Impact of renewable energy expansion on national grids – Challenges and viable solutions

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Agenda

1. Introduction
2. Basics – System Overview
3. Challenges and Solutions for Grid Integration of Renewable Energy Sources
   a. Market Perspective
   b. Transmission Grid Perspective
   c. Distribution Grid Perspective
4. Summary

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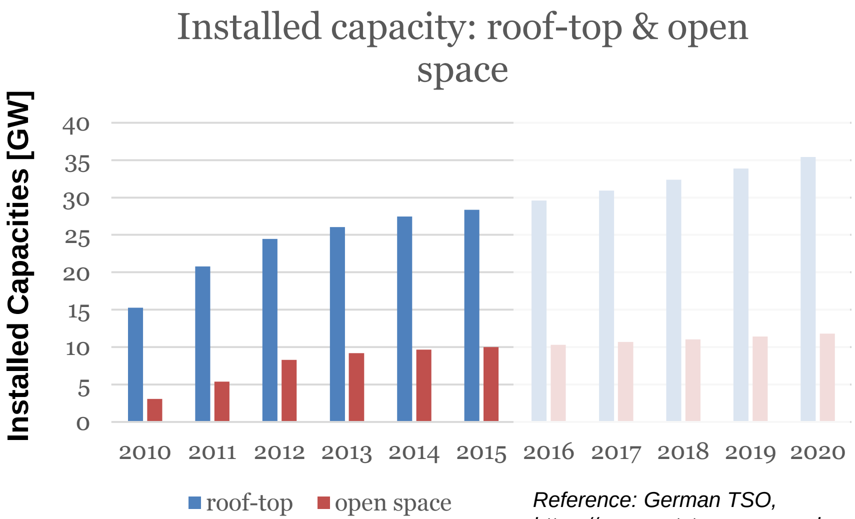
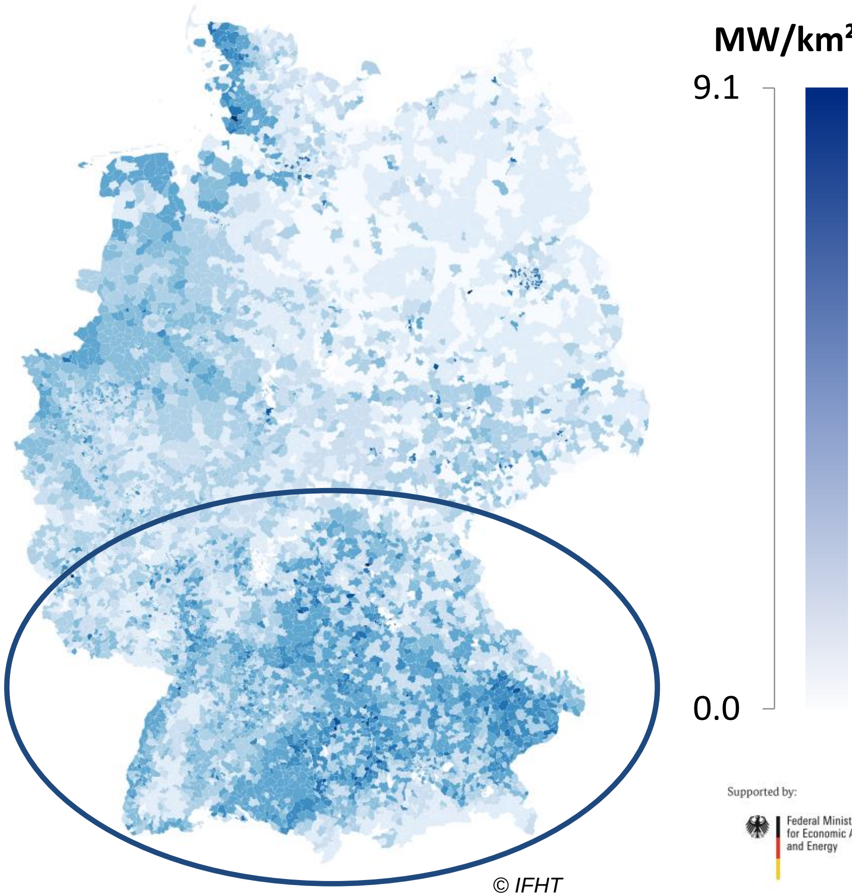
Introduction

- Geographic concentration of PV expansion in southern regions with high solar radiation and large roof surface
- Ratio of installed capacities of roof-top and open space PV units: ~75:25



