Power System Integration of Offshore Wind Farms:

Challenges Towards Horizon 2020

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Agenda

- What is EERA JP Wind?
- Power system integration challenges towards 2020
- Example projects:
  - Fraunhofer IWES
  - Other projects (EERA)
- What is EERA SP4 doing towards Horizon 2020
  - The Horizon 2020 call for projects
  - EERA SP4 project proposals

EERA Objectives

- Preparing pre-competitive research laying a scientific foundation for cost effective wind power production and integration.

- **O1: Wind power plant capabilities:** Enable wind power plants to provide services and to offer characteristics similar to conventional power plants.

- **O2: Grid planning and operation:** Sustainable enlargement of the transmission capacity and enhancement of the utilisation of the grids to allow large-scale deployment of wind energy technology

- **O3: Wind energy and power management:** Tools and business models (markets) to allow economic wind power utilisation

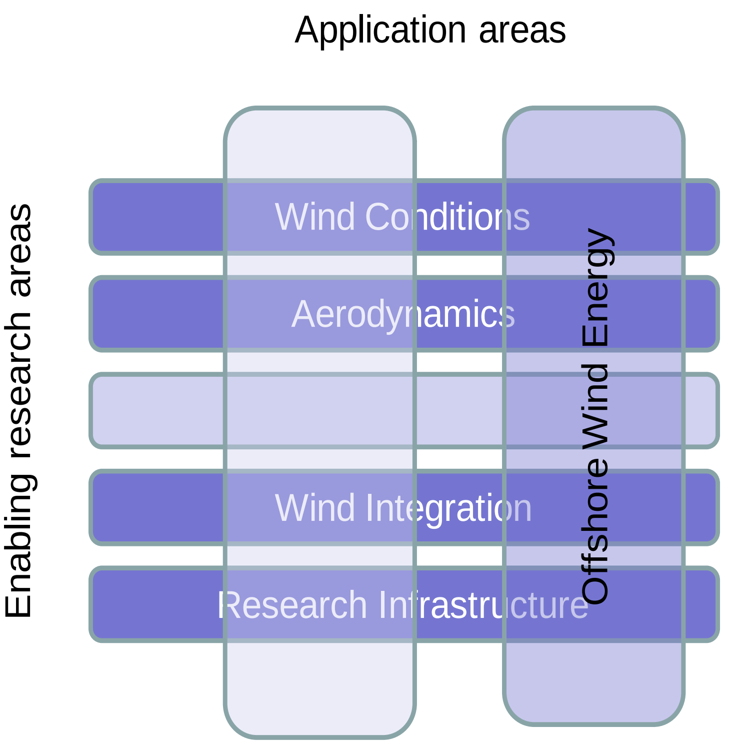
Ambition of the Joint Programme

- The EERA vision for the joint programme on wind energy is:
  - to provide the strategic leadership for the scientific–technical medium to long term research to support the EII and the Technology Roadmap's activities on wind energy and
  - on basis of this, to initiate, coordinate and perform the necessary scientific research.

- The vision calls for all the EERA participants and associates:
  - to align their research in wind energy topics which influence the use and deployment of wind energy and
  - Perform coordinated and structured research in medium to long-term programmes with shared research facilities.

Structure of the Joint Program

- The joint program comprises the following 5 sub-programs:
  - **Wind Conditions:** coordinated by DTU in Denmark.
  - **Aerodynamics:** coordinated by ECN in the Netherlands.
  - **Offshore Wind Energy:** Coordinated by SINTEF in Norway.
  - **Grid Integration:** coordinated by FhG IWES in Germany.
  - **Research Facilities:** coordinated by CENER in Spain.



POWER SYSTEM: INTEGRATION CHALLENGES TOWARDS 2020

Transformation of the Supply System

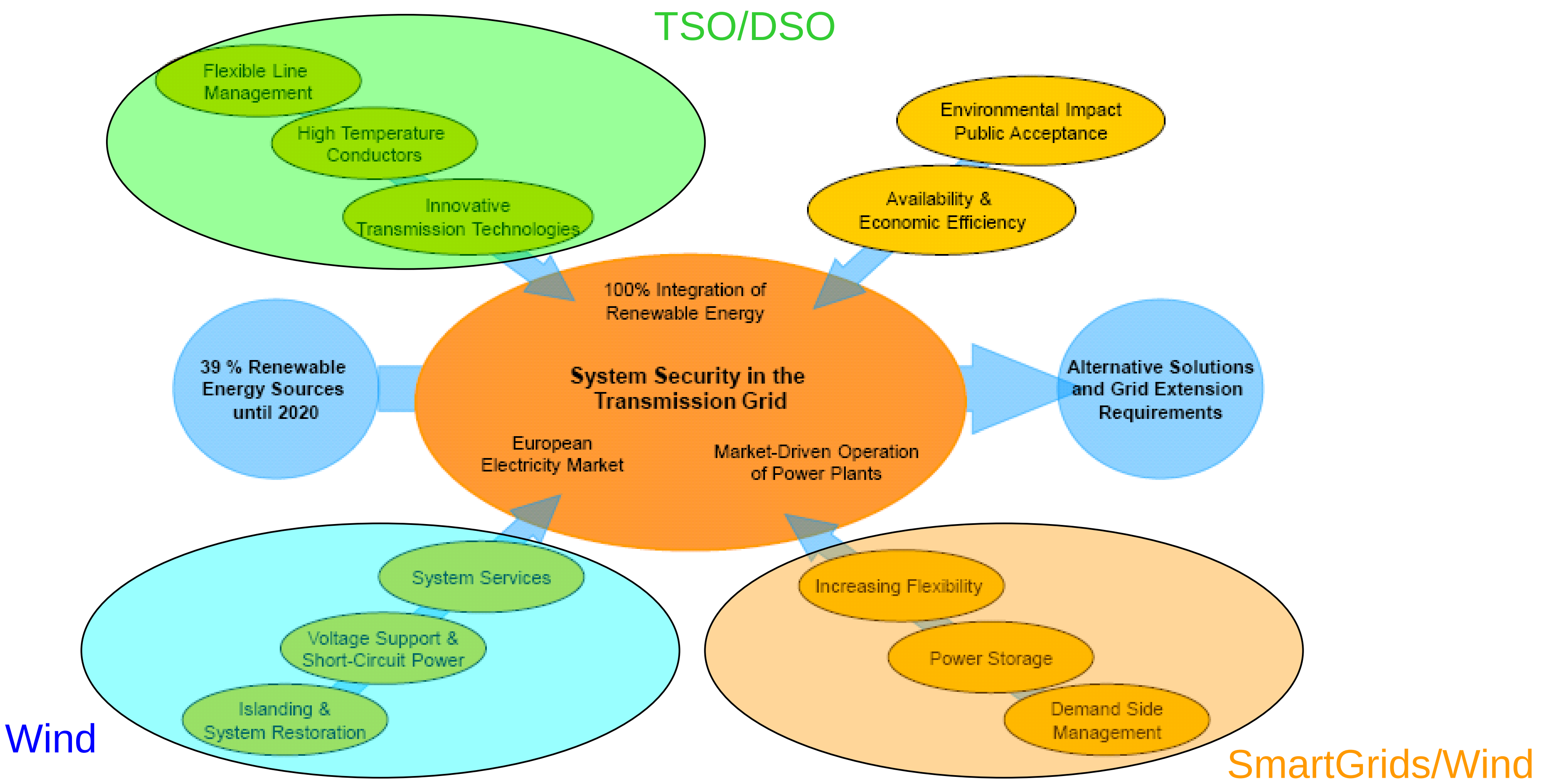
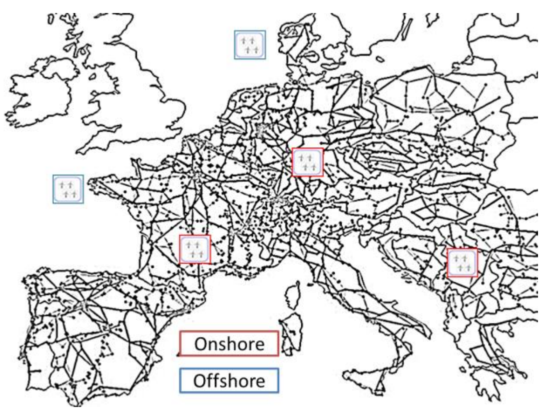


