SIEMENS on behalf of giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

ASIA CLEAN ENERGY FORUM, Manila, June 2016

“Renewables – challenges for system stability”

Dr. Edwin Lerch, Siemens AG, EM DG PTI PSC DYS

Content

- Actual situation
- Generator and grid stability
- The role of renewables
- Actions to be taken
- Outlook

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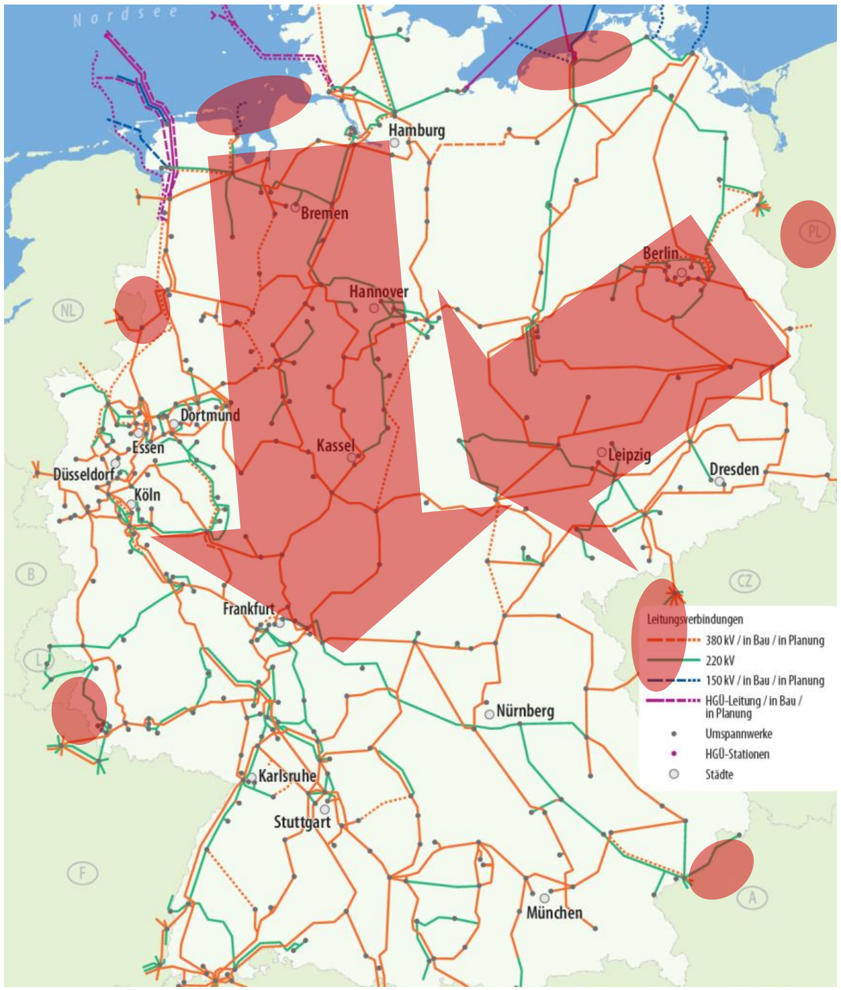
German electric power supply system (614 TWh)

Key data and selected issues – Transmission bottlenecks



Key data of German power system

- Peak demand 2014 — 80,000 MW
- Installed capacity 2014 — 194,000 MW
  - Gas 15 % — conventional 55 %
  - Hard Coal 11 %
  - Lignite 11 %
  - Wind 18 % (0.3 %) — renewable 45 %
  - PV 20 %

- Supply non-availability 20.4 min/a
- 2014 renewables 25,3 % of energy generation

Transmission bottlenecks

- North-South
- East-West
- International interconnections

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Motivation, Targets and Challenges to rebuild the German Power System (“Energiewende” renewable energy act)

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Motivation:	**Replacement of fossil sources by renewable source**
	Reduction of CO_2
	Retirement of NPP‘s (Fukushima 2011)

Targets:	**Co_2 reduction 80 % until 2050**
	Retirement of NPP‘s until 2022
	Stake of renewables 45 % (2020) and 70 % (2040)

Challenges:	**Maximum utilization of renewables (potential, storage, losses)**
	Balancing of fluctuating sources by conventional power plants

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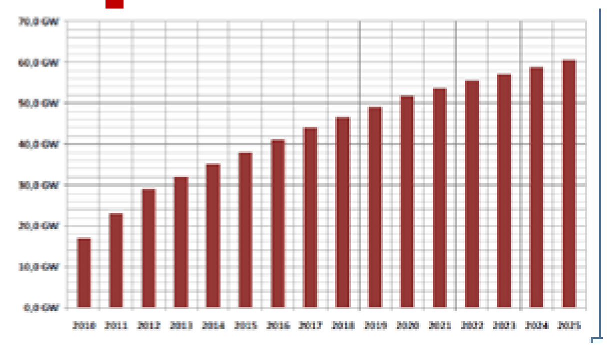
Development of Renewables in Germany

peak load Germany: ca. 80 GW (constant)
Expected into installed power until 2025

Wind onshore Wind offshore

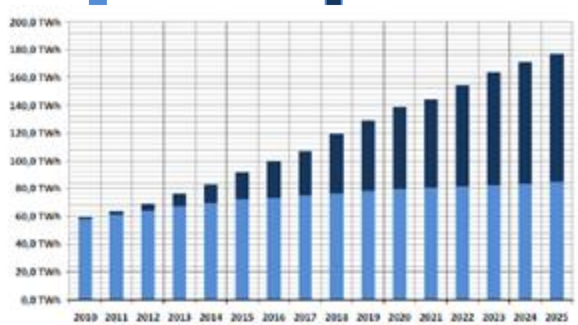
installed 2020:
Wind PV
51,0 GW + 51,7 GW
∑ 102,7 GW

Installed capacity PV



energy demand Germany 2011: app. 600 TWh (constant)

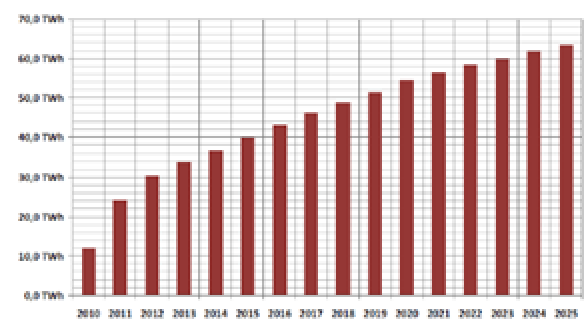
Wind onshore Wind offshore



harvest 2020:
Wind PV
138,8 TWh + 54,2 TWh
∑ 193 TWh

energy per year:
Wind 2000 kWh/kW
PV 1000kWh/kW

PV



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Predictability and Dynamics of Wind Power
Example: Vattenfall Europe