Reference: German TSO, https://www.netztransparenz.de



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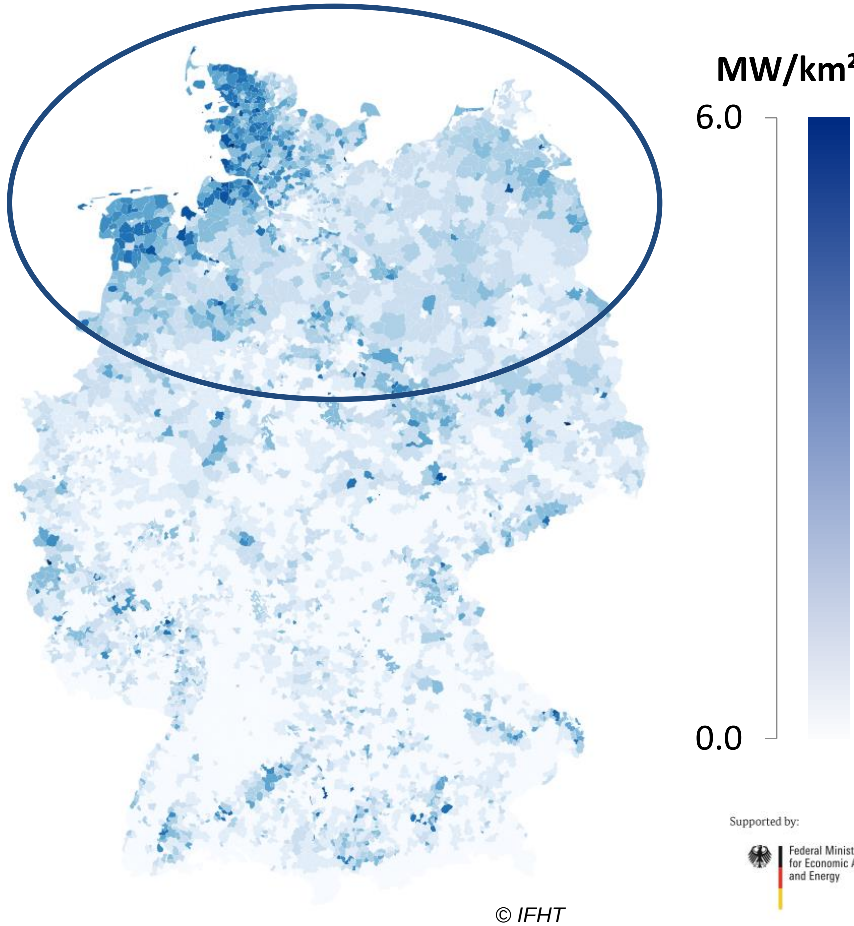
Introduction

- Geographic concentration of onshore wind energy expansion
- Expansion mostly offshore and in northern regions with high wind velocities
- Development of wind turbines with hub heights of >150 m and rotor diameters of >120 m

➢ More efficient use of wind power in low wind regions

➢ In future: expansion of onshore wind turbines in high wind (north) and low wind regions

➢ Utilization of total potential surface



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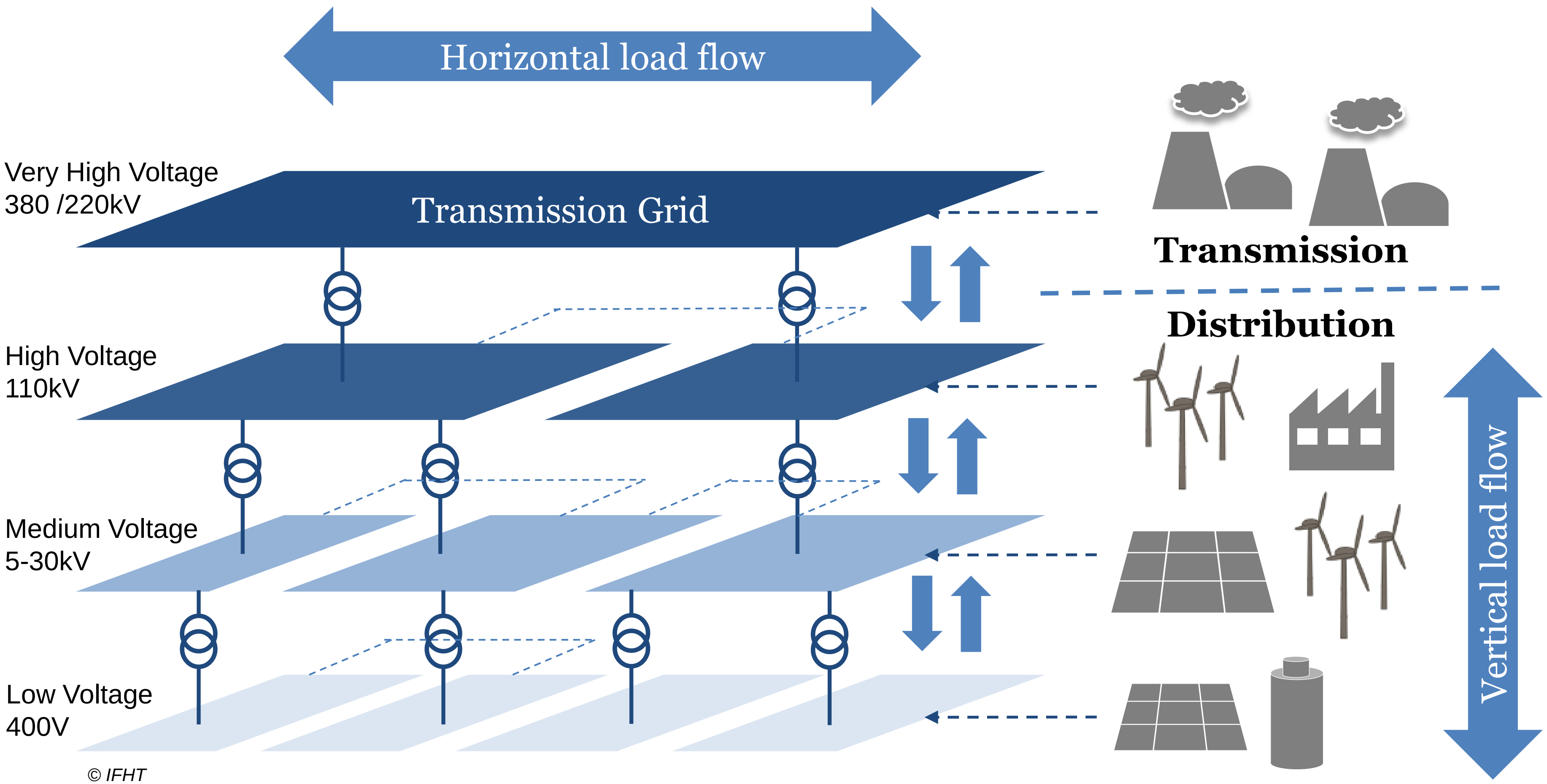
Basics – System Overview