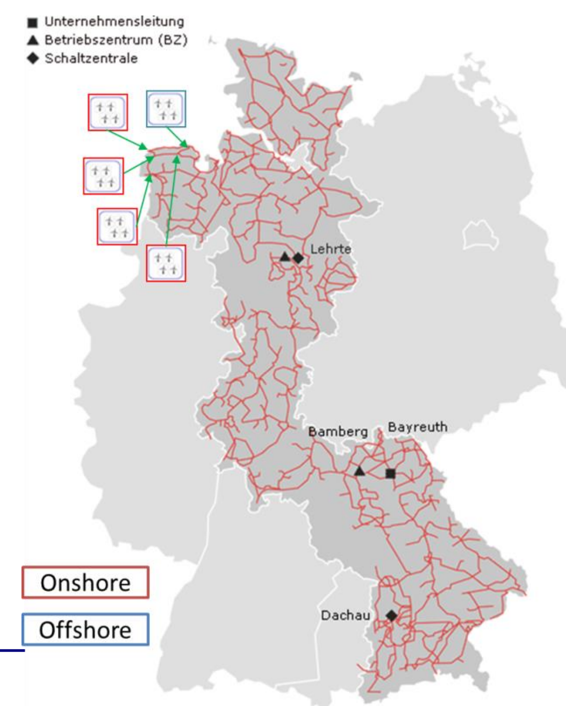
Figure 1: dena Grid Study II – schematic of subject area

O1: Active Contribution to System with Cluster Control

EERA
European Energy Research Alliance

Pan-European Synchronous Area	Control Area	Local/ Regional Area
1. Provision of Frequency Support: - Primary Reserve	1. Provision of Frequency Support: - Secondary Reserve	1. Provision of Voltage Support: - Voltage control - Reactive power
2. Congestion mgmt	2. Congestion mgmt	2. Congestion mgmt