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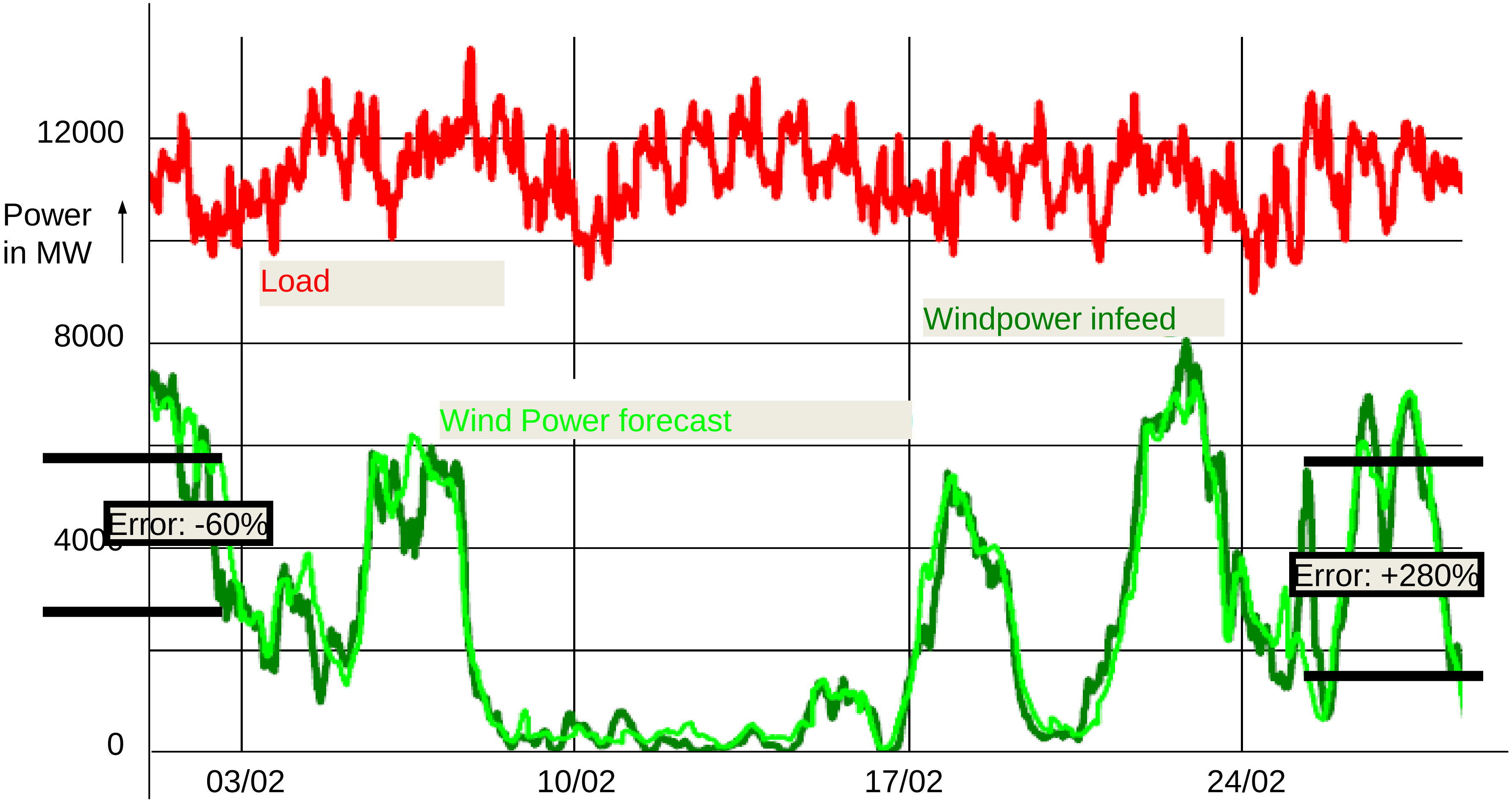

Source: IfR, TU-Braunschweig,
Vattenfall Europe Transmission, Feb. 2008

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Power Fluctuations through Renewable in Germany 2011/2012

Time period 01.10.2011 to 31.03.2012

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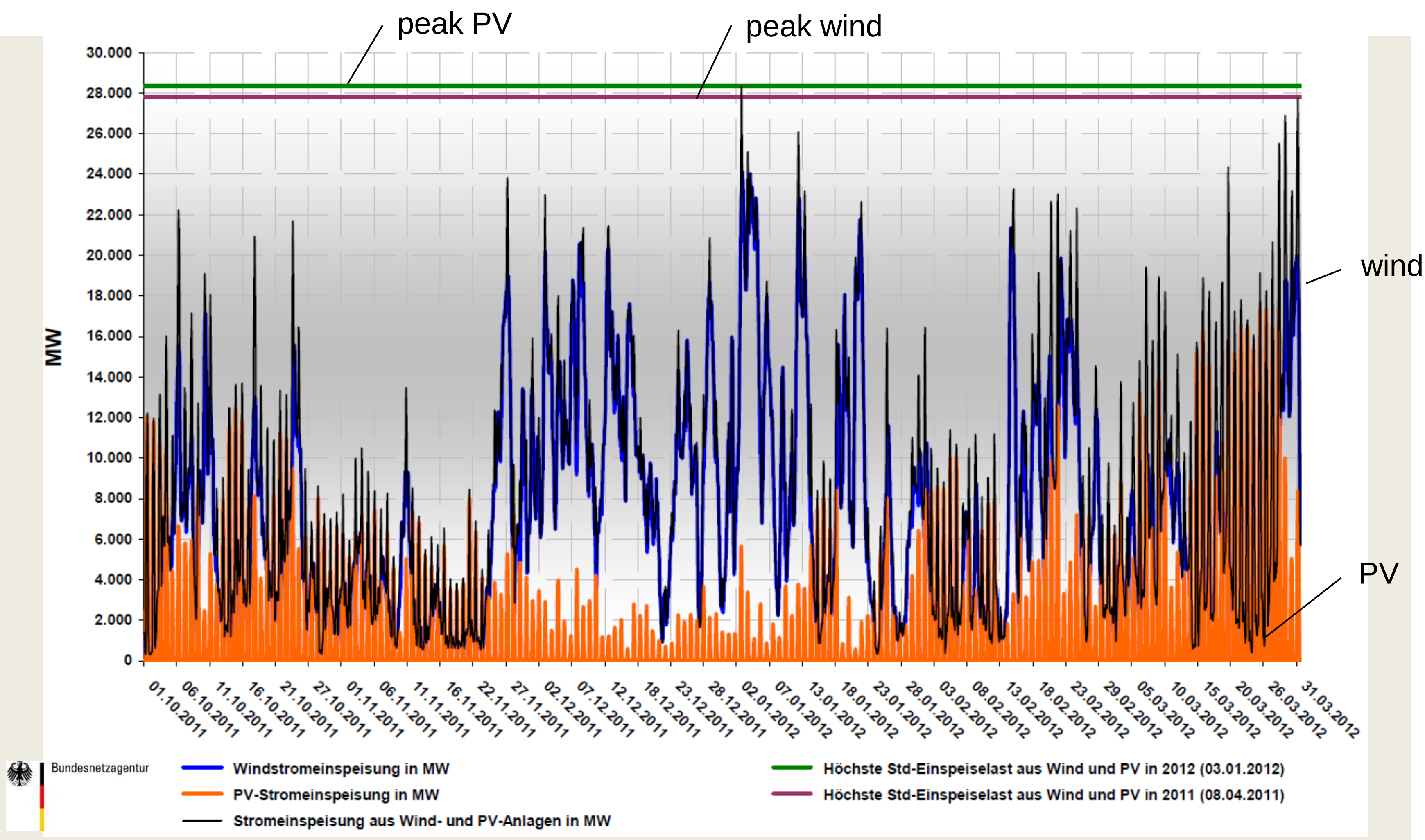

Source: EEG/KWK Transparenzplattform der ÜNB

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Grid stability

- Stability of generators after disturbances
- Frequency behaviour after generation outages
- Balancing of frequency
- Primary reserve stability
- Voltage stability
- Bottlenecks in transportation

