OTTO VON GUERICKE UNIVERSITÄT MAGDEBURG

FAKULTÄT FÜR ELEKTROTECHNIK UND INFORMATIONSTECHNIK

Institut für Elektrische Energiesysteme

RAVE RESEARCH AT ALPHA VENTUS

Eine Forschungsinitiative des Bundesumweltministeriums

Optimal Operation of Offshore Grid

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Projektträger

Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit

ptj Projektträger Jülich Forschungszentrum Jülich

Koordination

Fraunhofer IWES

Agenda

- Introduction
- Operational Requirements for Offshore Farms
- Coupled Simulation Environment
- Operational Strategies in Offshore System
- Conclusions and Further Research

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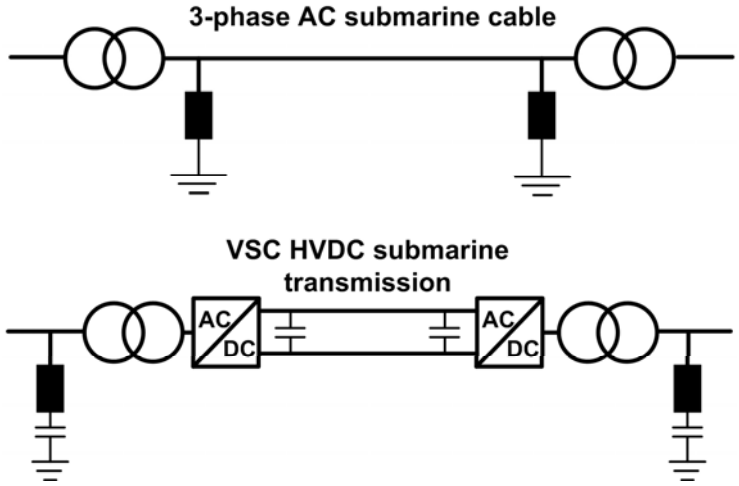
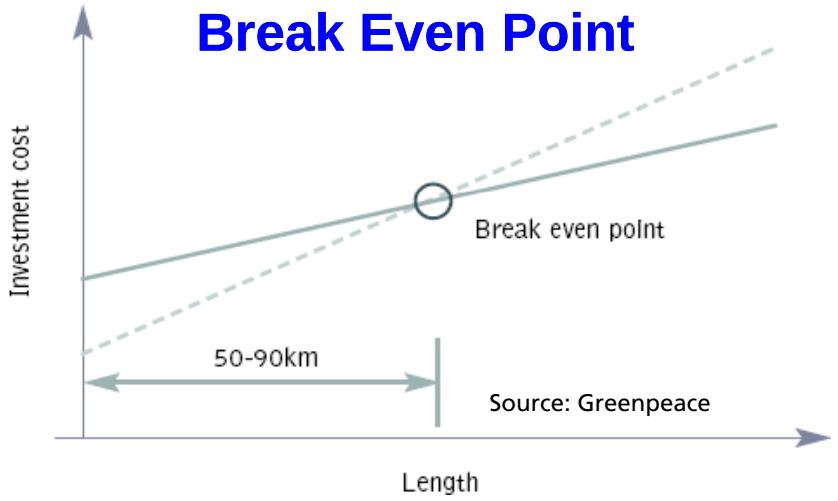
Introduction
OWF Grid Connection Practice

- Individual radial connectors (wind farm → onshore grid)
- AC-Technology at lower distances (up to 90km)
- DC-Technology at higher distances (over 90 km)
- Operational requirements according to the TSO's grid connection rules