Basics – System Overview

- Grid characteristics of renewable energies:

	Wind	Photovoltaics
Voltage level	Low voltage (approx. 0%) Medium voltage (**approx. 48%**) High voltage (**approx. 42%**) Very high voltage (approx. 10%, Offshore)	Low voltage (**approx. 69%**) Medium voltage (approx. 26%) High voltage (approx. 5%) -
Number of Units	approx. 25.000	approx. 1.500.000
Geographic concentration	North & Offshore (regions with high wind velocities)	South (regions with high solar radiation)
Seasonal generation	Autumn -> **Winter** -> Spring	Spring -> **Summer** -> Autumn
Intraday generation	volatile generation at 24 hours a day	generation just at daylight
Network connection point	directly to medium and high voltage	mostly low voltage (house connection point)
Congestions	Transmission grid -> thermal overload	Distribution grid -> voltage limit violation

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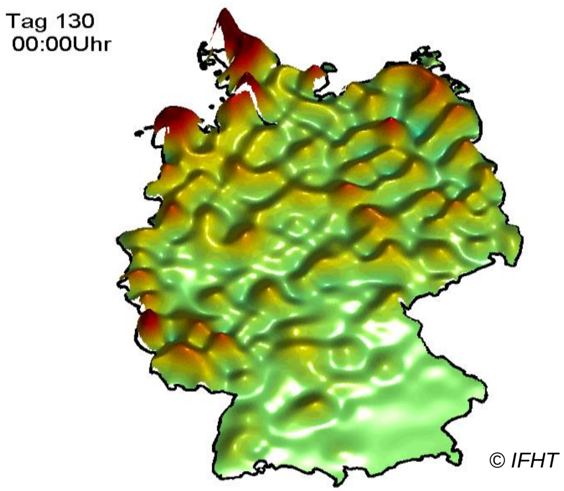
Challenges and Solutions – *Market Perspective*

- Increasing volatile feed-in of renewable energies
  - Wind Onshore
  - Wind Offshore
  - Photovoltaics
- Rising flexibility requirements for the energy system to guarantee security of supply
- Balancing of generation and load by different flexibility options
  - ➢ Electrical storages
  - ➢ International electricity exchange
  - ➢ More flexible conventional power plants (higher power gradients, shorter downtimes etc.)
  - ➢ Flexible loads/demand side management (e.g. Power2X)



Hourly feed-in of onshore wind: feed-in with regional and temporal dependency

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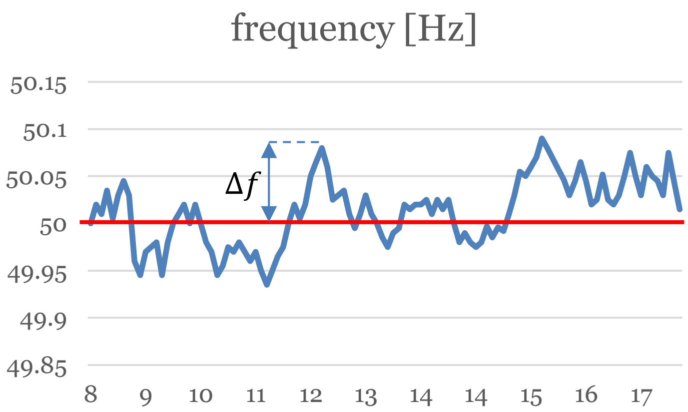
Challenges and Solutions – *Market Perspective*

- Imbalances of generation and load can occur due to:
  - Power plant failures
  - Forecast errors of REN
  - Forecast errors of load
  - Grid losses
- Undersupply: frequency lower than rated frequency
- Oversupply: frequency higher than rated frequency