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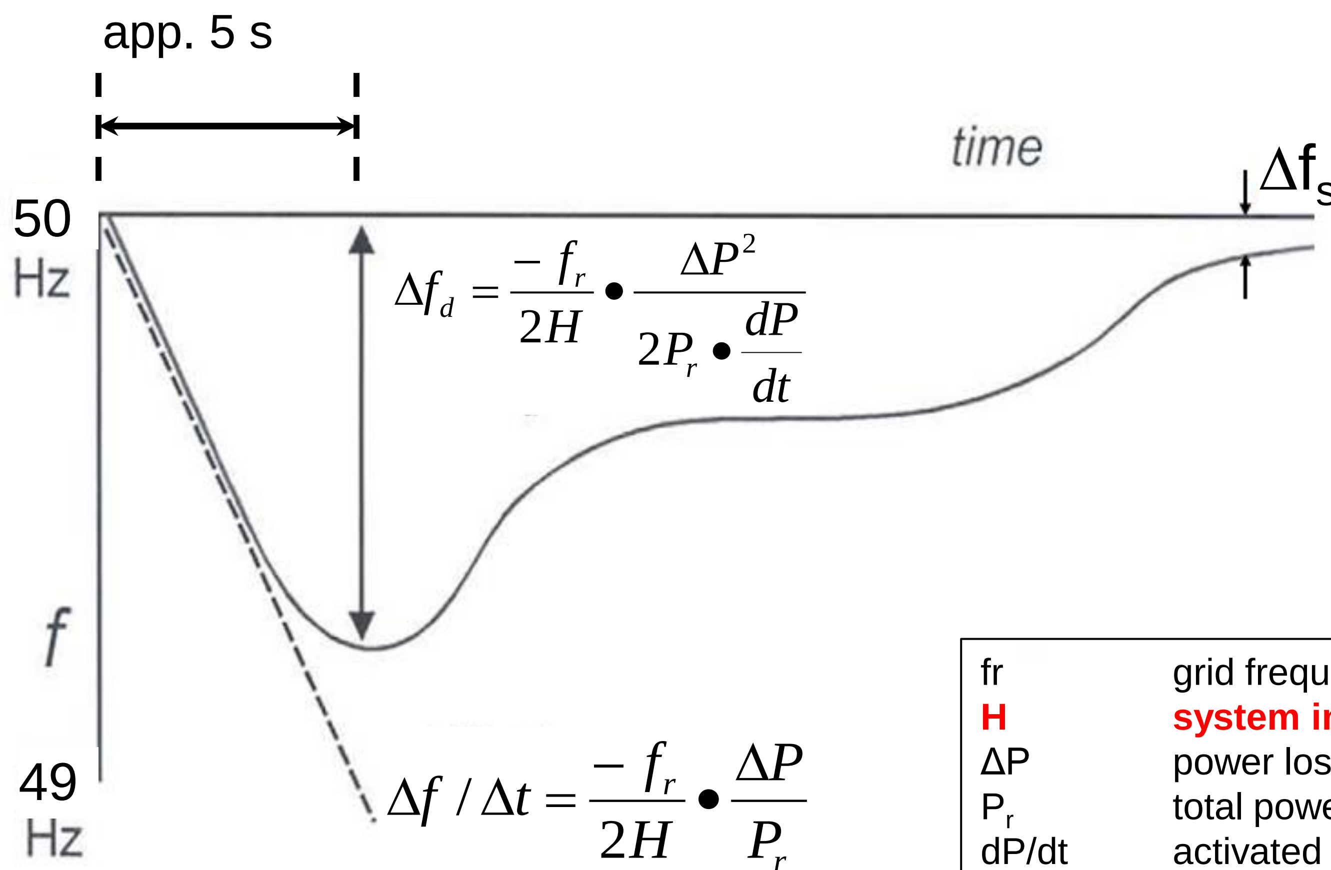
System behavior after outage of generation



fr	grid frequency (Hz)
H	**system inertia (MWs/MW)**
ΔP	power lost (MW)
P_r	total power (MW)
dP/dt	activated reserve power (MW/S)

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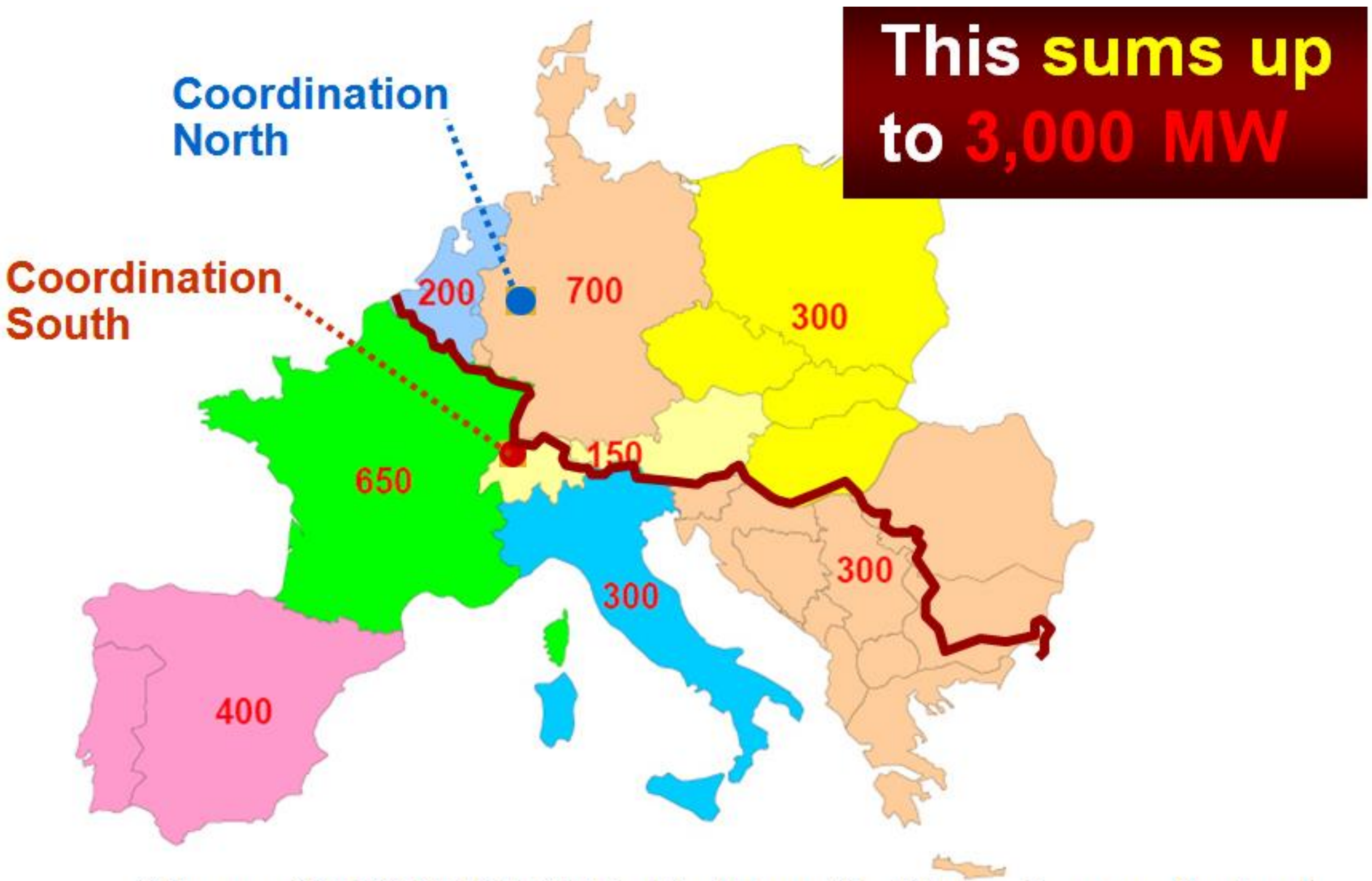
Necessary Primary Reserve to stabilze frequency



* Source: 2005-08-29 UCTE-GDR – Final Report 3 – Primary Reserve – Version 1

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Stability problems through renewables (1)

1. Balancing stability (global task)
   - large frequency gradients and frequency fluctuations
   - forecast errors
   - balancing power from conventional plants (renewable energy act)
     - primary reserve and secondary reserve
     - high flexibility for large frequency gradients
     - low efficiency at part load
     - high stress

2. Voltage stability (local task)
   - large power transportation from sources to loads
   - unbalanced voltage profile
   - lack of reactive power
   - danger of voltage collapse

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Stability problems through renewables (2)

3. Influence of renewables (today)

- renewables do not support stability
- no share of synchronizing torque → ROCOF (rate of change of frequency) is increasing from below 0,5 Hz/sec to above1 Hz/sec
- no primary reserve
- underfrequency / overfrequency problems
- reduction of frequency stability (no contribution to system inertia)
- wearout of conventional power plants (lifetime reduction)

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Voltage Stability

Former NPP Biblis A becomes synchronous condenser

Reactive power to support voltage profile and voltage stability

- Biblis A nuclear power plant shut down after Fukushima incident
- Generator 1,500 MVA

- Modification into synchronous condenser
  - Largest synchronous motor worldwide
  - Reactive power support from -400 to +900 MVAr
  - Commissioned in February 2012