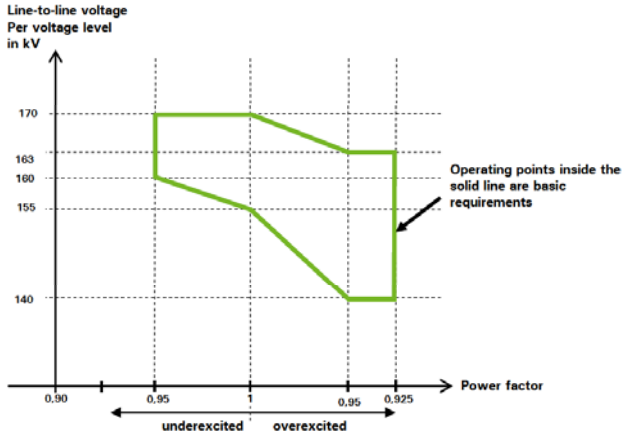
Operational Requirements for OWF
State of Art

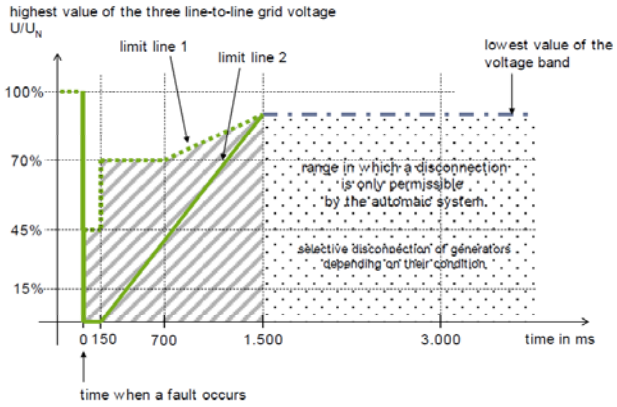
Stationary Behaviour:

- Voltage and Frequency Characteristics
- Active power output depending on frequency inclusive over-frequency reduction
- Reactive power exchange and voltage stability

Behaviour during Grid Failures:

- Fault Ride Through
- Voltage Support





Source: Tennet TSO GmbH

Coupled Simulation Environment (CSE)

WCMS and Grid Simulator

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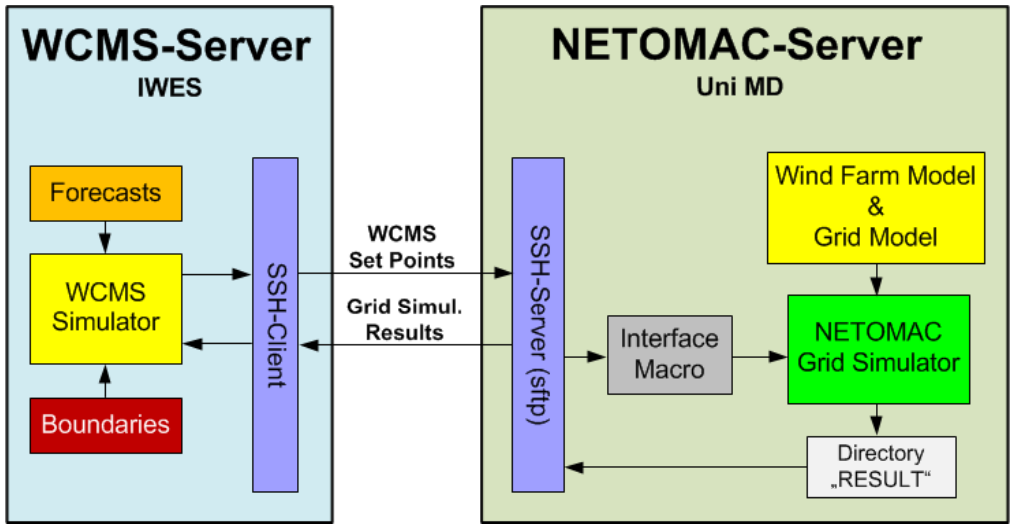
CSE Characteristic:

- emulation of stationary grid behaviour for WCMS testing
- validation of WCMS results
- improving the accuracy of the control strategies
- simulation of chosen scenarios regarding grid code fulfillment and grid support
- expandability for several clusters



*SSH : Secure Shell
*SFTP: Secret File Transfer Protocol

Functionalities:

- simulation control
- data exchange
- data security

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Coupled Simulation Environment

Grid Model Development

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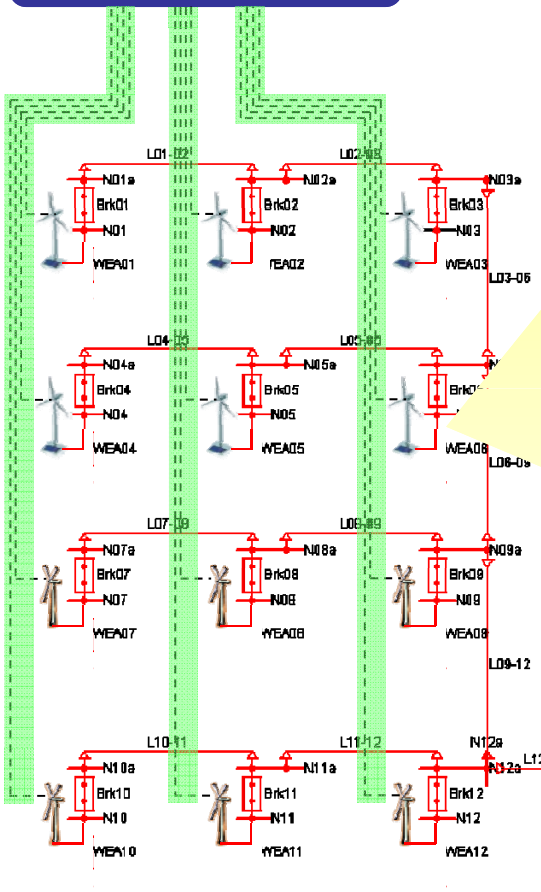
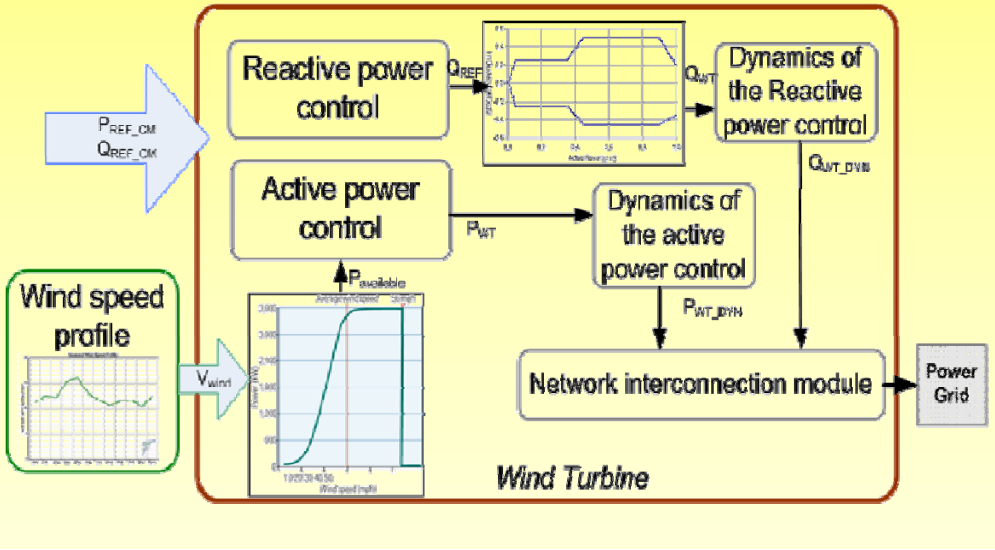
WCMS



Wind Turbine Stationary Model



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Coupled Simulation Environment