➢ Requirement for **control reserve**
  - Goal: adherence of power balance and to guarantee frequency stability (50 Hz)
  - Deviation control of frequency deviations due to imbalances in load and generation (active power control)
  - Positive control reserve: provision of power by power plants
  - Negative control reserve: curtailment of power or switching on of additional loads (e.g. Power2Heat)

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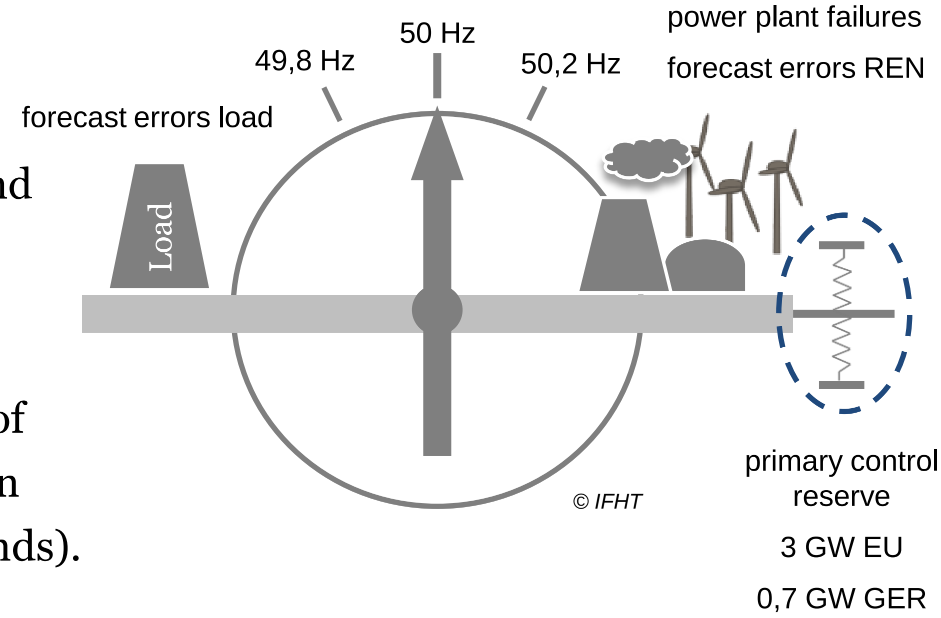
Challenges and Solutions – *Market Perspective*

- The Transmission System Operators (TSO) are responsible for power balancing
- There are three qualities of control reserve
- **Primary control reserve:** Automated and fast balancing of frequency deviations and stabilization of the grid within 30 seconds.
- **Secondary control reserve:** Balancing of imbalances in a control area of a TSO within 5 minutes (activation already after 30 seconds).
- **Minute reserve:** Replacement of secondary control reserve for power balancing. Balancing for at least 15 minutes on a constant level.



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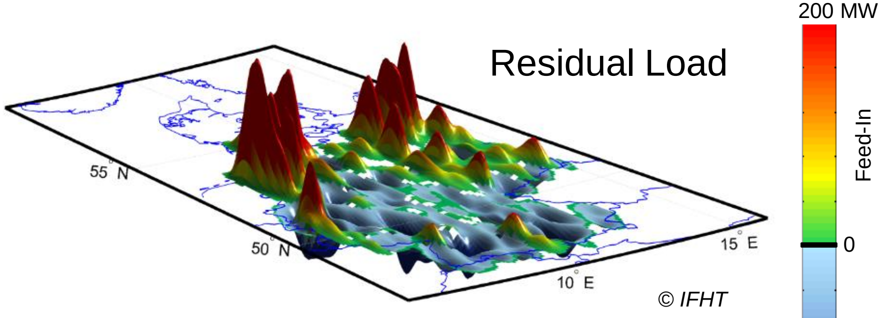
Challenges and Solutions – *Transmission Grid Perspective*

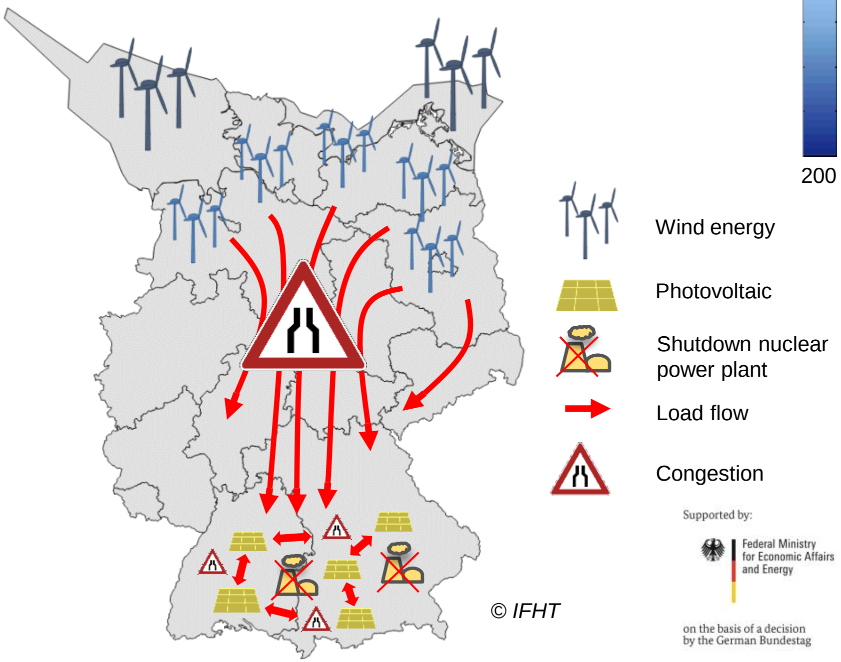
- Generation concentrates in the north
  - Main drivers: Wind Onshore and Offshore
- Load centers are near big cities and industry regions
- Less generation capacity in the south due to nuclear phase-out in Germany
- Transit of electricity from Scandinavia through Germany to southern Europe