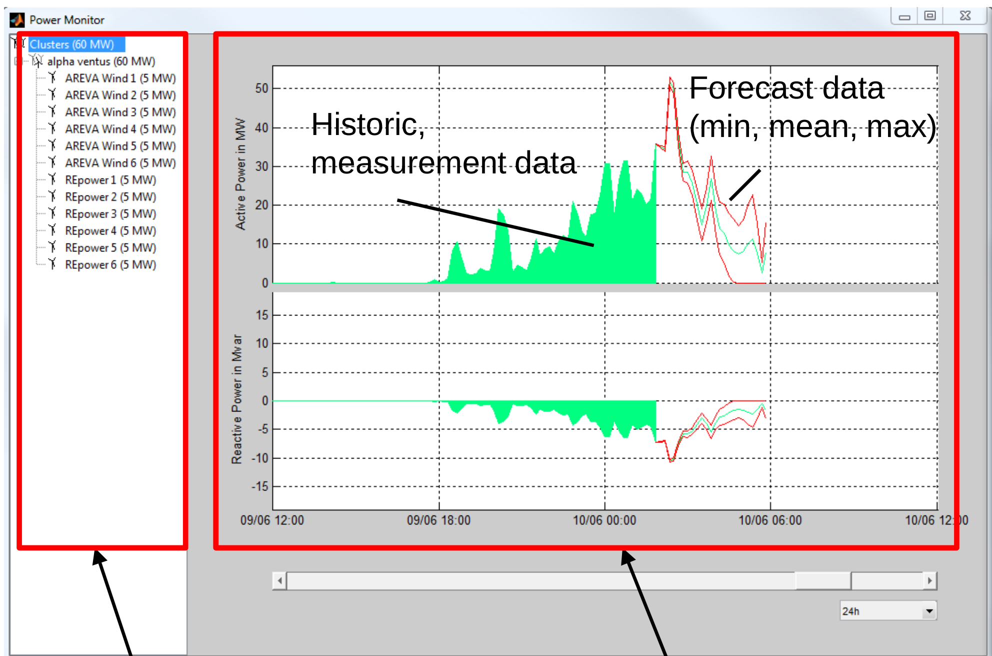


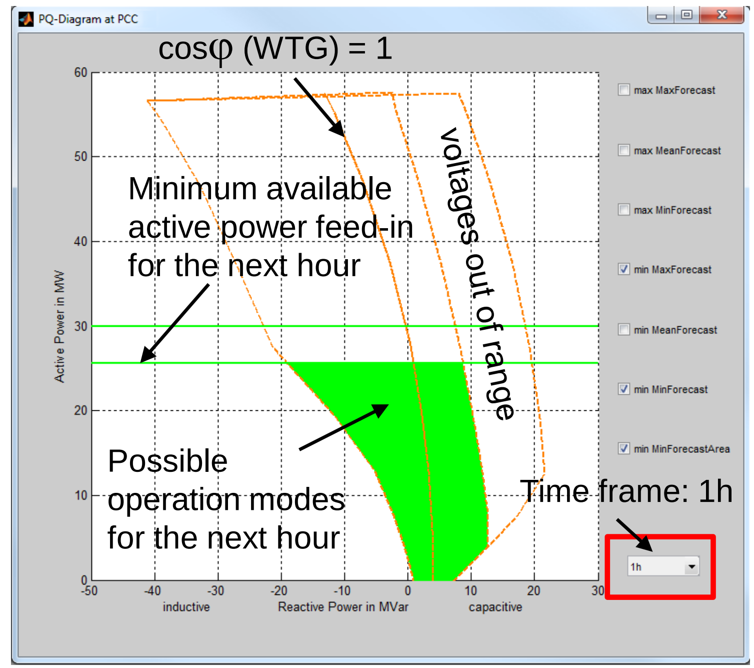


O1: Power Plant Capabilities

Power Monitor

PQ-Curve at UW Hagermarsch



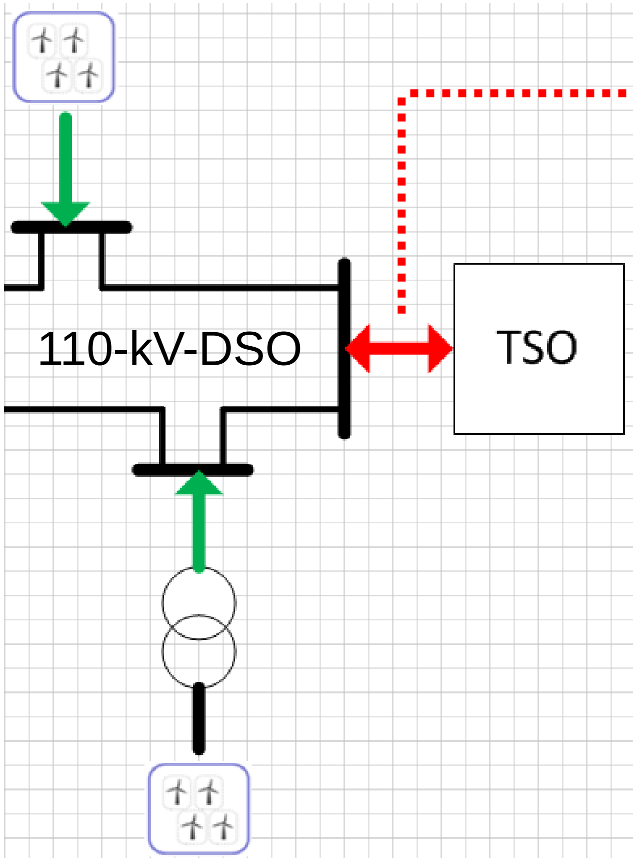


Get information of a single turbine or the whole cluster

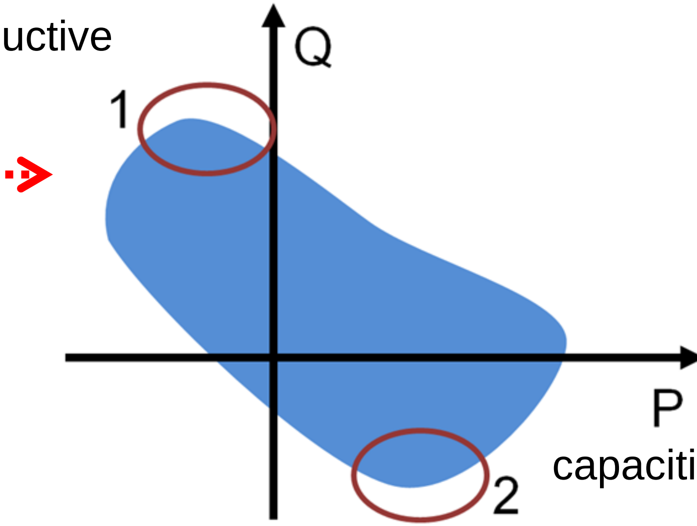
Active and reactive power data (gross values – without grid losses)

Active and reactive power data relating PCC node (net values – including grid losses)

O1: Reactive Power Management



DSO: Distribution system operator
TSO: Transmission system operator



Solution with the (new) WCMS

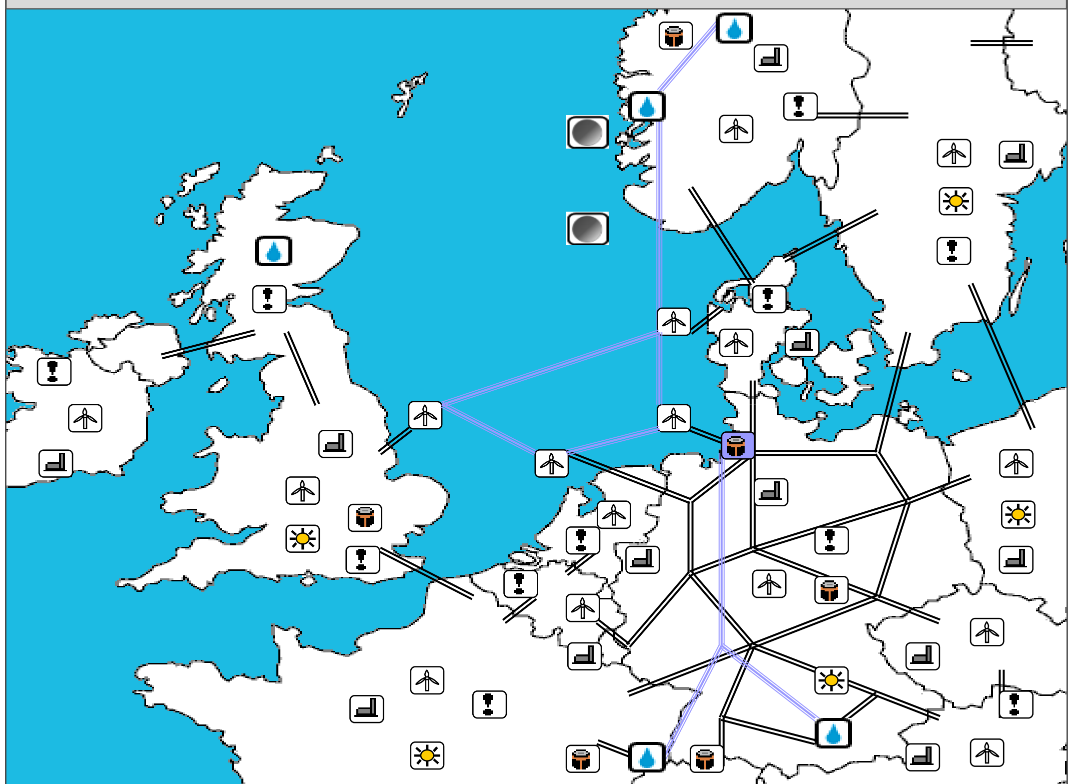
1. Dynamically adjusting the wind farm set point taking all **voltages and operational limits** into account
2. Try to realize an optimal **reactive power flow** (e.g. zero) between the grid levels