Exemplary Stationary Results

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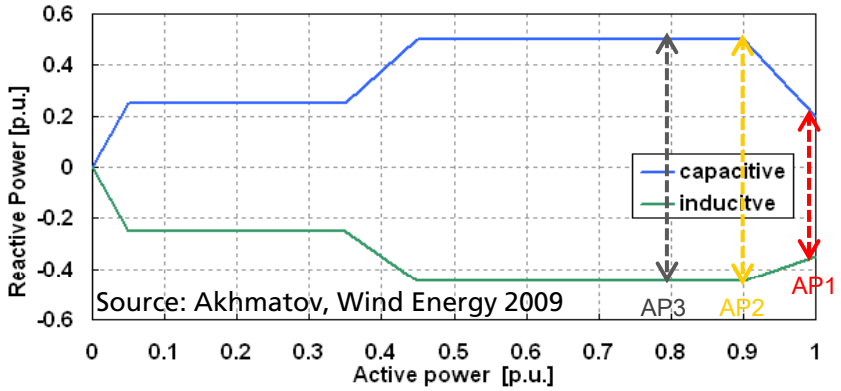
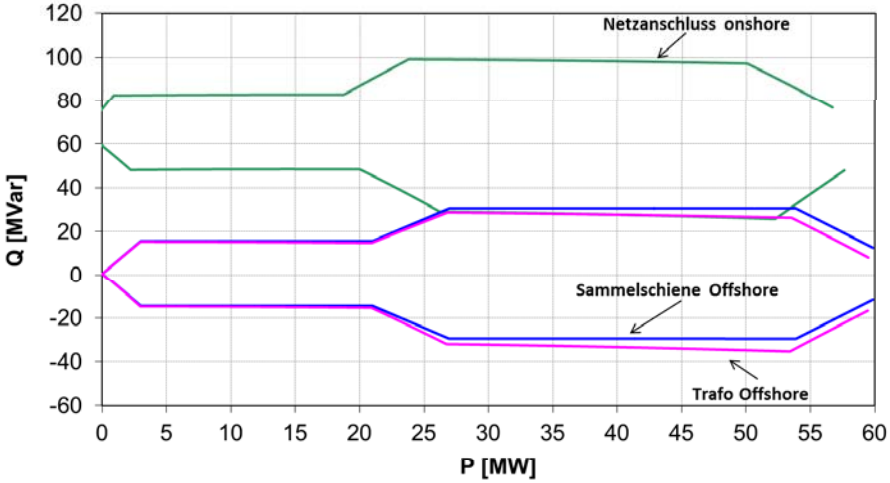
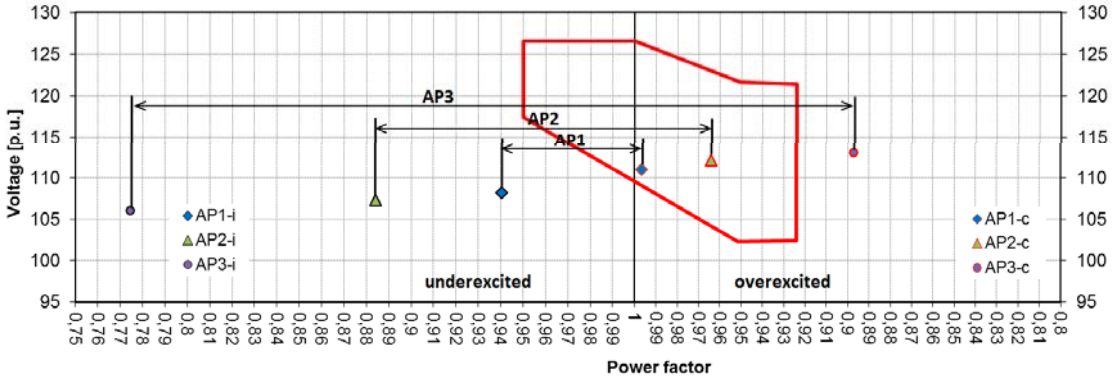
Exemplary PQ-Capability Curve of the WT