➢ Flow of electricity from the north to the south of Germany

➢ Generation and demand pattern show an energy transport problem

➢ **Need for transmission grid expansion**





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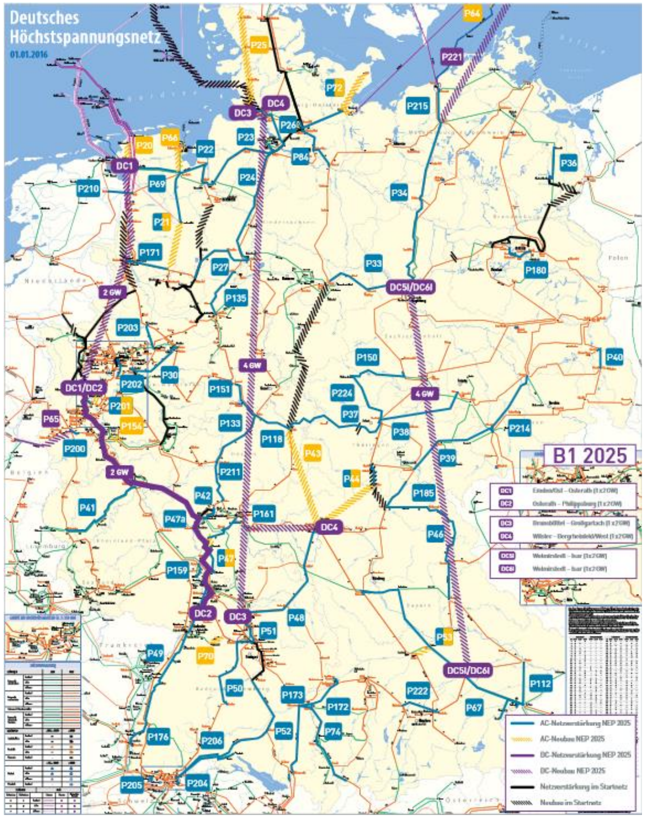
Challenges and Solutions – *Transmission Grid Perspective*

German Grid Development Plan (GDP)

- The German TSO’s create the GDP every second year
- Goal: In the GDP the future transmission grid is planned to guarantee an efficient electricity transport
- NDP contains several scenarios that describe possible future developments for different simulation years (e.g. NDP 2016: 2030 & 2035)
- Minimization of transmission grid expansion / GORE-principle

➢ **G**rid **O**ptimization prior **R**einforcement prior **E**xpansion



Reference: German TSO, https://www.netzentwicklungsplan.de

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Challenges and Solutions – *Transmission Grid Perspective*

(Grid) Optimization	▪ Power flow control -> HVDC-control, phase shifting transformers (PST) ▪ Overhead line monitoring	GO
Reinforce-ment	▪ Voltage upgrade (220 kV -> 380 kV) ▪ Increase of transmission capacity	R
Expansion	▪ New HVAC (380 kV) lines ▪ New electrical switchgear ▪ Overlay-grid (HVDC)	E

