Institute for Advanced Sustainability Studies
IASS in Potsdam

Integration of distributed energy resources into the grid

Results from an interview series with German distribution grid operators

Coimbra, November 2016

Benjamin Bayer
Content

1. Basic information on renewables in Germany

2. Integration of photovoltaics in the low voltage grid

3. Regulatory framework for distribution grid operators
Basic information on renewables in Germany
Development of renewable energies in Germany

- Hydro power
- Wind energy onshore/offshore
- Photovoltaics
- Biomass
Structure of the electric grid

- Extra high voltage grid
  - 220 kV and 380 kV

- High voltage grid
  - 110 kV

- Medium voltage grid
  - 20 kV

- Low voltage grid
  - 0,4 kV

Transmission System Operator (TSO)

Distribution System Operator (DSO)
Grid connection of wind energy and photovoltaics

Wind energy

- Low voltage 0.4 kV
- Medium voltage 20 kV
- High Voltage 110 kV
- Extra high voltage 220 kV and 380 kV

Installed Capacity [GW]

Photovoltaics

- Low voltage 0.4 kV
- Medium voltage 20 kV
- High Voltage 110 kV
- Extra high voltage 220 kV and 380 kV

Installed Capacity [GW]
Distribution system operators

- 881 DSOs operate the low, medium and high voltage grid
- We conducted 10 interviews with the largest DSOs
Integration of photovoltaics into the low voltage grid
Impact of PV systems on amperage

- Reverse flow may exceed power rating of transformers and cables
Impact of PV systems on voltage

- Voltage may exceed the upper 10% limit

![Graph showing voltage levels and feed-in conditions compared to load conditions. The graph has a vertical axis labeled with voltage levels (+10%, 400 V, -10%) and a horizontal axis representing load conditions. The graph indicates that feed-in conditions can exceed the upper 10% limit.]
Classic solutions

Replace transformer

Install additional transformer(s)

Lay parallel cable(s)
Classic solutions

Replace cable(s)

Change grid topology
Innovative solutions

Wide area control

- Actively control the voltage at the 20/100 kV substation
- Control algorithms also includes current generation from distributed energy resources
Innovative solutions

Variable distribution transformers

- Substitute classic transformers with variable transformers
- Voltage of low voltage grid can be controlled individually
Innovative solutions

Booster

- Variable transformer that can increase/reduce voltage
- So far only pilot projects implemented in Germany
- Boosters may be an efficient solution for long distribution lines
Innovative solutions

Reactive power feeding

- Reactive power can reduce voltage
- PV inverters are required to generate a certain amount of reactive power
Germany's incentive-based regulation
Germany’s incentive-based regulation

- Germany’s regulator determines a revenue cap (budget) for each operator.

- This revenue cap is primarily based on past costs of grid operators.

- Grid operators calculate the grid fees according to the revenue cap.

- The regulator established two inventive mechanisms to keep costs low.
Incentives through budget approach


1. Regulation period  2. Regulation period  3. Regulation period
Incentives through efficiency comparison
Incentives for innovative solutions?

- Germany’s incentive-based regulation is technology neutral.
- Grid operators could implement the desired solutions in the past.
- There are no restrictions regarding the use of new technologies.
- Strong incentive for capital intensive solutions as there’s an grid operators receive an return on equity of 9%.
Summary and conclusions

- Grid integration of distributed energy is a challenge but there are several technical solutions available.

- Conventional grid extensions were in most cases the most efficient solution.

- In economic terms, grid operators in Germany are not affected negatively by the development of distributed energy resources.
Obrigado pela atenção!

Benjamin Bayer
Research Associate
Institute for Advanced Sustainability Studies
benjamin.bayer@iass-potsdam.de