O2: Grid planning and operation

O2: Grid planning and operation

European Commission identified
offshore grid in the North Sea as a priority corridor[1]),
connecting northern and central Europe

North Sea Offshore and Storage Network (NSON)

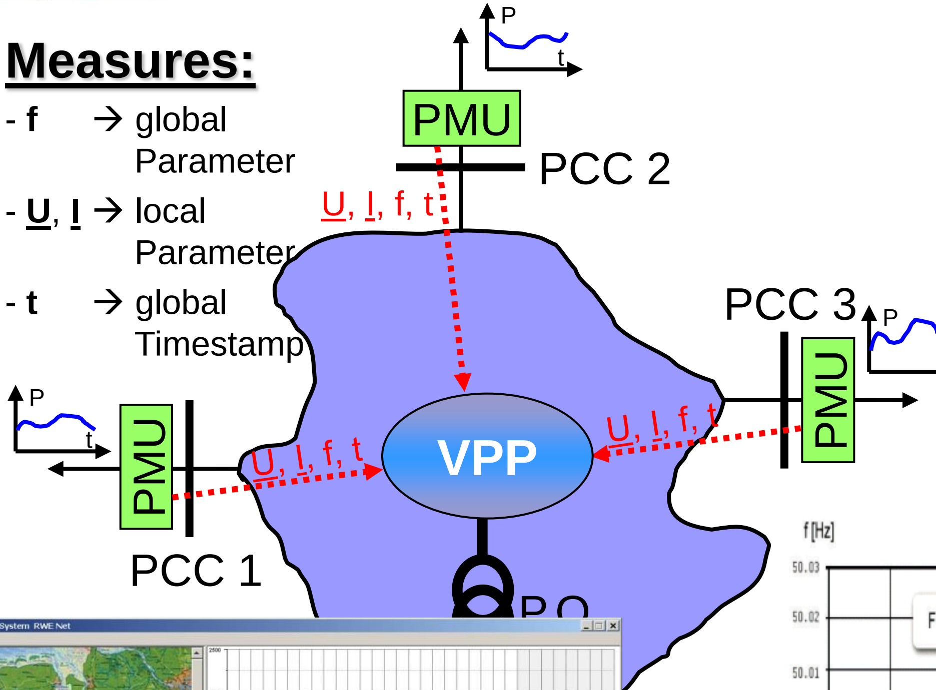


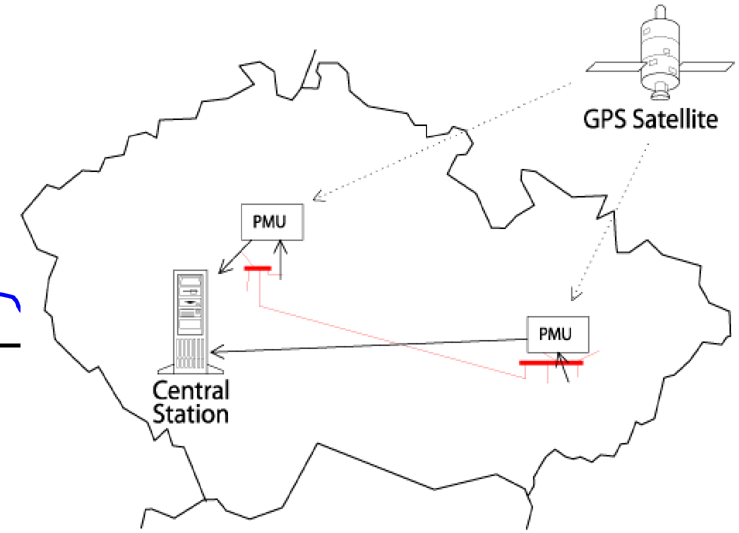
[1]) European Union (2011): Energy infrastructure priorities for 2020 and beyond. A Blueprint for an integrated European energy network.