Reference: German TSO, https://www.netzentwicklungsplan.de

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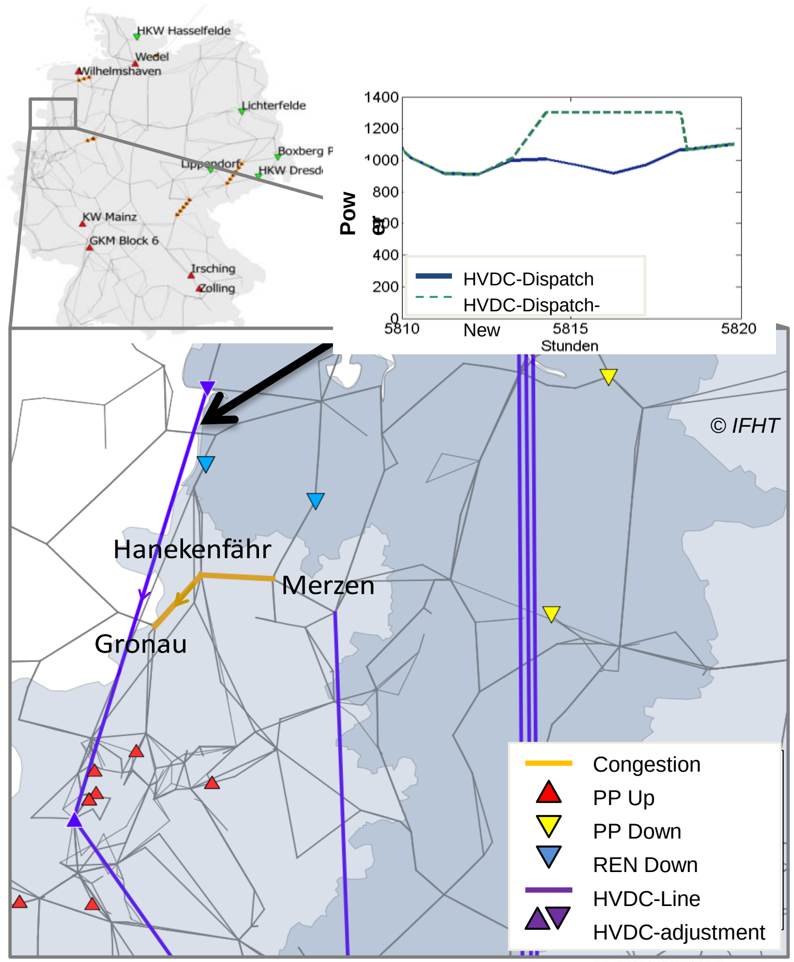
Challenges and Solutions – *Transmission Grid Perspective*

- Temporary solutions until grid expansion proceeds
- Short-term remedial actions for elimination of network congestions and to guarantee system security, e.g (n-1)-security
  - Redispatch: *Intervention of the TSO in the power plant dispatch in order to guarantee system security*
  - REN feed-in management / Peak shaving
  - HVDC-adjustment
  - Reserve power plants (system services)
  - Power2Gas in the north & transport of gas by gas pipelines to power plants in the south
- No alternative for required grid expansion in the long run!



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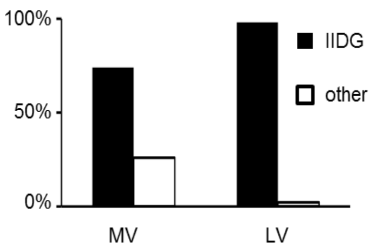
Challenges and Solutions – *Distribution Grid Perspective*

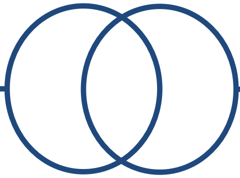
Changing conditions in distribution grids

- Generation / Storage / Loads



Share of IIDG for LV and MV in a distribution system with >180,000 distributed generators [1]

- Different powerflows & new technologies
- New marketing concepts
- Increasing ICT infrastructure

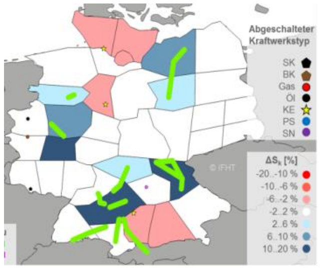


Changing demands on DSO

1. Local services and operational requirements
2. Implications for normal and faulty operation
3. Services / requirements of the overlayed grid

Changing conditions in transmission grids

- Decreasing number of rotating masses/inertia



- Spatial divergence generation <-> load
- Providing ancillary services increasingly critical

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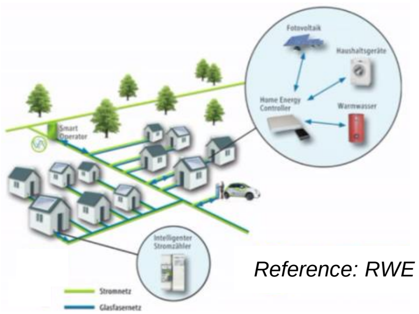
Challenges and Solutions – *Distribution Grid Perspective*

- Future smart grid
  - Smart components monitor the state of the electrical grid and keep balance between generation and load
  - Goal: Efficient use of regional infrastructure through smart operation/control (optimized grid operation)
  - Controllable loads (e.g. e-mob, white goods) , storage (grid- and home storage), new equipment (voltage regulated transformer, switch)
- Further Challenges
  - High complexity in possible operation points and options in action
  - Control in „real time“ with limited resources (Hardware)

SMARTOPERATOR
Steuert Energie intelligent durchs Netz.