Simulation Results

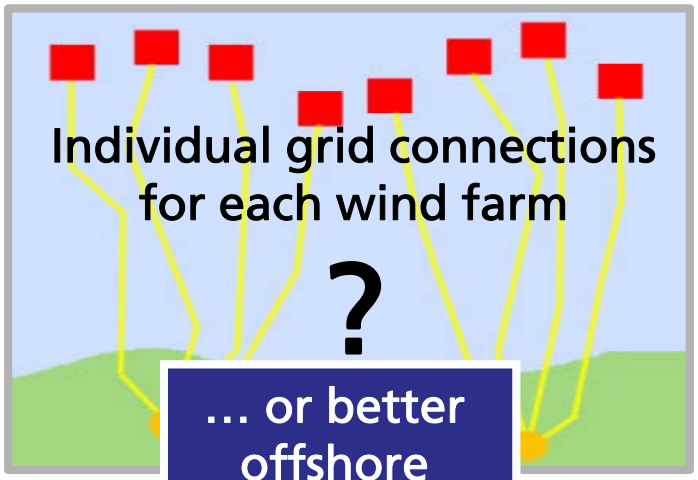


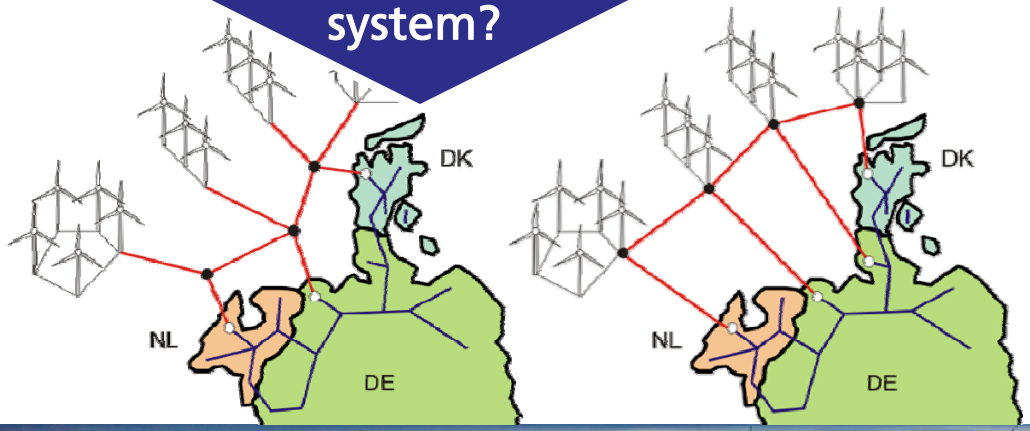
Using PQ-capability curve of WTs, the PQ-characteristic of the other nodes in the wind farm (especially for PCC) can be determined.
Thus, the steady state voltage can be analyzed and evaluated.



Working point *AP1* represent the wind farm generating and consuming maximum reactive power at the rated active power output

Offshore Wind Farms
Challenges for Integration





Challenges:

- High installed wind capacity
- Long distances to shore
- Transmission technology AC-DC
- Control and protection strategies (no commercial DC breaker)
- Multi-terminal operation
- Mixed AC-DC operation