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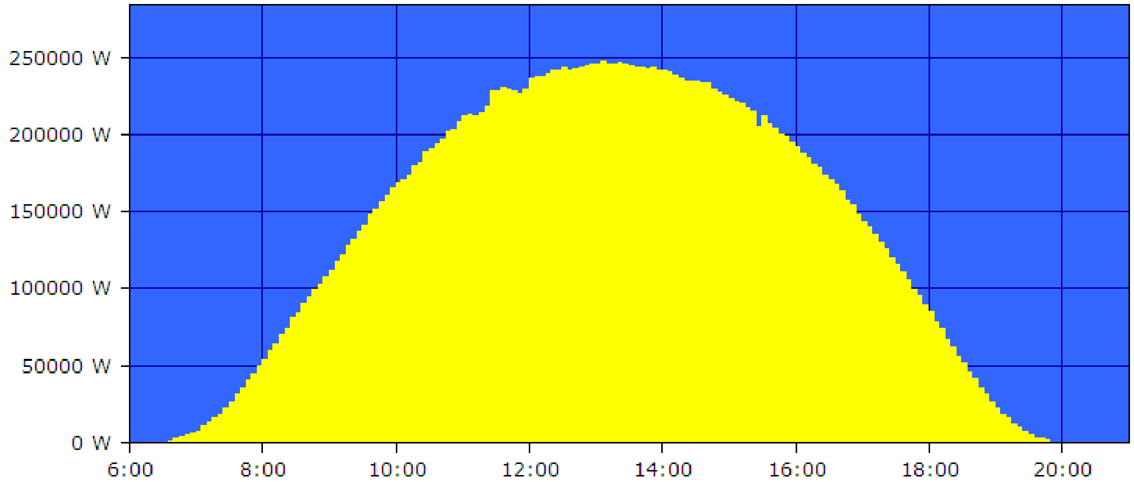
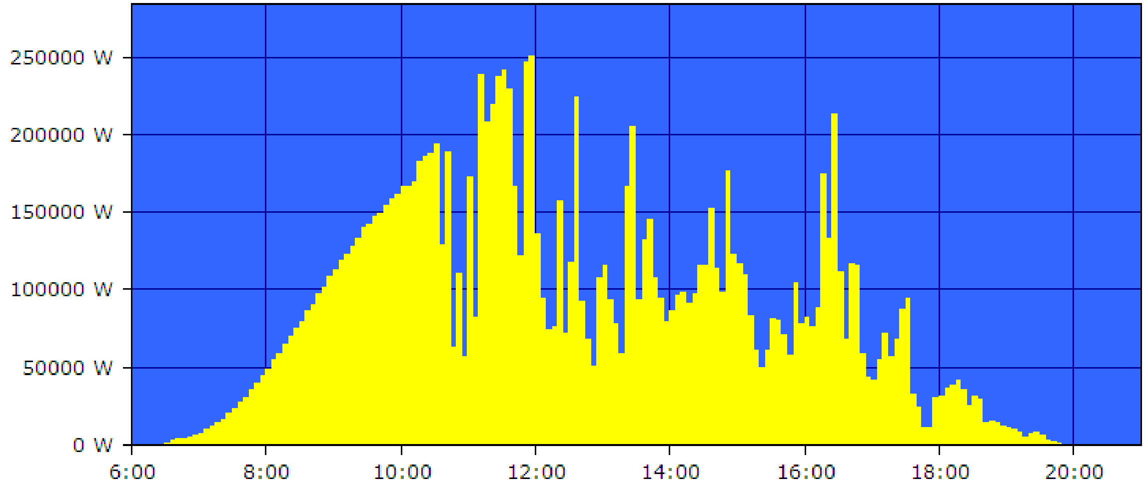
Predictability and Dynamics of Solar Power

Sunny Day, April: 1,9 MWh



Cloudy Day, April: 1,2 MWh



Source: Michael Weinhold & friends

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2016, May 15: Marking a milestone for chancellor Angela Merkels ‚Energiewende‘ policy

May 8 clean energy 95 % of power needs

May 15 clean energy (wind & solar) met pretty much 100 % of Germany‘s power needs (45.8 kW)

- **for several 15 min power price turned negative (57 $/MW)**
- **Commercial customers were being paid to consume electricity for few hours**

Power system still to regid for suppliers and consumers to respond quickly to price signal

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Dec. 2014 grid instability in Ireland by 37 % wind (full generation with part load → reduced generation with full load (H = 2 MWsec/MW))

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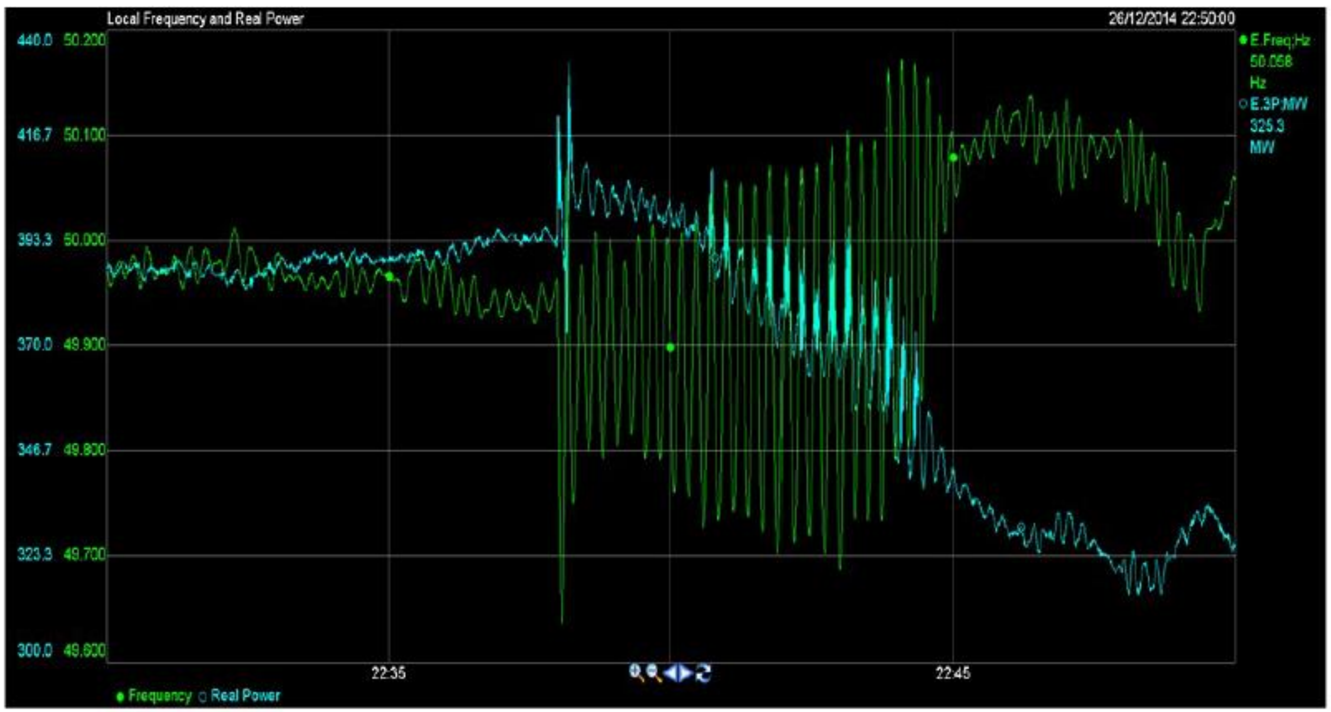
Oscillations – 22:38 26 December 2014

EIRGRID



- C30 Trip at 22:38
- DB1 MW; Hz
- 7 Min Oscillation
- Pk-Pk: ~0.3 – 0.4 Hz
- Period of Osc: 15 s (0.066 Hz)