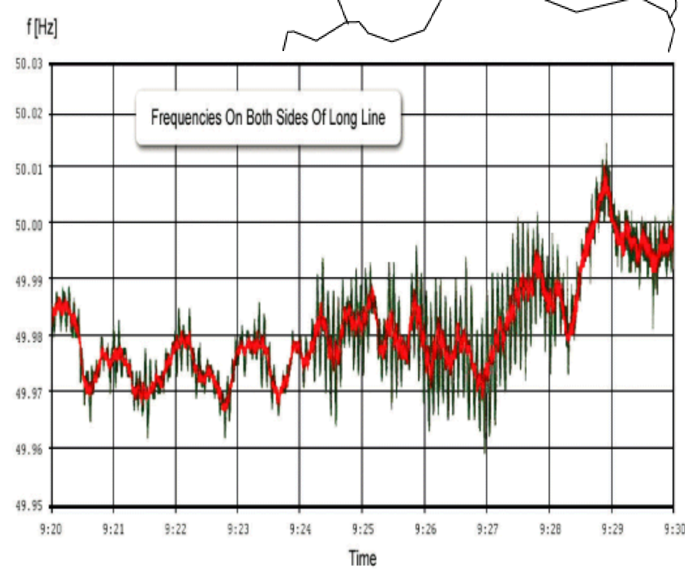
O2: Active Support of Grid Operation

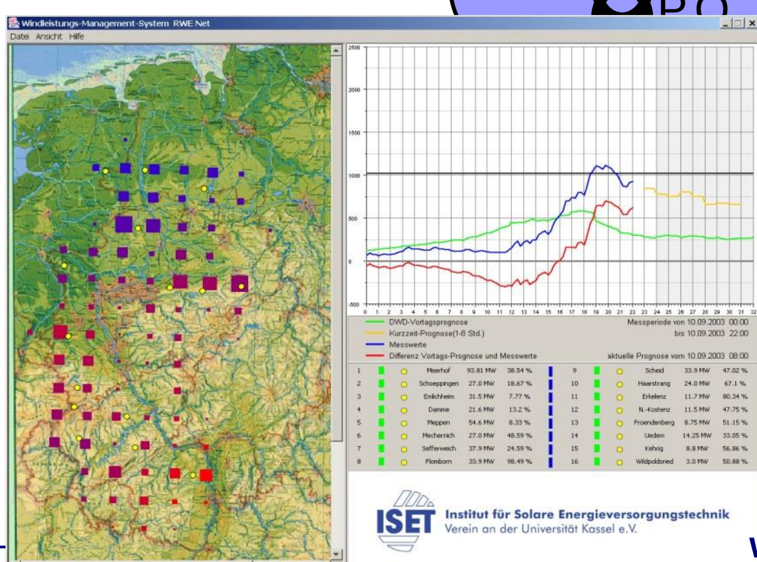
Measures:

- **f** → global Parameter
- **U**, **I** → local Parameter
- **t** → global Timestamp