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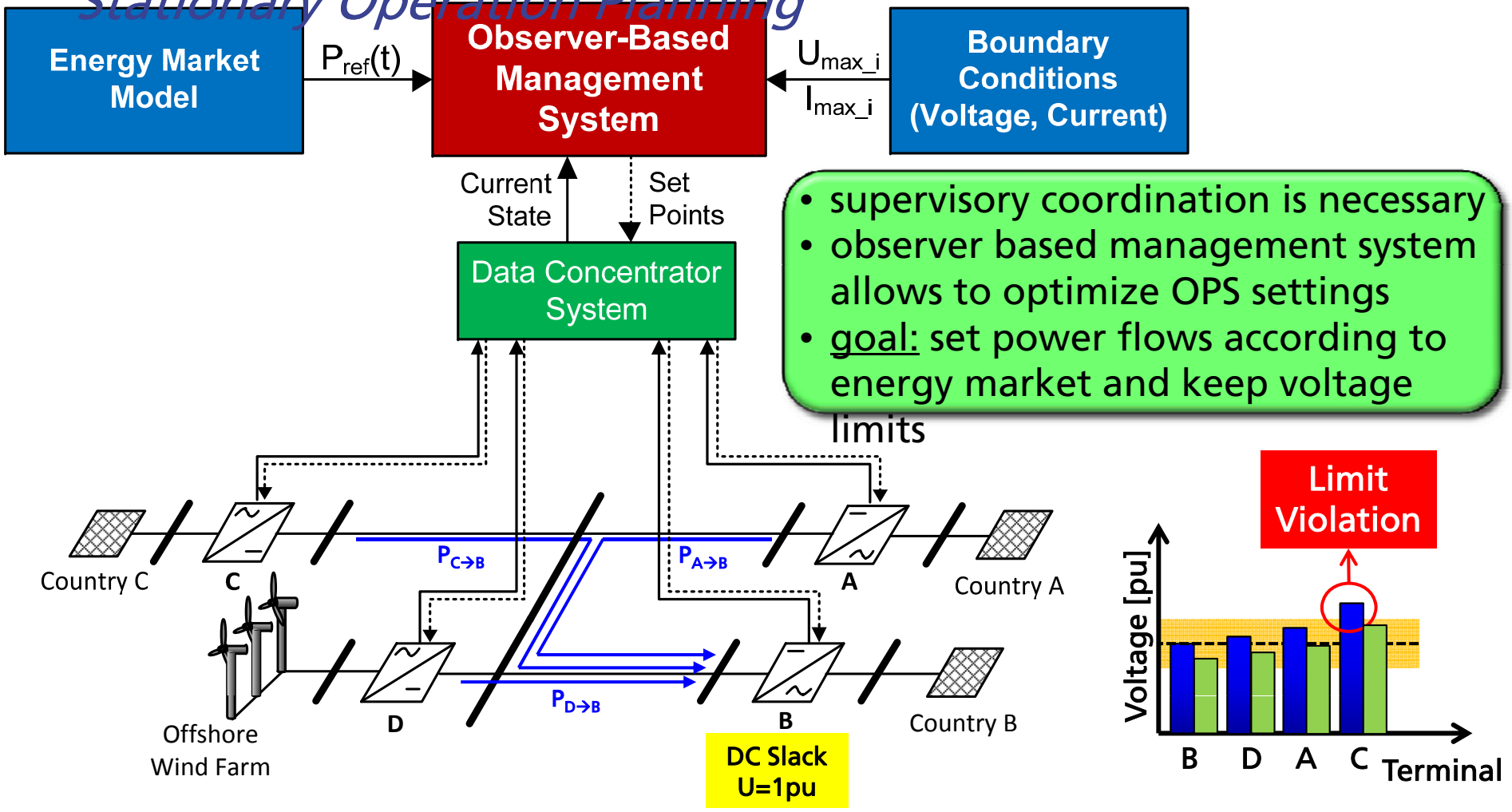
Future Research-Offshore Power System

