Energy

Grid Integration of Wind Generation

Experience from Germany

www.german-renewable-energy.com
The German Power Sector

- Liberalized, unbundled power sector
- 4 Transmission system operators (TSOs)
- >800 Distribution network operators

- Installed generation capacity – *conventional*: 102GW
  (year 2010 according to NEP 2012)
- Installed generation capacity – *renewable*: 56GW
  (year 2010 according to NEP 2012)
- Annual peak load: 84GW
  (estimated, according to NEP 2012)
  (low load around 35GW)
The German TSOs and Wind Installations

Source: NEP 2012

Wind Generation in Germany

- End of April 2012: 29012MW installed wind capacity
  (+ 25000MW of installed PV-capacity by end of 2011)
- **54 000 MW of installed variable capacity**
- Large number of small wind farms connected to MV grids
- Only relatively few wind farms with connection at 110kV
- Almost no (onshore) wind farm with connection >110kV
- Wind generation in Germany is highly distributed.
- Many issues relating to the grid integration of wind generation in Germany are a consequence of highly distributed generation (not necessarily wind generation)
Development of Wind Generation Capacity in Germany

Installed Wind Generation Capacity in Germany

Grid Code Requirements for Wind Generation
Grid Code Requirements for Wind Generation

► Power systems with low share of wind generation:
  ▶ Wind generation feeds into an “infinite grid”;
  ▶ Almost no influence on the overall system behaviour;

Requirement:
  ▶ Wind generation shall not disturb the grid

► Power systems with large share of wind generation:
  ▶ Substantial influence on the overall system behaviour;

Requirement:
  ▶ Wind generation shall not disturb the grid;
  ▶ Wind generation must actively support the grid (provide ancillary services);
Connection Conditions for Wind Generation – FRT

Wind generators without FRT:

- Disconnection in case of voltage sags

Consequence:

- Large loss of generation in case of single line faults.
- System stability endangered.

Mitigation:

- Connect only WTGs with FRT

Source: dena 1 grid study, 2005
Connection Conditions for Wind Generation – Reactive Power-Voltage Control

380/220kV

110kV

20/10kV
Connection Conditions for Wind Generation – Reactive Power – Voltage Control Requirements

During high wind conditions many synchronous generators are disconnected -> reduced reactive power levels

Risk:

- Low voltage control capability of the system, high/low voltages
- Voltage instability

Mitigation:

- Require reactive power contribution and reactive power control capability from wind farms.
- Install additional reactive power sources (switched shunts, dynamic reactive power compensators in the grid)
Connection Conditions for Wind Generation – Summary

- Voltage and frequency band of operation
- FRT (fault ride through requirements)
- Reactive power/voltage control requirements
- Power quality aspects (harmonics, flicker)
- Protection guidelines

- Compliance validation through tests and simulation is essential.
- In Germany, SDLWindV grid code compliance certificates are mandatory (since 2009)
Future Requirements for Wind and PV Integration in Germany
High amount of wind generation has a substantial impact on power flows in the German system:

Risk:
- Grid congestions already exist and will further increase
- System security endangered

Mitigation:
- Advanced congestion management
- Grid reinforcements (new transmission lines)
Future Requirements in Germany - 2022

Assumptions 2022:

- Installed capacity conventional: 89GW (-13GW)
  (no nuclear, more gas and pump storage)
- Installed wind capacity onshore: 48GW (+16,8GW)
- Installed wind capacity offshore: 13GW (+13GW)
- Installed PV capacity: 54GW (+36GW)

Total variable capacity (Wind + PV): 115MW (>peak load)

Source: NEP 2012, Scenario 2022b (lead scenario), reference: year 2010
Required Grid Reinforcements in Germany, NEP 2012

► 1 300km of new conductors on existing transmission lines
► 2 800km of new transmission lines on existing corridors
► 1 700km of new AC-transmission lines on new corridors
► 2 100km of new DC-transmission lines on new corridors (10GW)

Investment: around 20 000 Mio (20 Bio) Euro (over 10 years)
In future systems with very high share of wind generation, participation in active power/frequency control services will be required:

- Participation in system balancing (wind curtailment, or storage);
- Participation in load following reserve;
- Participation in primary and secondary frequency control;
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Summary
The definition of proper connection conditions for wind generation is essential:

- FRT requirements.
- Reactive power – voltage control requirements.
- Frequency band of operation.
- Power quality aspects.

In Germany, wind generators have to be tested and certified for grid code compliance (SDLW indV)

Further growth of wind and PV generation will require substantial grid reinforcements and participation in frequency control and balancing services