Source: Uni Rostock

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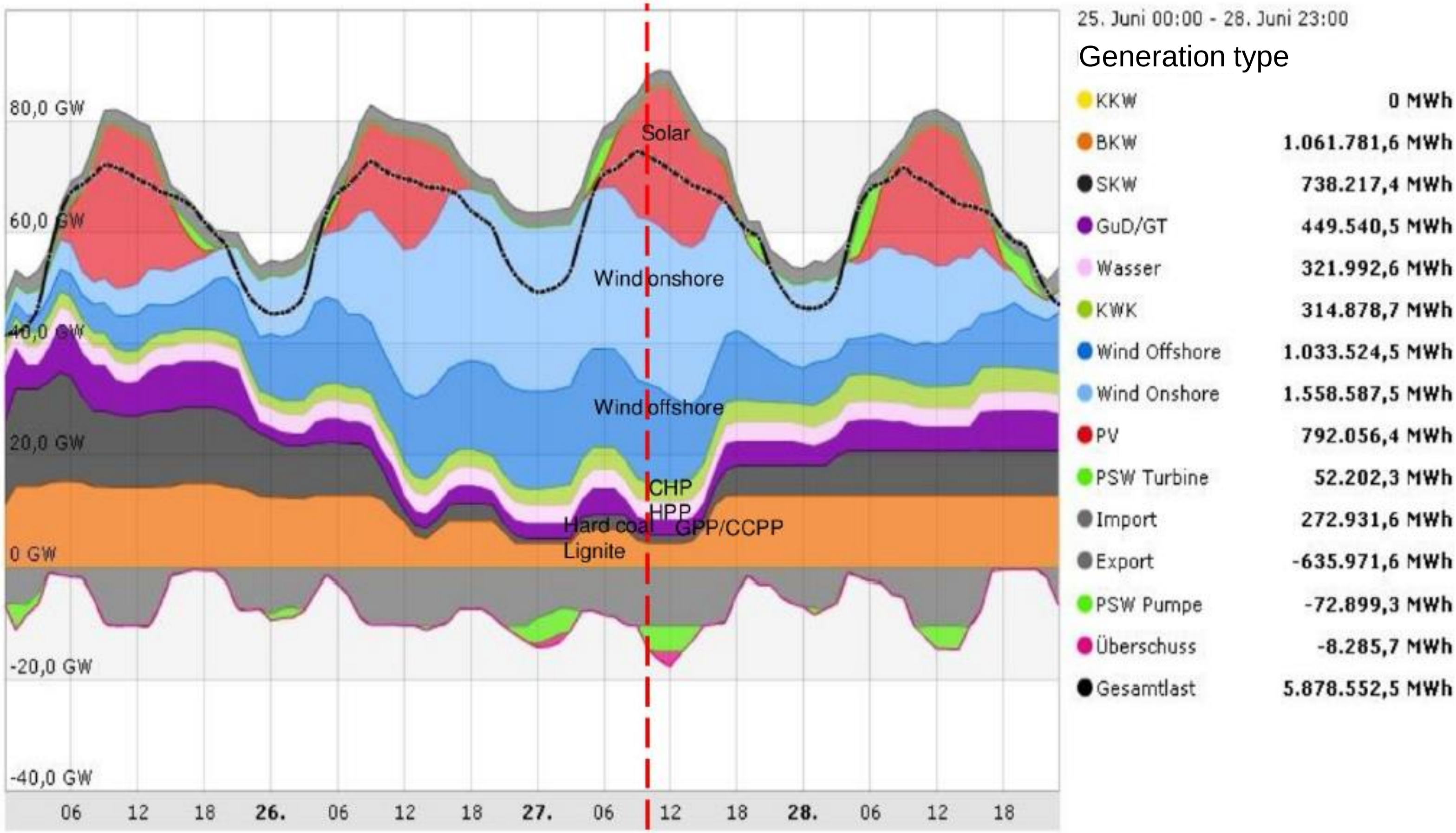
Uni Rostock: summer generation scenario 2023



Source: Uni Rostock

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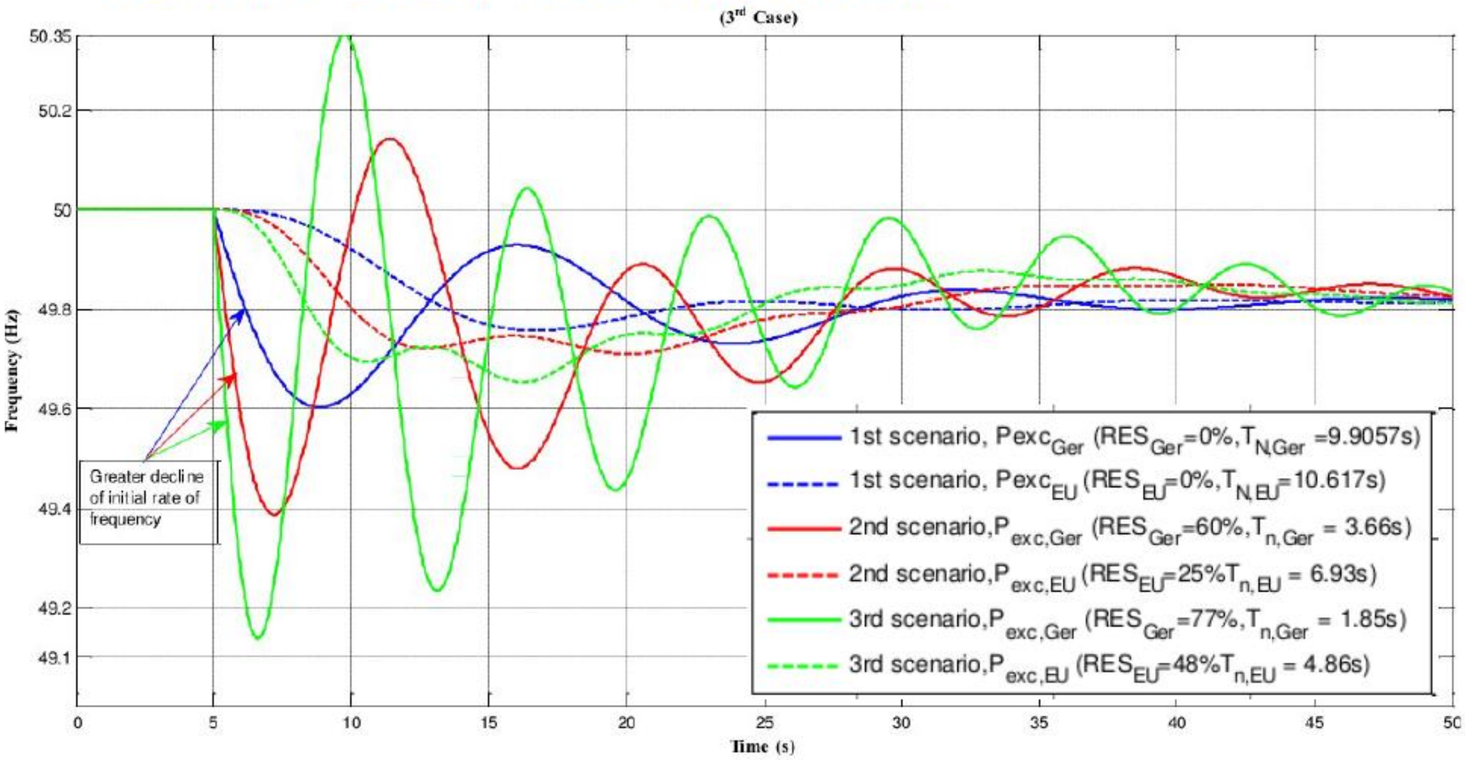
Frequency changes: generation scenario 2020: 3000 MW outage



f_{min} ↓ min frequency

d ↓ damping

$\frac{df}{dt}$ ↑ frequency gradient

Source: Uni Rostock

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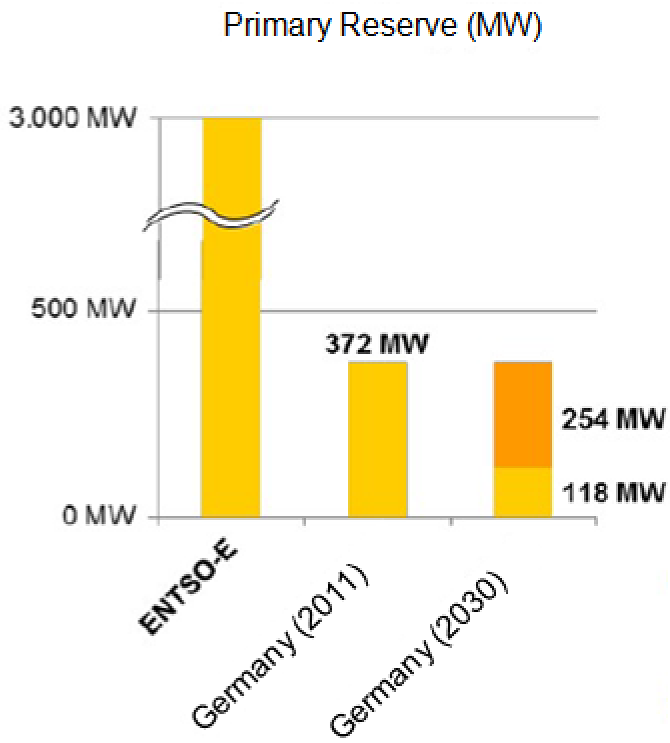
Dena* Investigation: Necessary primary reserve