Stationary Operation Planning



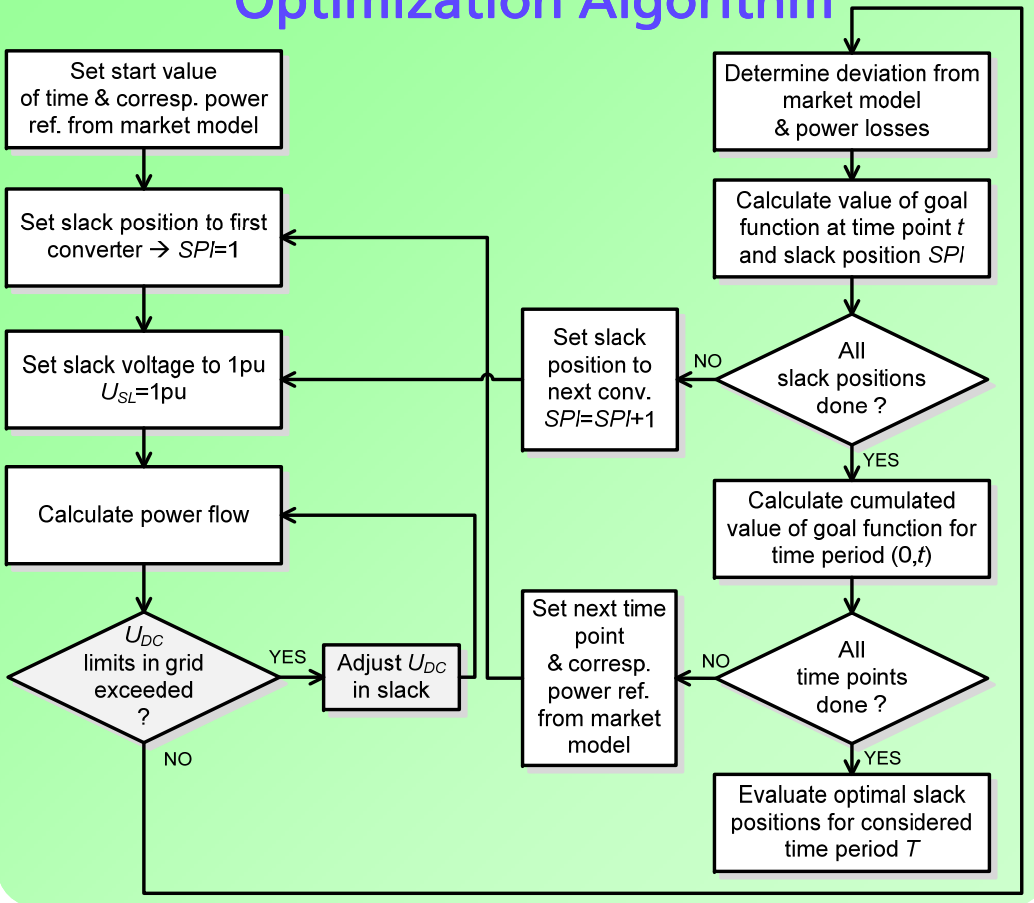
Future Research-Offshore Power System

OBMS – General Characteristic

OBMS (Observer Based Management System) - Characteristic

- based on the model of the offshore power system
- multiple power flow calculation with different DC slack positions
- for each slack position the DC voltage value optimized by binary search algorithm
- evaluation of power losses and deviation from energy market at each slack position

