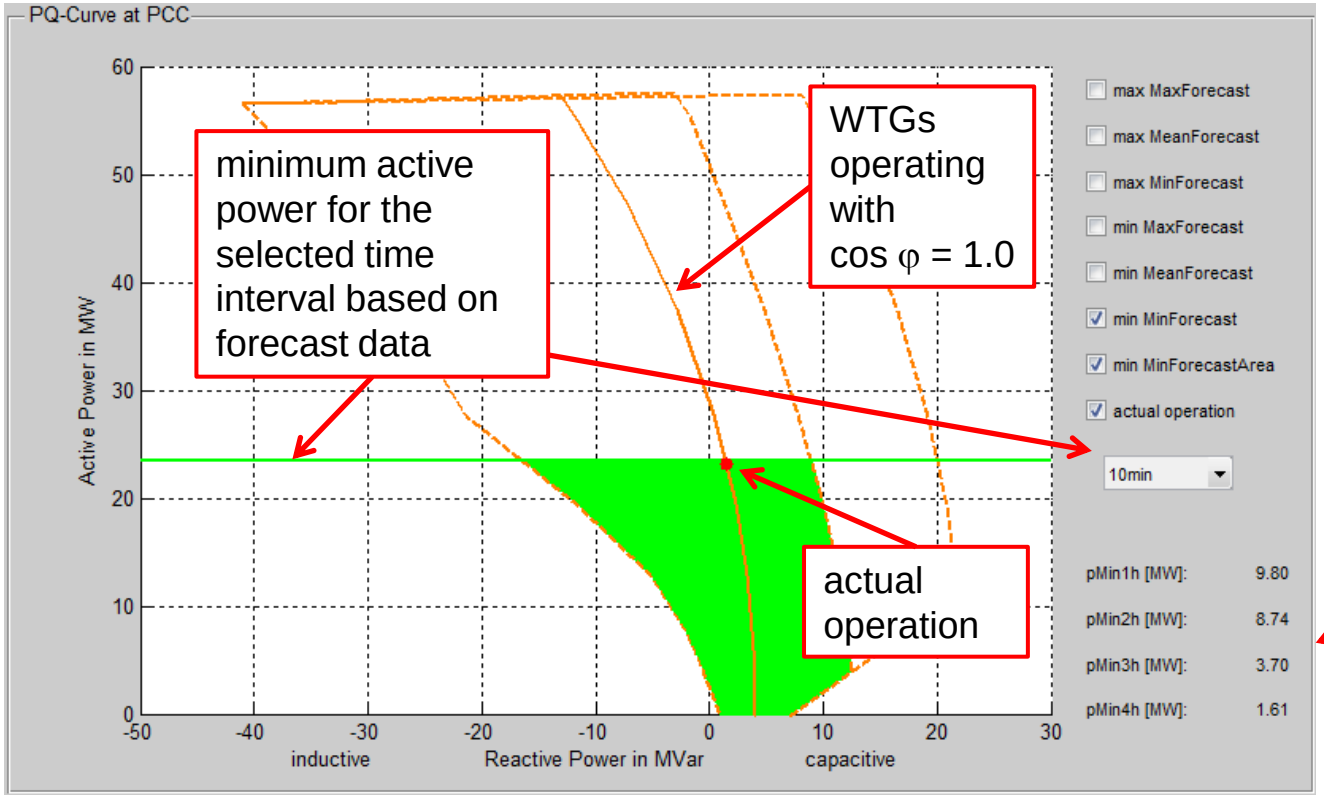
Providing control possibilities of the WF relating its onshore PCC



