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European Experience Integrating Large Amounts of DG Renewables

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Christian Hewicker, KEMA - Bonn, Germany

David Korinek, KEMA - San Diego, CA

Karin Corfee, KEMA – Oakland, CA

Experience you can trust.

Overview

- Objectives and Overview
- Grid Infrastructure and DG Interconnection
- Network and System Operation
- Summary of Observations

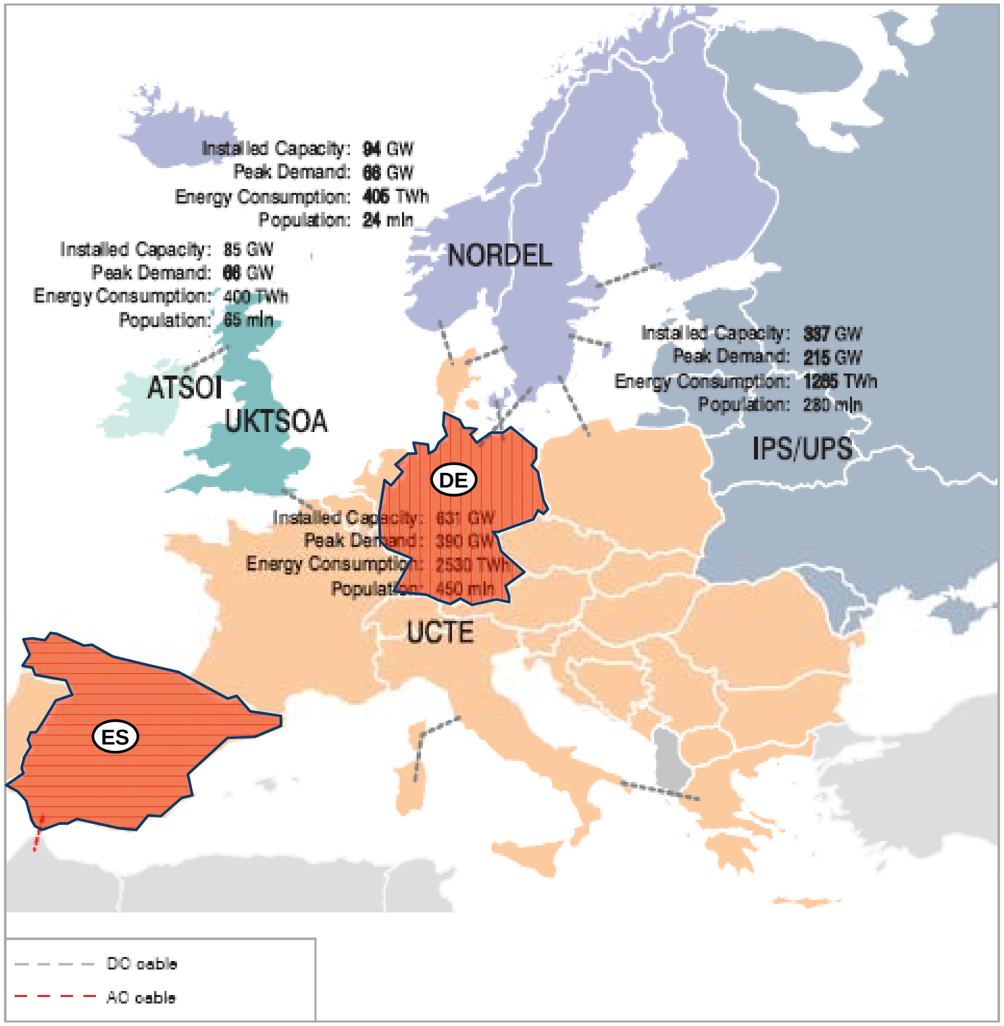
Key Questions Investigated (Memo 1)

- How are electric T&D systems configured in Germany & Spain (vs. California)
- How has the configuration been changed to allow for greater DG integration?
- How do they handle grid voltage impacts and back-feed issues?
- What ancillary technologies (e.g., storage) and policy measures allow for greater back-feed?
- Do German and Spanish grid operators simply allow greater risks in order to accommodate DG/renewables?