OBMS Optimization Algorithm



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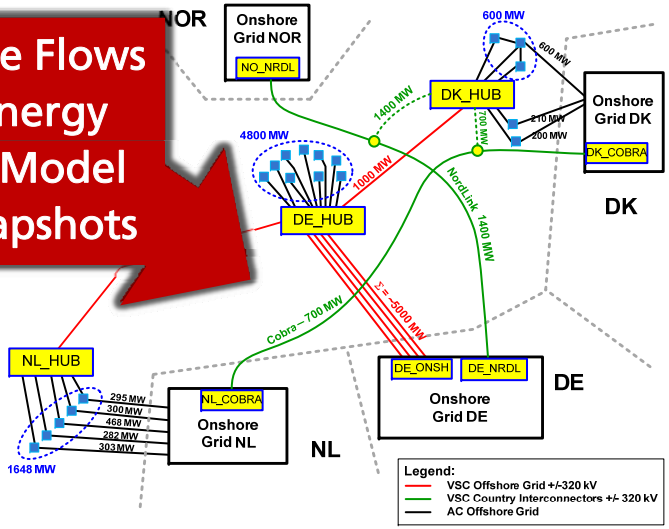
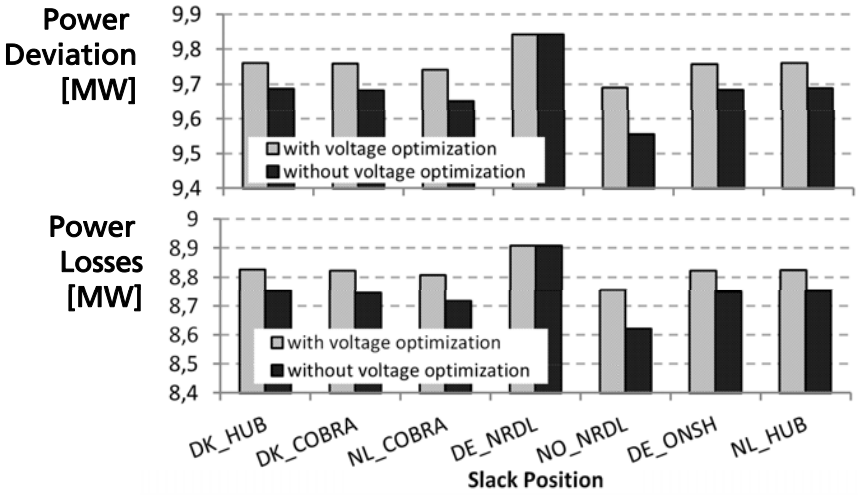
Future Research-OPS Operation

Optimization Results

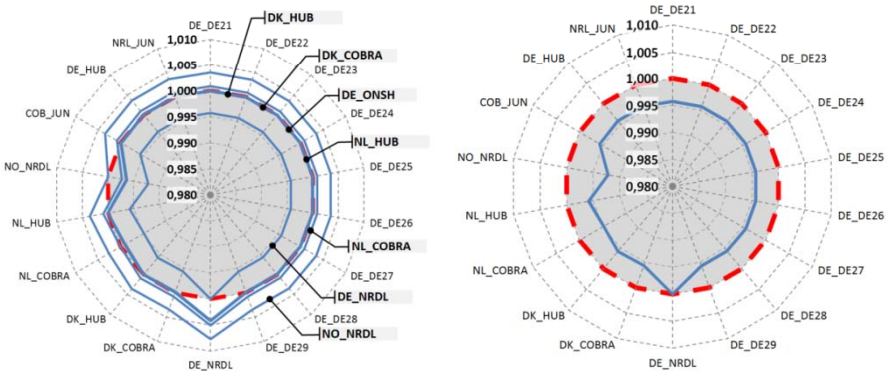
Reference Flows from Energy Market Model 1600 Snapshots



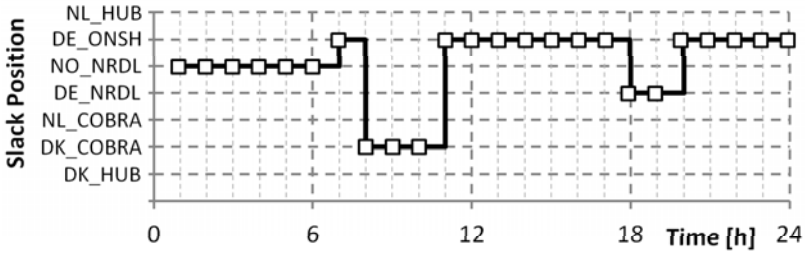
Results at One Time Point



Voltage Profile without and with Optimization



Optimal Slack Position



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Conclusions

- Coupled Simulation Environment (CSE) for stationary analysis was developed within RAVE-Grid Integration Project
- CSE allows to analyse wind farm cluster management system operation especially regarding active and reactive power production for AC grid support
- Using the PQ-capability curve its possible to determine the reactive power compensation at the PCC and to guarantee the steady-state voltage to fulfill the grid code requirement
- However, future multi-terminal offshore power system requires further research activities regarding e.g. control and management strategies as proposed in this presentation
- Other challenges concerning especially protection issues and regulatory framework need to be investigated

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Thank you for your attention

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