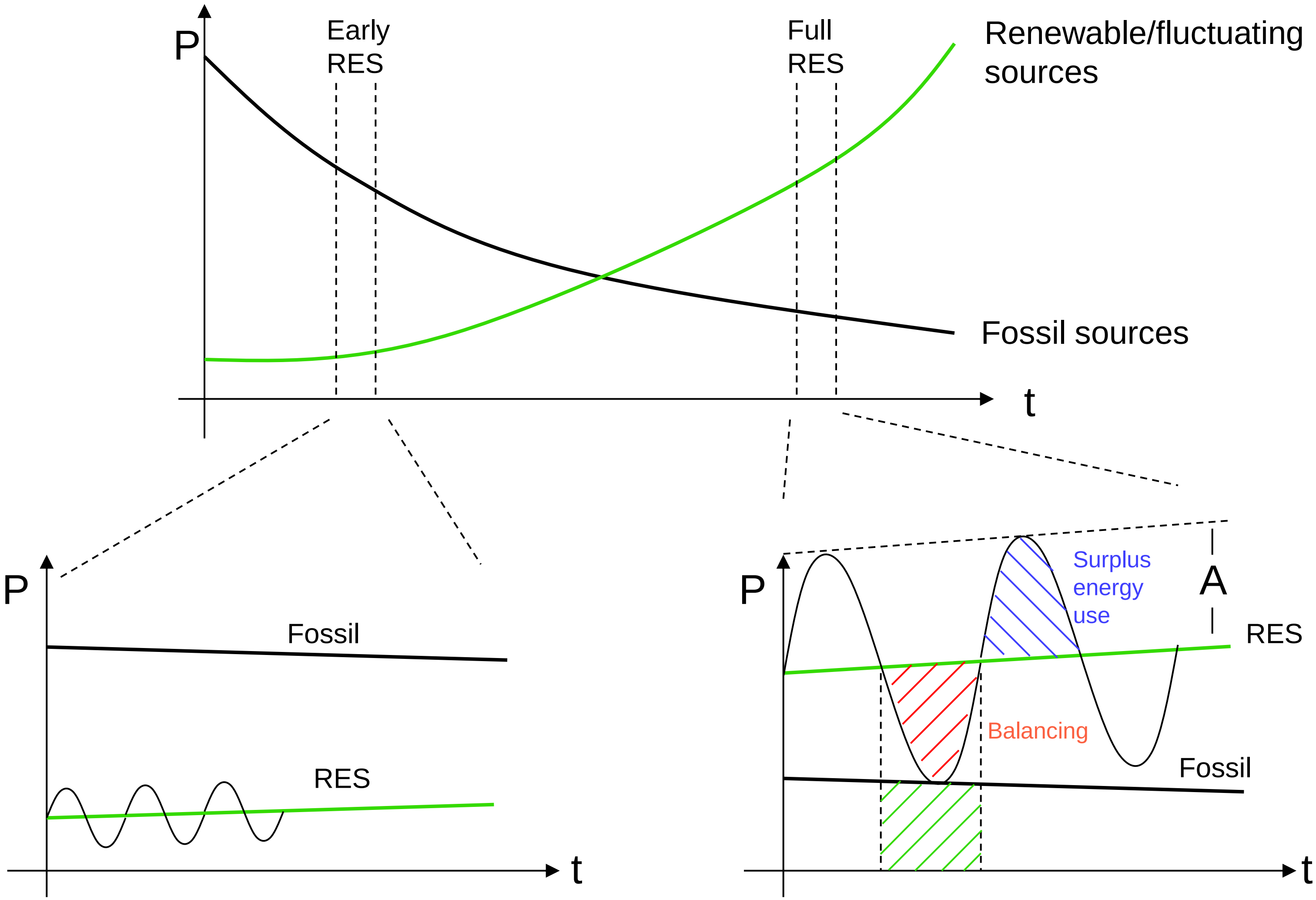






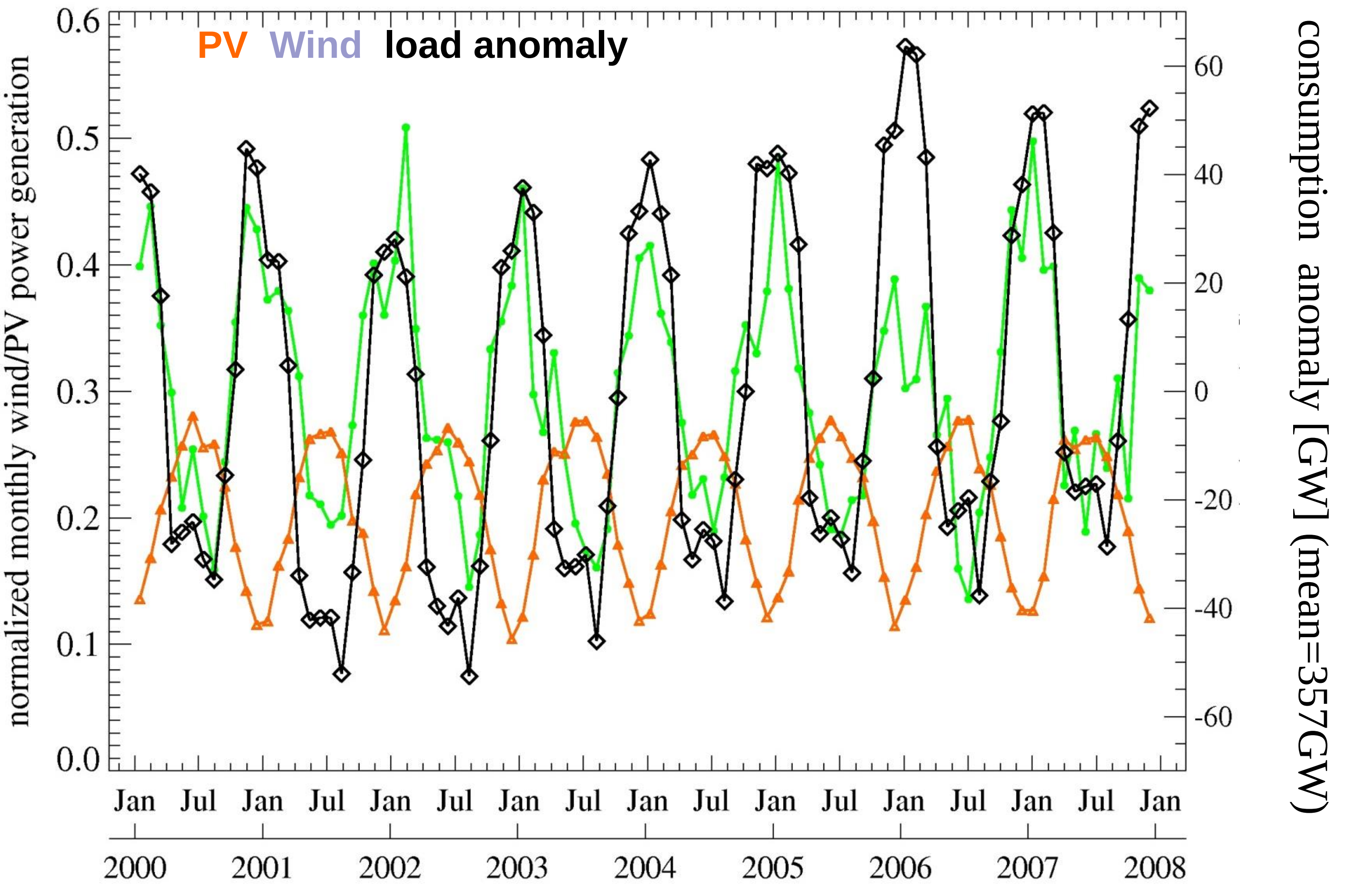


O3: Wind energy and power management



At the threshold for the age of transmission & storage

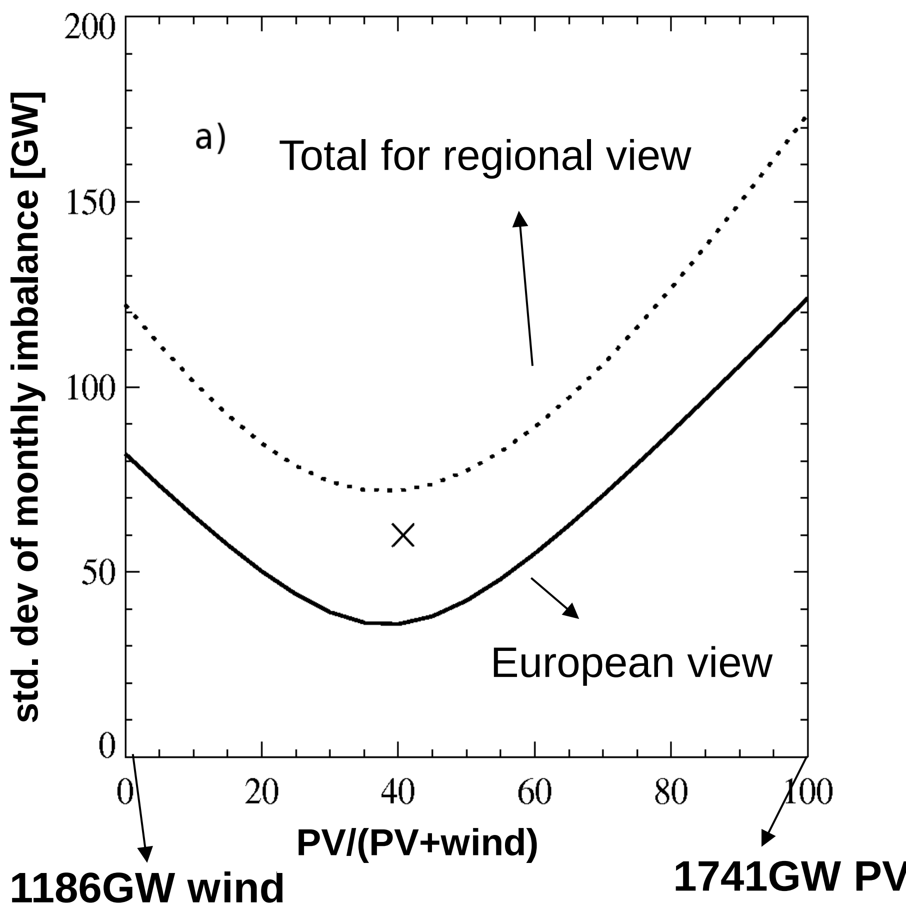
O3: Wind energy and power management



Seasonal load anomaly compared to wind and solar

O3: Wind energy and power management

➢Fluctuation of monthly residual load (RES-consumption) in a 100% renewables scenario



Max. reqiuired average transmission capacity: 15 GW (in D) – Max. >>>

Required storage capacity: 0,5% - 8% of average European electricity demand per year 16-260 TWh/a