Source: Screenshot (cut-out) of the developed program

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Research: RAVE Project

Operational & Simulation Tool

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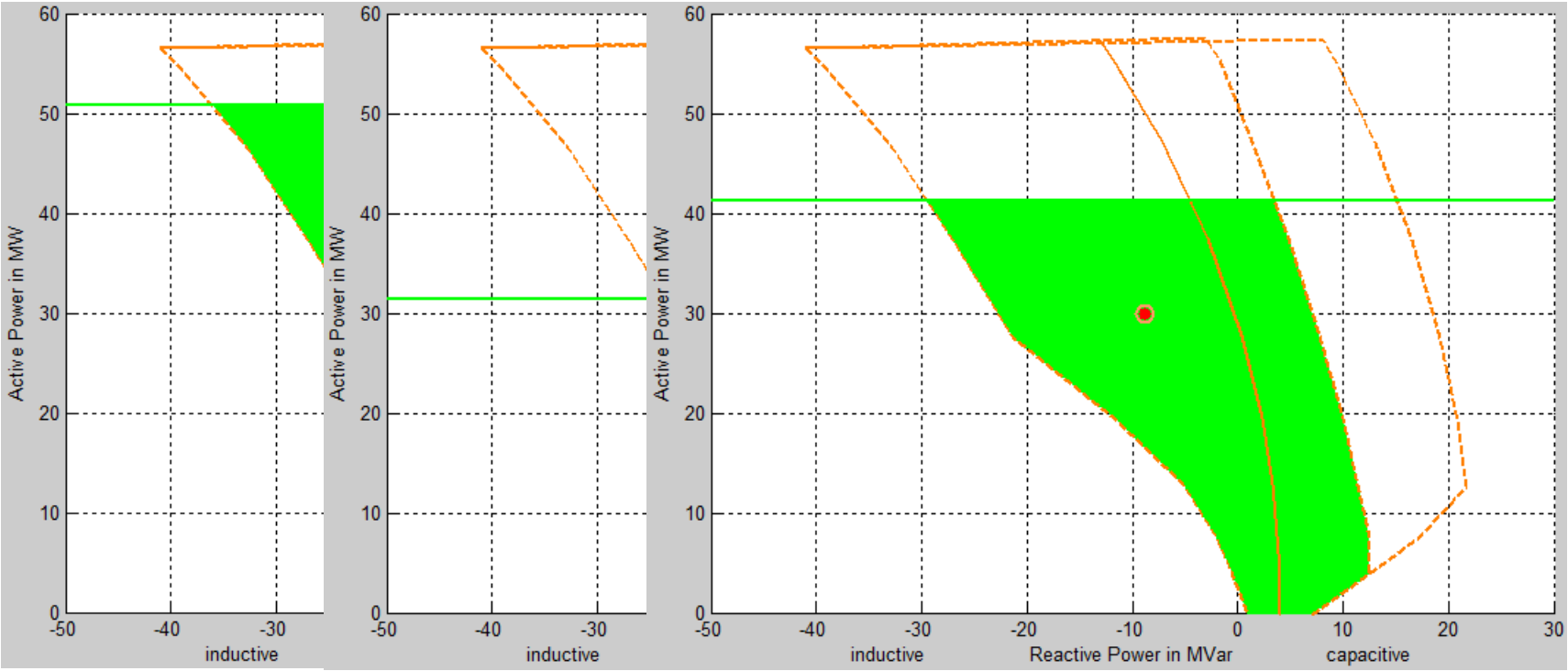
Providing control possibilities of the WF relating its onshore PCC
Examples:

P_{max}, cos φ = 0.98 ind. P_{max}, Q = -5 Mvar P = 30 MW, Q = -10 Mvar



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Research: RAVE Project

Operational & Simulation Tool

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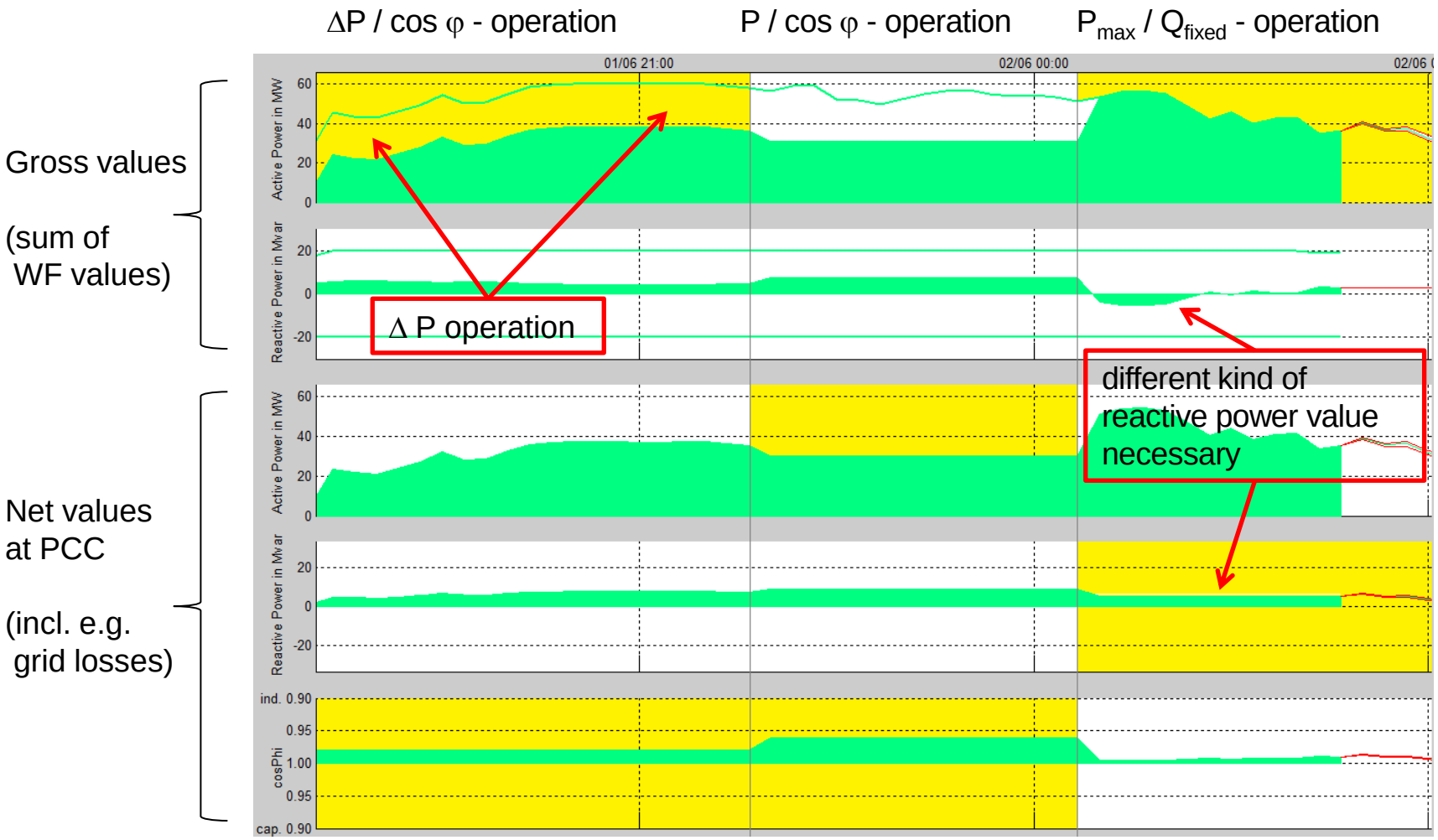

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Research: RAVE Project

Operational & Simulation Tool

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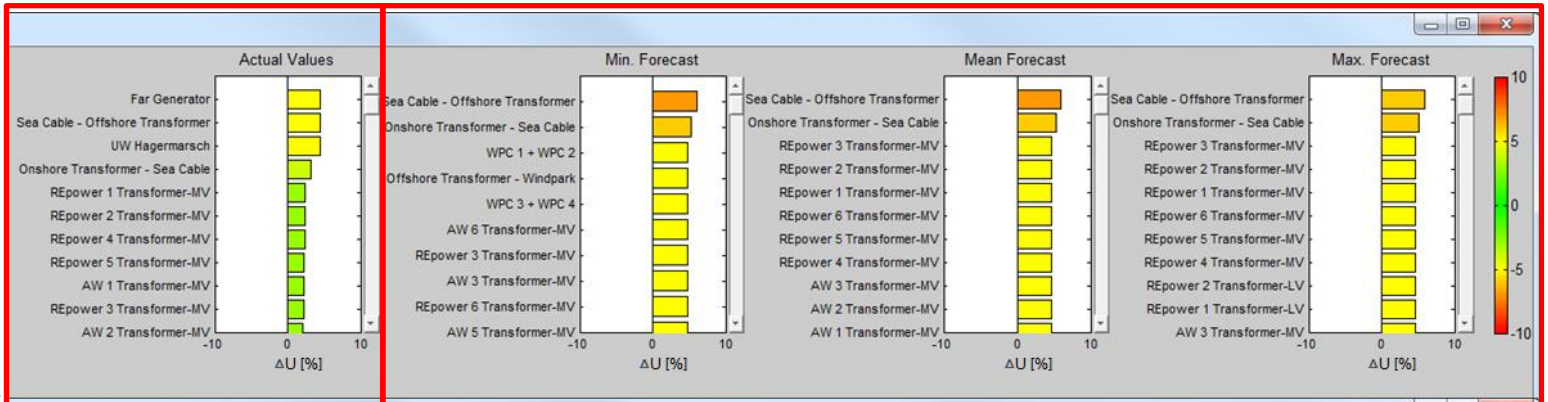
Providing voltage and utilization information