*German Net Agency



Alternative from renewable sources

conventional

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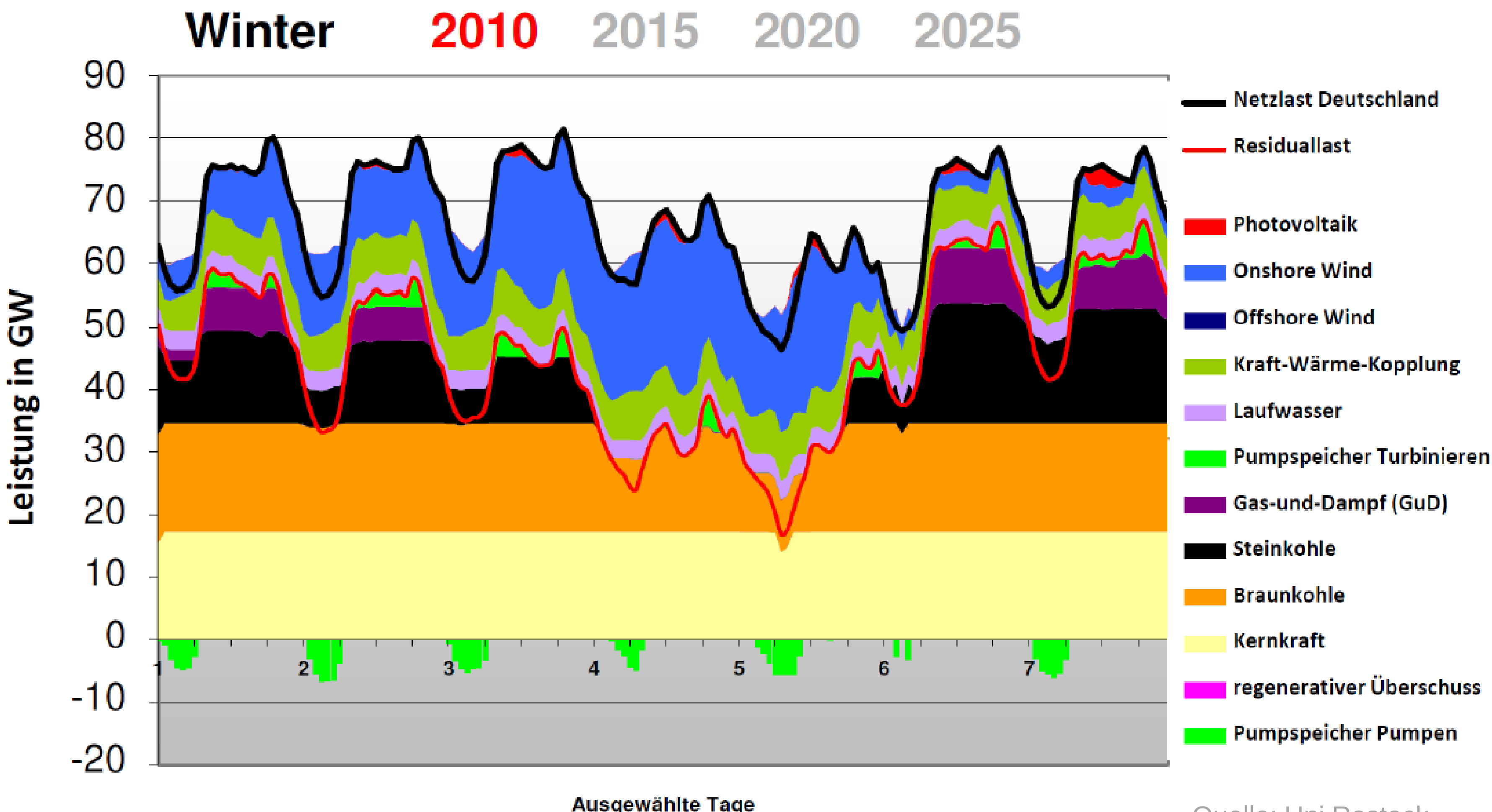
Elimination of conventional power plant winter scenario



Quelle: Uni Rostock

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Elimination of conventional power plant winter scenario

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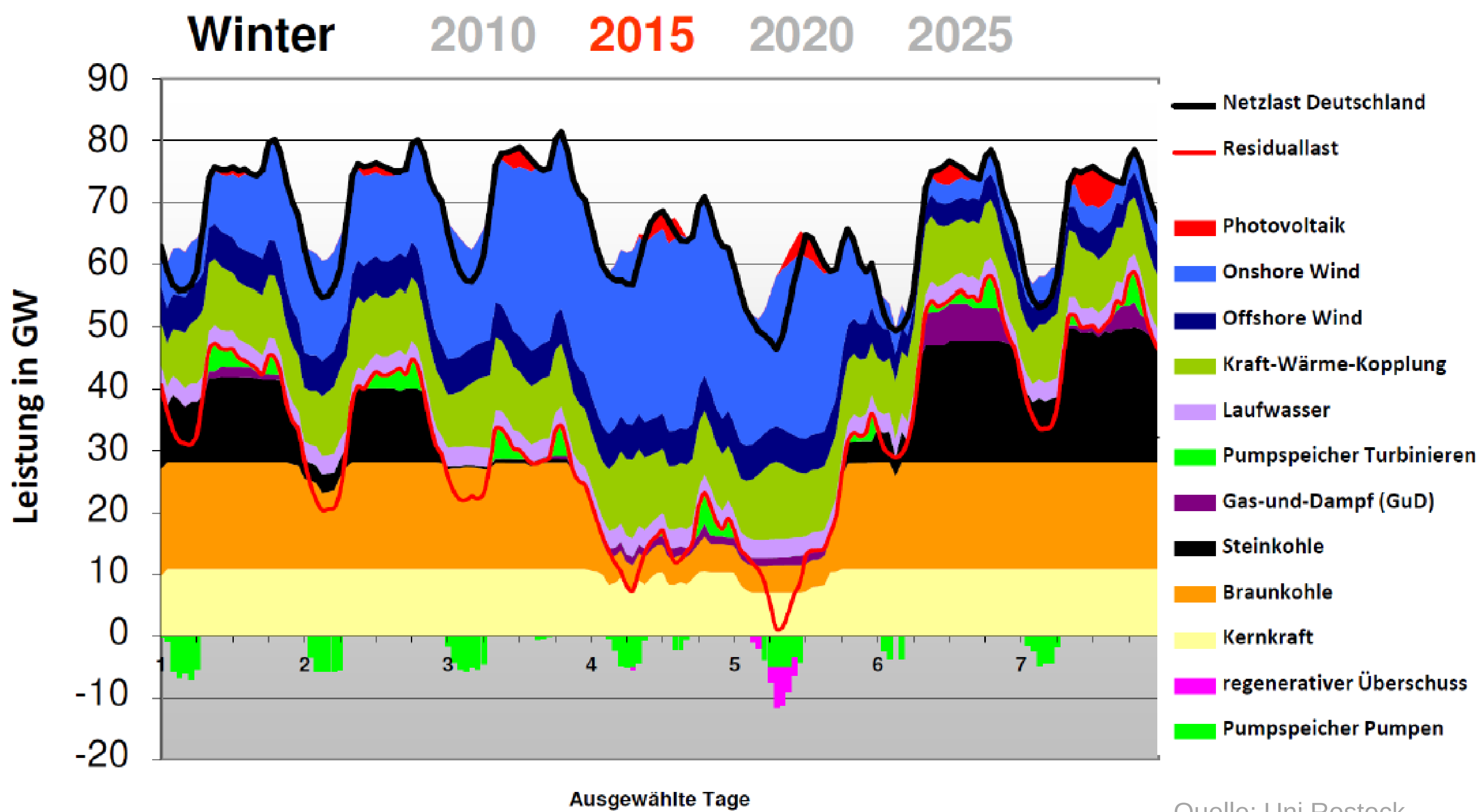