Challenges

- **C:** Provision/support of system services (frequency, voltage, islanding, black start)
  R: Superior control mechanisms, VPP

- **C:** Sustainable grid extension/expansion and grid planning
  R: Models and planning tools including wind (&RES) generation

- **C:** Reliable grid (system) operation considering millions of individual generators
  R: close co-operation of TSO/DSO, generation, and trading, new operating mechanisms supported by advanced monitoring and dynamic security assessment

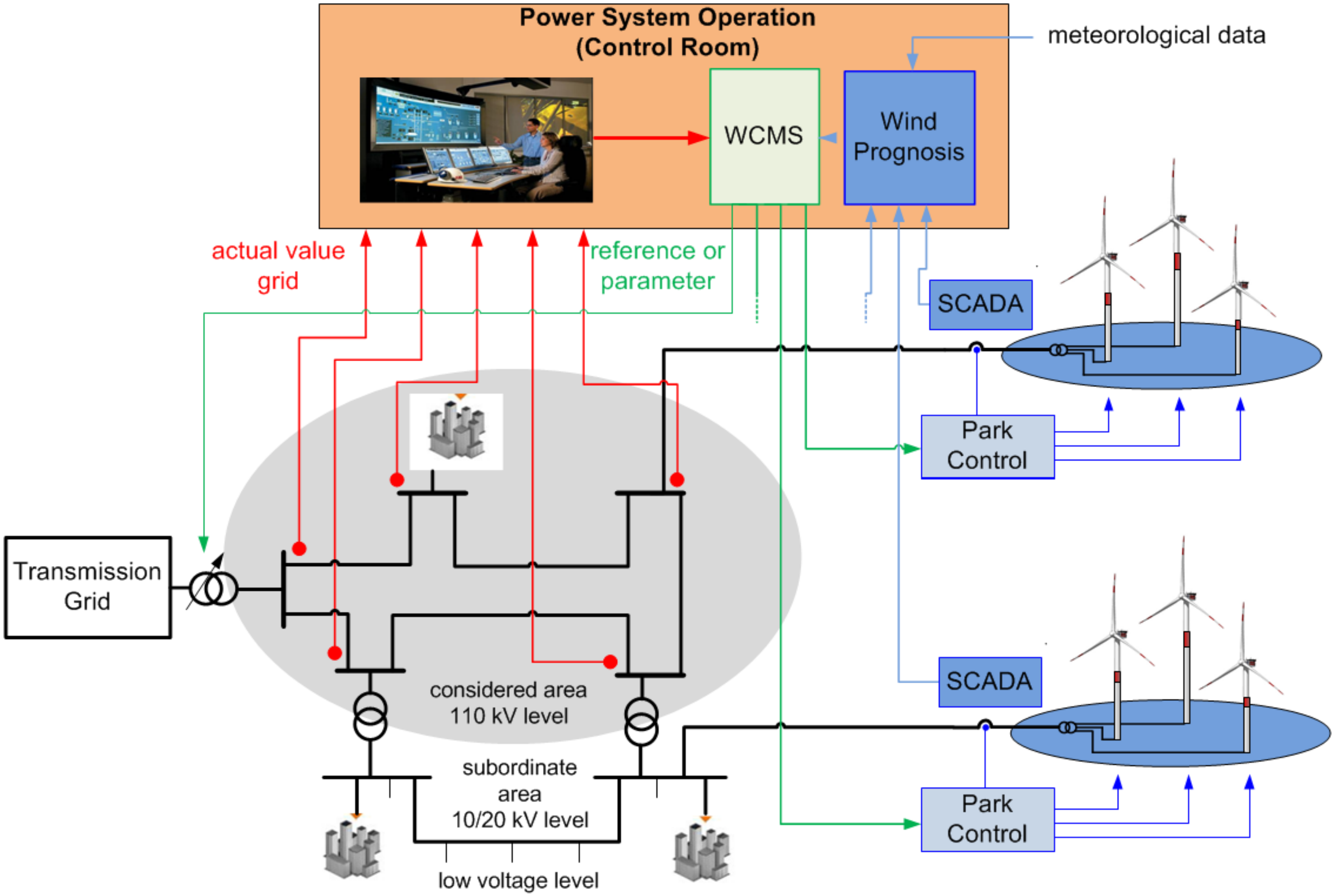
- **C:** balance large fluctuations in rage of x0 TWh
  R: forecast tools (minutes to months) and simulation of RES-development scenarios considering all RES and demand sectors

EXAMPLE PROJECTS

Example projects

- IMOWEN
  - Integration of large amount of wind energy using intelligent local operation and control
- EERA-DTOC
  - Design Tool for Offshore Wind Farm Clusters
  - Ancillary Service Analysis will be presented at DeepWind
- NSON
  - North Sea Offshore and Storage Network

IMOWEN


Power System Operation
(Control Room)
meteorological data
WCMS
Wind
Prognosis
actual value
grid
reference or
parameter
SCADA
Park
Control
Transmission
Grid
considered area
110 kV level
subordinate
area
10/20 kV level
low voltage level
SCADA
Park
Control

IMOWEN

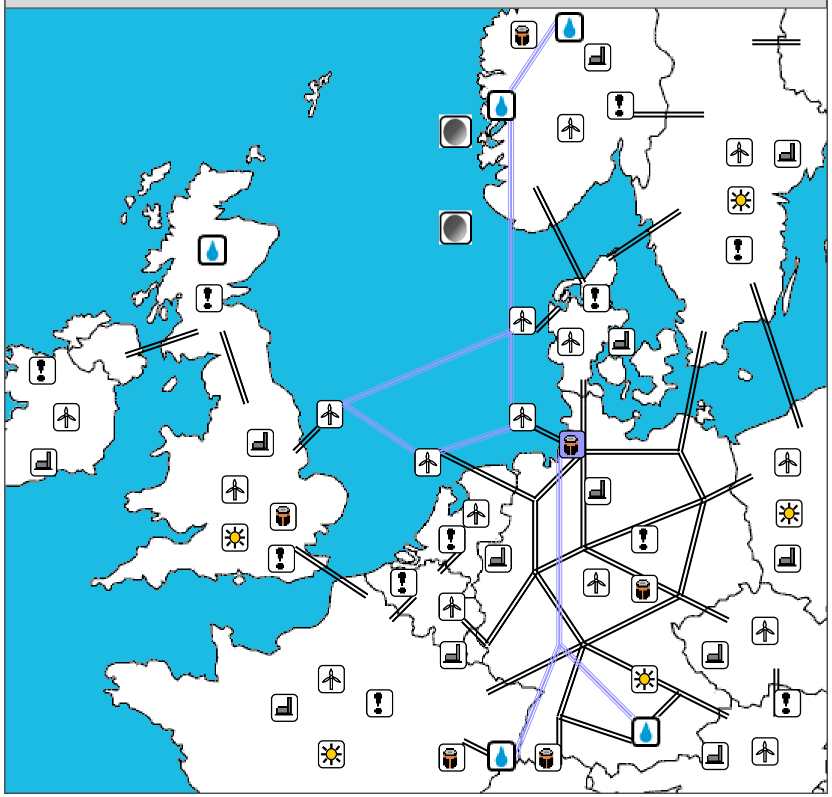
- Typical 110-kV DSO district
- High penetration of wind
- Double-busbar topology, highly meshed, 7 TSO feeders, underlayed MV grid
- Cluster based on controllable wind parks with decent electrical distance