Reference: RWE

➢ **Need for an intelligent control system with an online-self-learning algorithm (smart operator)**

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Challenges and Solutions – *Distribution Grid Perspective*

- Smart Operator: Process of development
  1. Simulation based conceptual design
  2. Implementation on used hardware
  3. Validation with real grid components in the test center / laboratory
  4. Collecting operating experience in field tests

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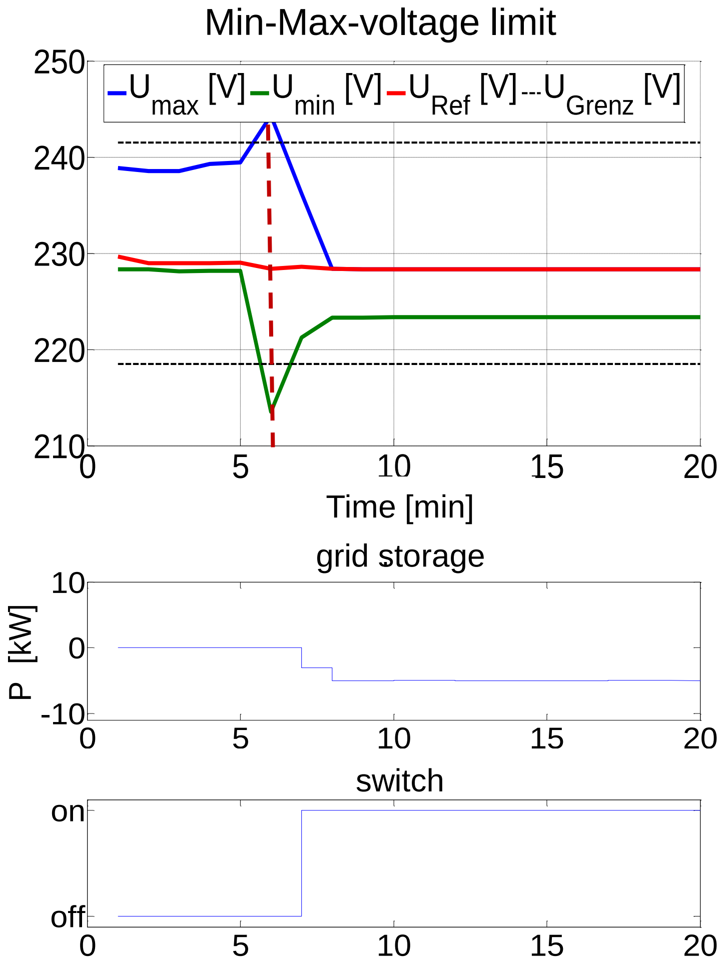
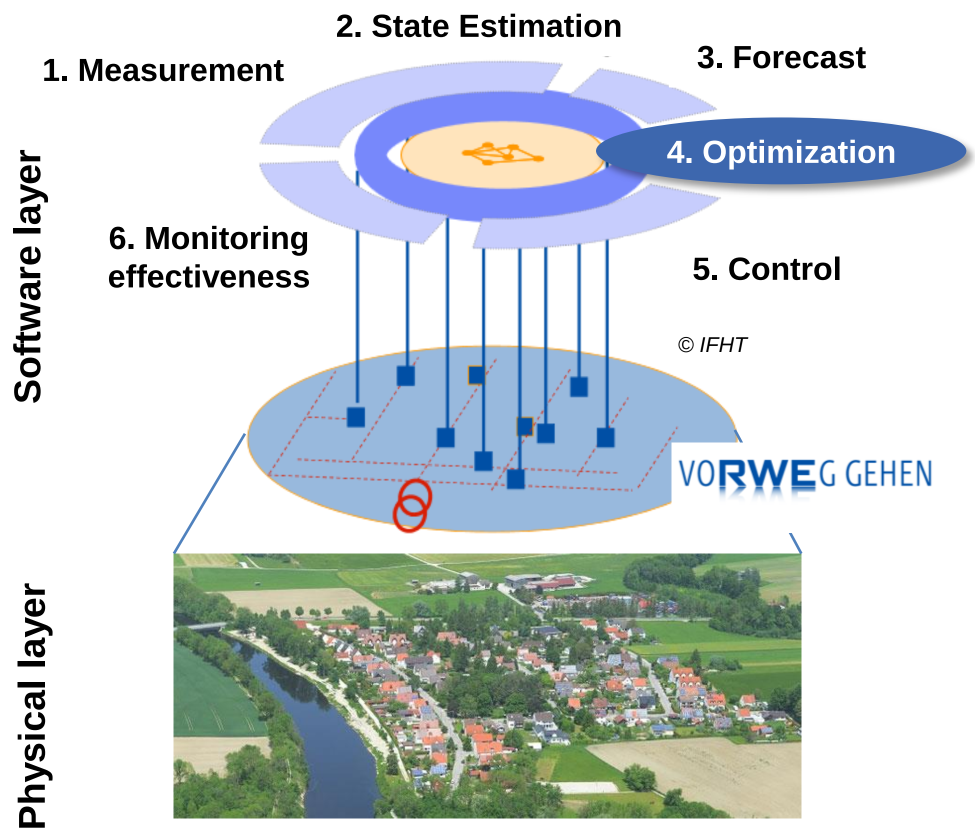


Challenges and Solutions – *Distribution Grid Perspective*

- Control options in distribution grids:
  - Feed-in management
  - Reactive power control
  - on-load tap-changer
  - Flexibilities from private households
- Central intelligence controls low-voltage grid
  - Self-learning algorithm
  - Learning from information from measurements and meteorological data
  - State estimation for determination of current grid state
- Day-ahead forecast for efficient battery usage
- Use of powerflow calculations for validation of switching action
- Field tests show the successful operation
  - Day-ahead forecast is preventing invalid grid states in over 90% of cases