Quelle: Uni Rostock

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Elimination of conventional power plant winter scenario

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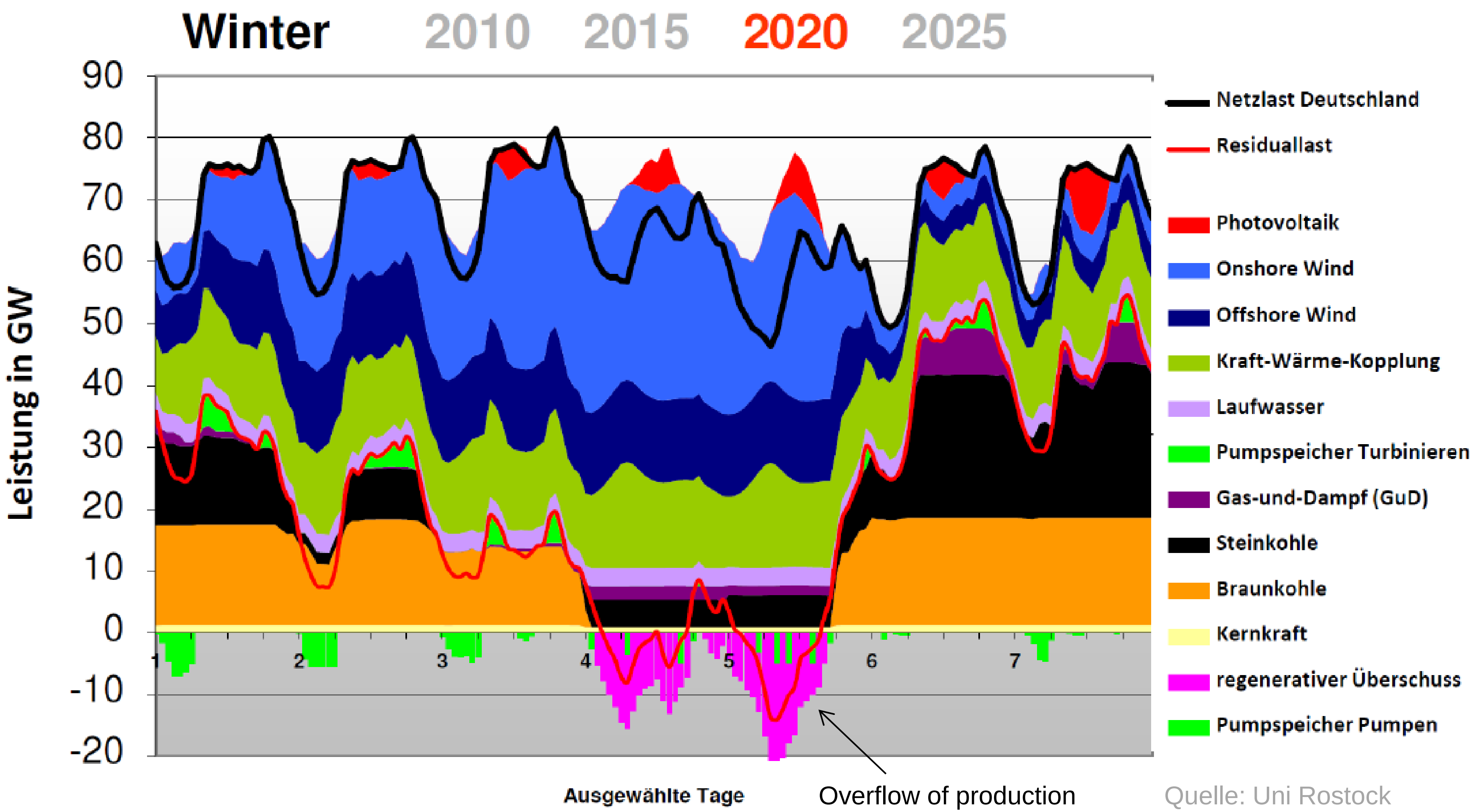

Quelle: Uni Rostock

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Elimination of conventional power plant winter scenario

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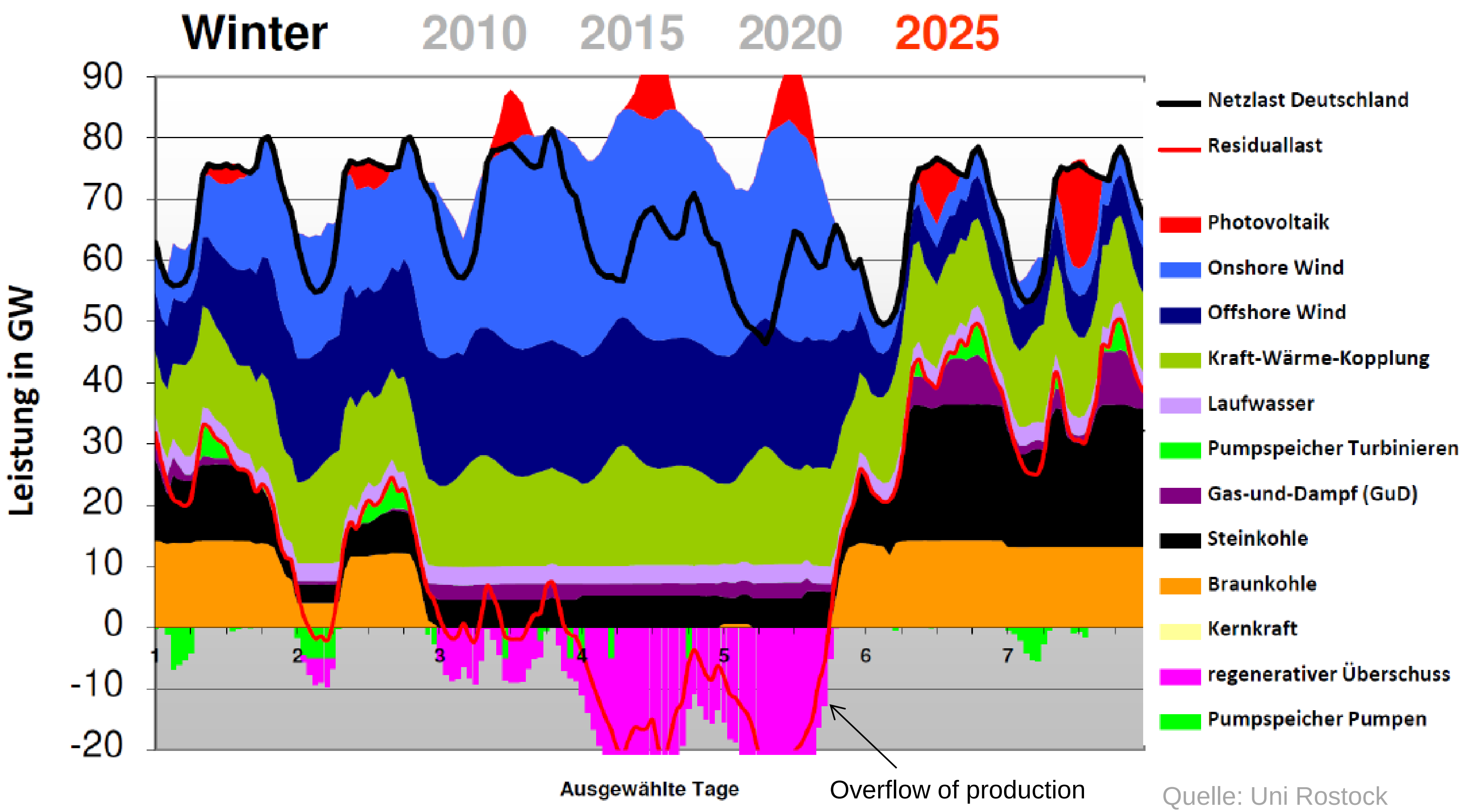

Quelle: Uni Rostock

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Highly efficient Combined-Cycle Power Plant Irsching 4 retiered because of uneconomicalness