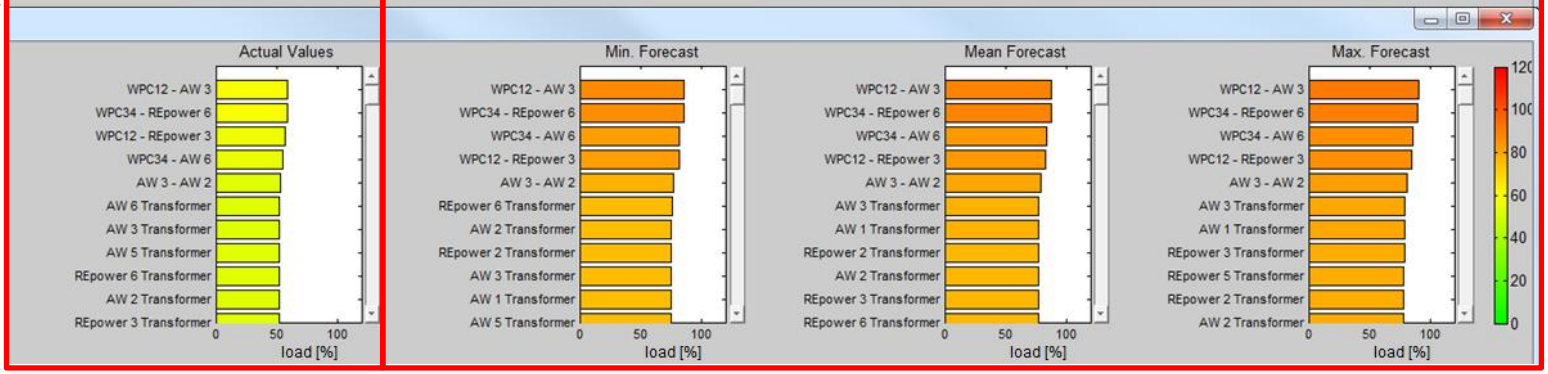
Actual values

Data based on power forecast

Voltage Monitor



Utilization Factor Monitor



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EERA DTOC
THE EUROPEAN ENERGY RESEARCH ALLIANCE
DESIGN TOOLS FOR OFFSHORE WIND FARM CLUSTER

What is EERA-DTOC

Software tool > for design phase

Integrated and validated design tool combining the state-of-the-art:

- Wake Effects (WP1)
- Yield (WP3)
- Electrical models (WP2)

Product Vision

A robust, efficient, easy to use and flexible tool created to facilitate the optimized design of individual and clusters of offshore wind farms.

Target (main) Users

The prospective users of EERA DTOC fall into the following primary categories:

Strategic Planners

- Design process at the highest level
- Commonly responsible the definition of project boundaries
- Determine what infrastructure should be created to accommodate projects
- Goals of a strategic planner may include:
  - Achieving a legislated target for installed capacity.
  - Minimizing the cost of energy to consumers.
  - Ensuring the security of the supply of energy to consumers.

Project Developers

- working within the broad project definitions determined by strategic planners.
- The primary goal of a project developer will be to maximize their financial return.

WP2: „Interconnection Optimisation and Power Plant System Services“

Objectives:

- to develop a **design tool** and **procedure** for the **optimisation** of the electrical design of offshore wind farm clusters…

- ….including the provision of power plant system services by the cluster.