	Generation	Load	Reactive power handover in Mvar	Theoretical Controlling range (inductive and capacitive) in Mvar	Relative Possibilities
Szenario A	100 %	100 %	640 (ind.)	170	0.27
Szenario B	100 %	40 %	550 (ind.)	170	0.31
Szenario C	60 %	100 %	340 (ind.)	100	0.29
Szenario D	60 %	40 %	220 (ind.)	100	0.45
Szenario E	30 %	100 %	120 (ind.)	50	0.42
Szenario F	30 %	40 %	10 (cap.)	50	5.0

NSON

European Commission identified
offshore grid in the North Sea as a priority corridor[1]),
connecting northern and central Europe

North Sea Offshore and Storage Network (NSON)



NSON initiative is determined
to tackle challenges of an offshore grid in the North Sea
as a combined effort of
Univ. of Strathclyde, SINTEF and Fraunhofer IWES
in a pre-project and feasibility phase

Objectives of the NSON initiative's pre-project and feasibility phase:

- Analyzing and evaluating different market and grid design concepts of a NSON and their socio-economic cost-benefit allocation
- Evaluating potential of offshore storage systems in a NSON
- Examining effects of a NSON on European supply system
- Assessing repercussions on onshore grid infrastructure
- Developing reusable mathematic optimization methods for transmission grid planning and operation

[1]) European Union (2011): Energy infrastructure priorities for 2020 and beyond. A Blueprint for an integrated European energy network.

NSON

Technical topics for offshore power system planning:

- Portability of conventional planning rules
- Planning guidelines for DC systems
- Fulfillment of reliability and redundancy requirements
- Feedback on investment costs
- Modular expansion stages
- Optimize grid under consideration of evolving technologies and market releases of components

WHAT IS EERA SP4 DOING TOWARDS HORIZON 2020

The Horizon 2020 call for projects

- EU major challenges is to make its energy system:
  - Clean,secure and efficient, while…
  - ensuring EU industrial leadership in low-carbon energy technologies.

- Call H2020-LCE-2014/2015 aims at:
  - developing and accelerating the time to market of affordable, cost-effective and resource-efficient technology solutions
  - to decarbonise the energy system in a sustainable way
  - to secure energy supply
  - to complete the energy internal market in line with the objectives of the SET-Plan

EERA SP4 project proposals

- EERA SP4 will address various projects:
  - 4 to LCE2 → 2014
  - 1 to LCE5 → 2015
  - 1 to LCE5 → 2015

- For LCE2 (this year) is preparing:
  - 2 regarding control strategies: 1 at WF level and 1 at WT level
  - 2 regarding innovative substructures
  - 2 regarding material development
  - Proposal will be presented in April 2014

EERA SP4 project proposals

- For LCE5 and 6 (next year) are two pre-proposals:
  - North Sea Offshore and Storage Network (NSON) “phase one” proposal
  - Minimization of curative re-dispatch improving preventive methods based Wind Cluster Management Infrastructure

Nationally funded NSON projects part of a pre-project/ feasibility phase – H2020 NSON project on European level next step towards realization

Initial pre-project and feasibility phase

Horizon 2020 „phase one“

„phase two“

Regulators and authorities

Finished and ongoing projects (i. e. FP7 projects)

NSON project(s)
on national level
with international
cooperation and exchange

Manufacturers, TSOs, renewable operators, …

Large-scale RD&D NSON project
large-scale RD&D on European level

„phase one“

deliver compulsory plan

Large-scale RD&D NSON project
leading to full-scale commercial operation

„phase two“

I	**Who are potential key partners?**
II	**Which objectives have to be defined in order to achieve the expected impact?**

North Sea Offshore and Storage Network (NSON) proposal

- **Addressing:** LCE5 - Innovation and technologies for the deployment of meshed off-shore grids
- **Deadline:** 03/03/2015

Expected impact:

- **Accelerating** the **deployment** of **meshed HVDC off-shore grids**, with particular emphasis on Northern Seas partner countries, **before 2020**
- Ensuring that the **technology** will be **ready for deployment** in other regions in Europe for all transnational corridors defined in the trans-European energy infrastructure regulation, or be **compatible** (plug-and-play) **with** other **upcoming technologies** (e.g. ocean energy, solar energy, geothermal energy, etc. as soon as these technologies are ready for similar capacities)
- Ensuring **plug-and-play compatibility of all relevant equipment** of the key suppliers
- **Preparing** for **corresponding priority infrastructure** projects identified under the trans-European energy infrastructure regulation
- **Facilitating** the efficient **connection** of **off-shore wind resources to on-shore loads** and with other available generation **resources for balancing**, covering the main Northern Seas partner countries

Minimization of curative re-dispatch improving preventive methods

- **Addressing:** LCE6 - Transmission grid and wholesale market
- **Deadline:** 03/03/2015

Expected impact:

- To develop:
  - a) methodology to reduce the utilization of the curative methods;
  - b) manager system allows for mitigative actions of wind power plants and controllable power system components prior to an incident.
- Applying a continuous coordination process ? intelligent mgmt system.
- Usage of high resolution probabilistic forecast data for intermittent renewable energy resources.
- Usage of additional Information provided by the WCMS to the TSO

THANK YOU FOR YOUR ATTENTION.