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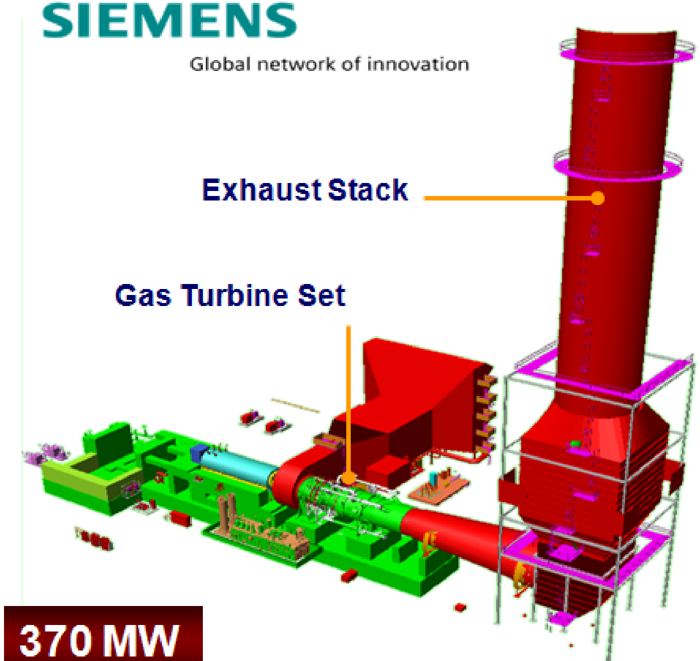
Perspective 2015 (E.ON): „the economic perspective of the plant is very critical“

Phase 1: Erection and Testing GT

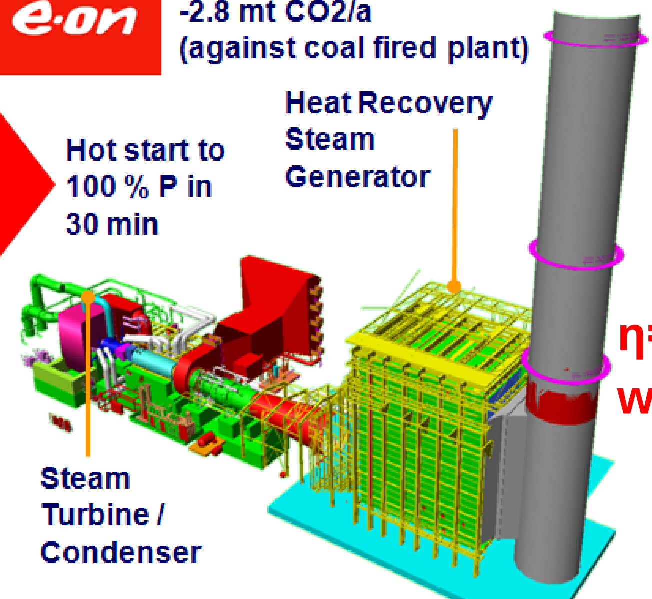


370 MW

Phase 2: Extension to CCPP

e.on

-2.8 mt CO_2/a
(against coal fired plant)



η= 60,7 %
world record 2011

+ 200 MW → **In total: 570 MW**

The SGT5-8000H will be validated prior to Market Introduction to provide superb Product Quality and Reliability to the Customer

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Ancillary services for system operation and stability are of essential importance

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voltage	frequency	supply	operation
• reactive power • voltage control • power transportation	• control power • re-dispatch • primary reserve	• black start capability	• congestion management • monitoring • generation management • DSA

What is necessary?

- adjust market for renewables to support ancillary services
- coordination between all parties concerned
- guaranty of profitability for all parties
- timely requirements are necessary

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Technical Capabilities of Offshore Windfarms for the Provision of Primary Reserve

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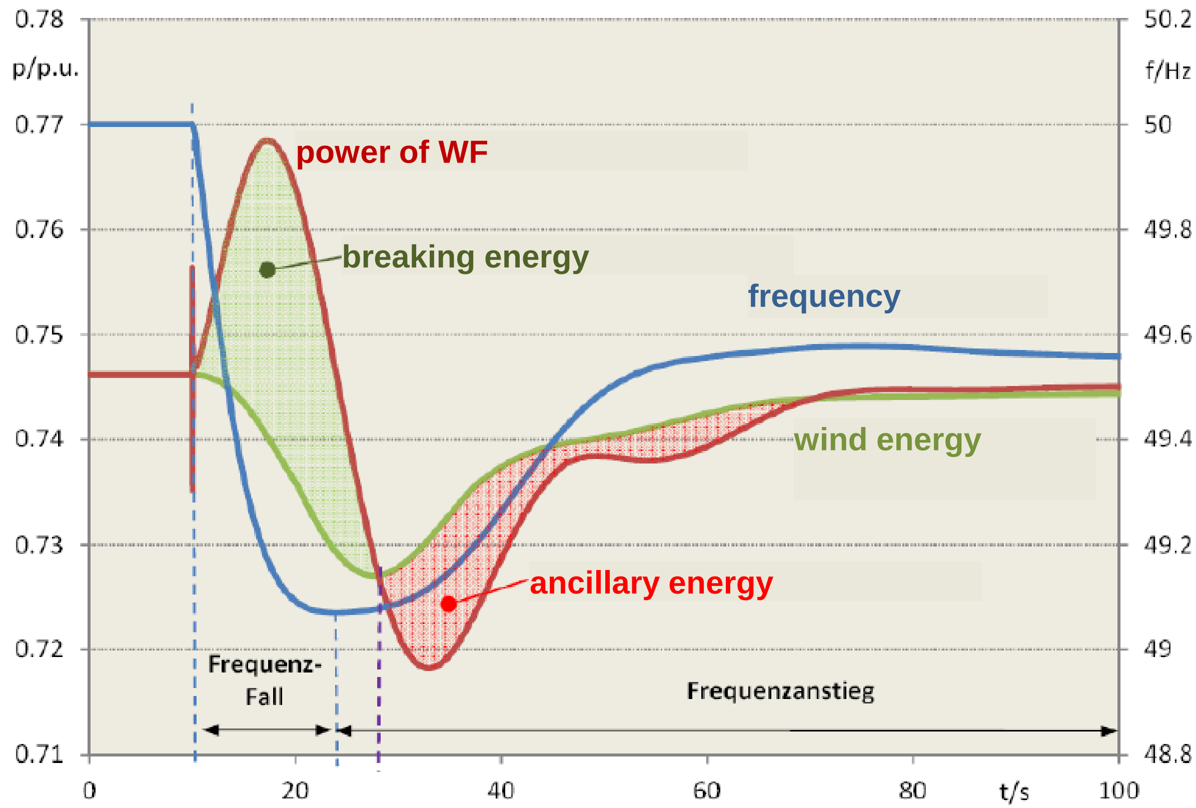
The Future: Synthetic Inertia Capability through pitch control and storage equipment



DONG energy

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Challenges for all parties concerned

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System solutions

- evolutionary system adaption following technical and economical demand
- flexible and faster system planning
- adaption of renewables following technical progress and economic demands

- Electric-Heat-Gas-Traffic coupling
- heating with electricity

- decentralized / cellular energy supply
- local storage to reduce residual load
- flexible consumption (smart metering)

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Challenges for all parties concerned

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System reorganisation

- reserve through power limitation in wind farms (smaller size, more full load hours)
- combination of wind power and pump storage plants
- storage of energy at wind generators (DFIG with capacitor banks)
- faster control (FACTS, faster and more flexible conventional plants)
- renewables with virtual inertia , power electronic with inherent ‘inertia’

Market and consumers

- renewable energy act to be adapted to market condition
- reduction of subventions
- trading in real time (smart meter)
- monitoring of overflow and shortage (consumer self-control)
- ancillary services from renewable sources
- MV system form energy regions, balancing power between LV consumer cells

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Challenges for all parties concerned

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Stability

- limited by inertia of conventional plants
- faster control (FACTS, faster and more flexible conventional plants)
- new role: voltage stabilization in low and medium voltage systems
- renewables with virtual inertia
- power electronic with inherent ‘inertia’
- limitation of frequency gradients

Fluctuations

- reduction of stress, wearout and high dynamic (conventional and renewable plants)
- limitation of life time reduction of generation

Operation an Monitoring

- new and faster re-dispatch strategy (today per year 1 billion €)
- Smart meters, PMU montoring and control
- DSA for operation at the system stability limits

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The future of renewable energy

When we stop and control all these challenges
we are able
to operate power systems
with high penetration of renewables
with high safety and suitable availability

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Thank you very much for your attention!

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