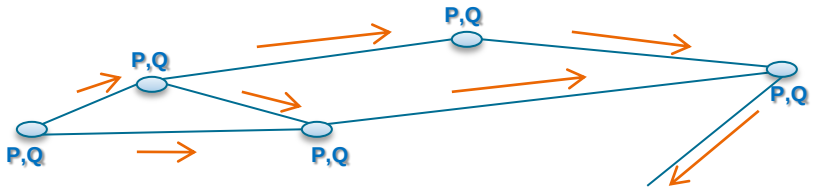
Participants in WP2:

Research: EERA-DTOC

Design Tool

EERA DTOC
THE EUROPEAN ENERGY RESEARCH ALLIANCE
DESIGN TOOLS FOR OFFSHORE WIND FARM CLUSTER

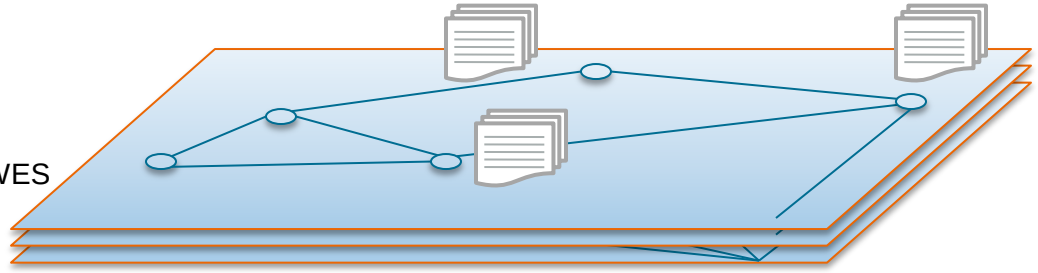
- Fraunhofer IWES



WCMS model
Analysis of the availabi[illegible]
power plant system services

2.4

- Strath
- SINTEF



Grid Codes compliance
PSS/e & PSCAD/EMTDC
Transient analysis

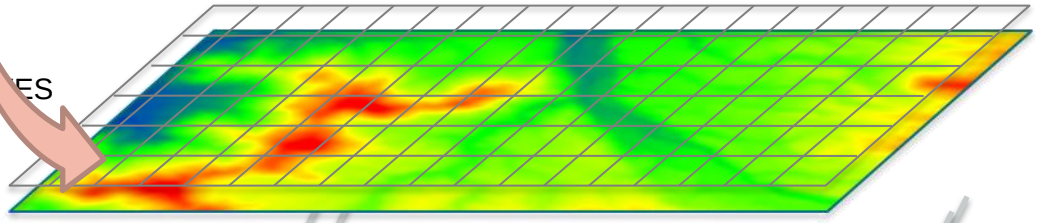
2.3

- SINTEF
- Fraunhofer IWES
- Strath
- Statoil
- Hexicon

NET-OP model
Grid optimization
Steady-state

2.2

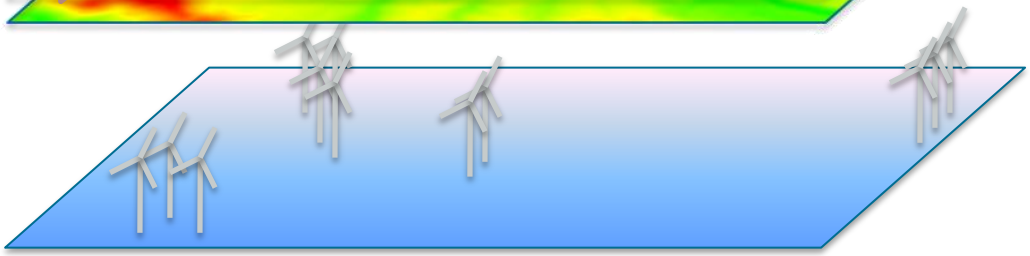
- Risoe DTU
- Fraunhofer I[illegible]ES
- CIEMAT



Analysis on variability & predictability

2.1

CorWind model



Off-shore development
Wake modelling

WP1

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Conclusions/ Possible solutions

- Need for technical and operational **improvements**
- WPP/WFC shall **provide (more) Ancillary Services** in future scenarios
- WPP/WFC can/ shall take part in **congestion management** strategies
- **ICT solutions** should be improved/ widely used → SmartGrids
- Integration of commercial and technical platforms is required
- **Advanced control techniques** and software solutions are required