Field test in the low-voltage grid in „Wertachau“ (research project „Smart Operator“)

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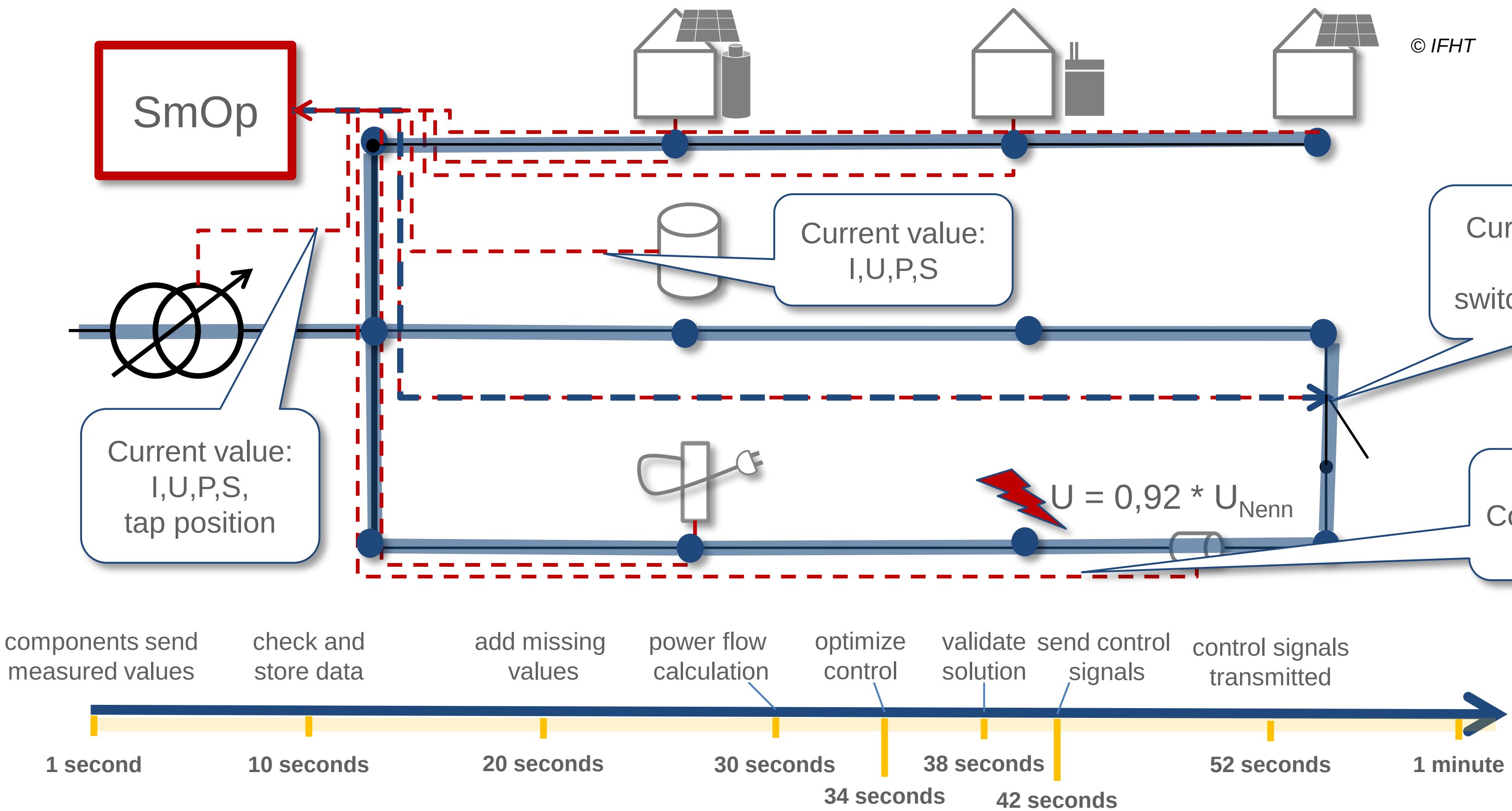
Challenges and Solutions – *Distribution Grid Perspective*

- Input / output activities of a smart operator – real time control



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Summary

1. REN installed capacities and REN feed-in have been increased significantly and further expansion is expected in the next years

2. Spatial divergence generation <-> load: no regional balance
   - Energy transport problem in the transmission grid
   - Need for **transmission grid expansion** (Grid Development Plan)
   - Principle: **G**rid **O**ptimization prior **R**einforcement prior **E**xpansion
   - Temporary solutions: Short-term remedial actions for elimination of network congestions

3. Volatile feed-in of renewable energies requires the **expansion of smart distribution grids** (smart grids)
   - Rising number of Prosumers (Producers and Consumers)
   - Need for flexibility and control options in distribution grids
   - Need for good state estimations & forecasts and smart operation (software)

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Thank you for your attention!

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