Key Questions Investigated (Memo 2)

- How is “DG” defined in Germany and Spain?
- What analytical methods and tools are used for DG/renewable integration and operation?
- How do Germany and Spain forecast for and manage renewable resource variability?
- How do European grid frequency “control performance requirements” compare to CA?
- What specialized grid operator training is provided in regard to renewables?
- How is curtailment of renewables handled in operational planning and real-time dispatch?

Analysis focused on two of the largest European markets

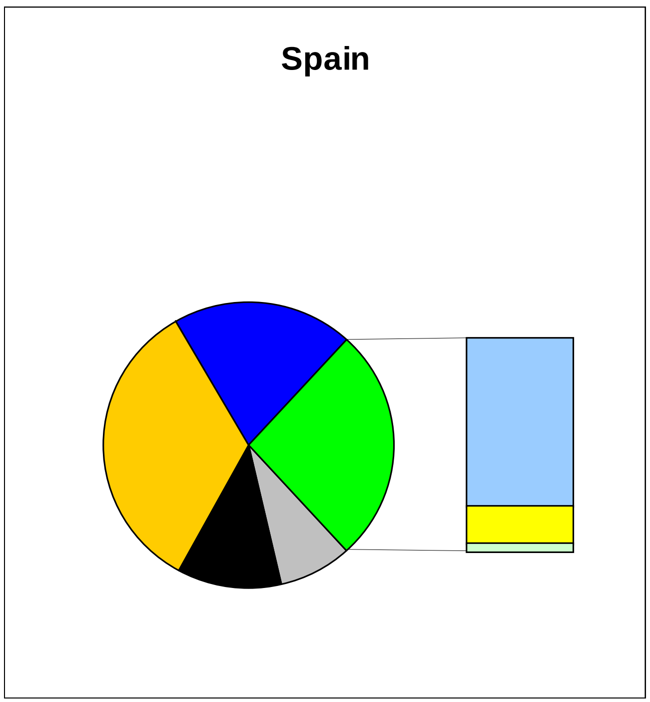


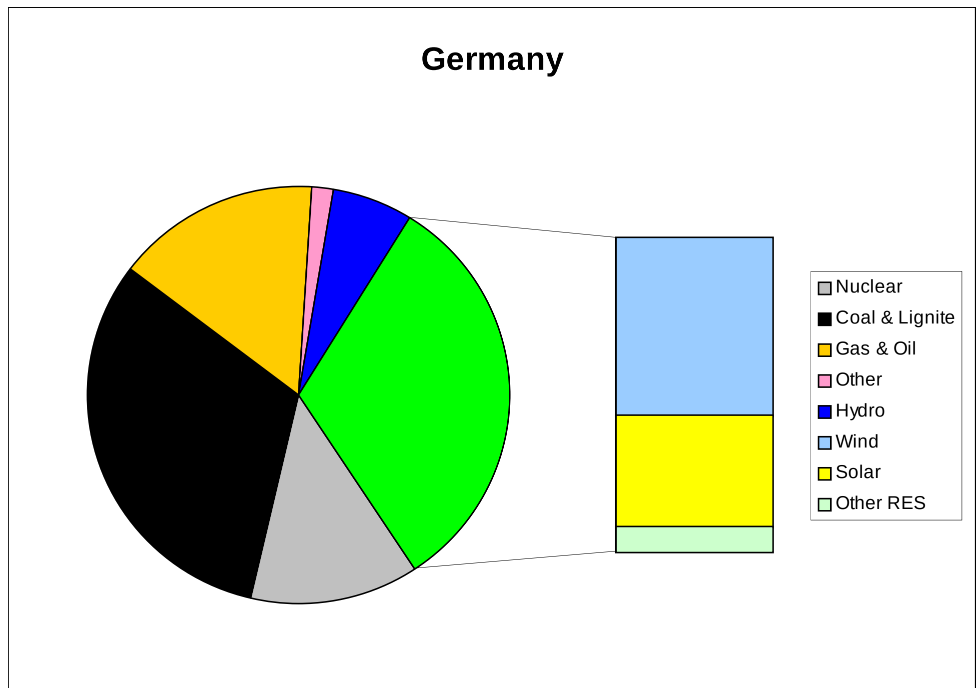
Both countries are part of UCTE, one of the largest interconnected systems in the world

UCTE – Union for the Coordination of the Transport of Electricity
UPS/IPS – Unified / Integrated power system
UKTSOA – Association of UK TSOs
ATSOI . Association of the Transmission System Operators of Ireland

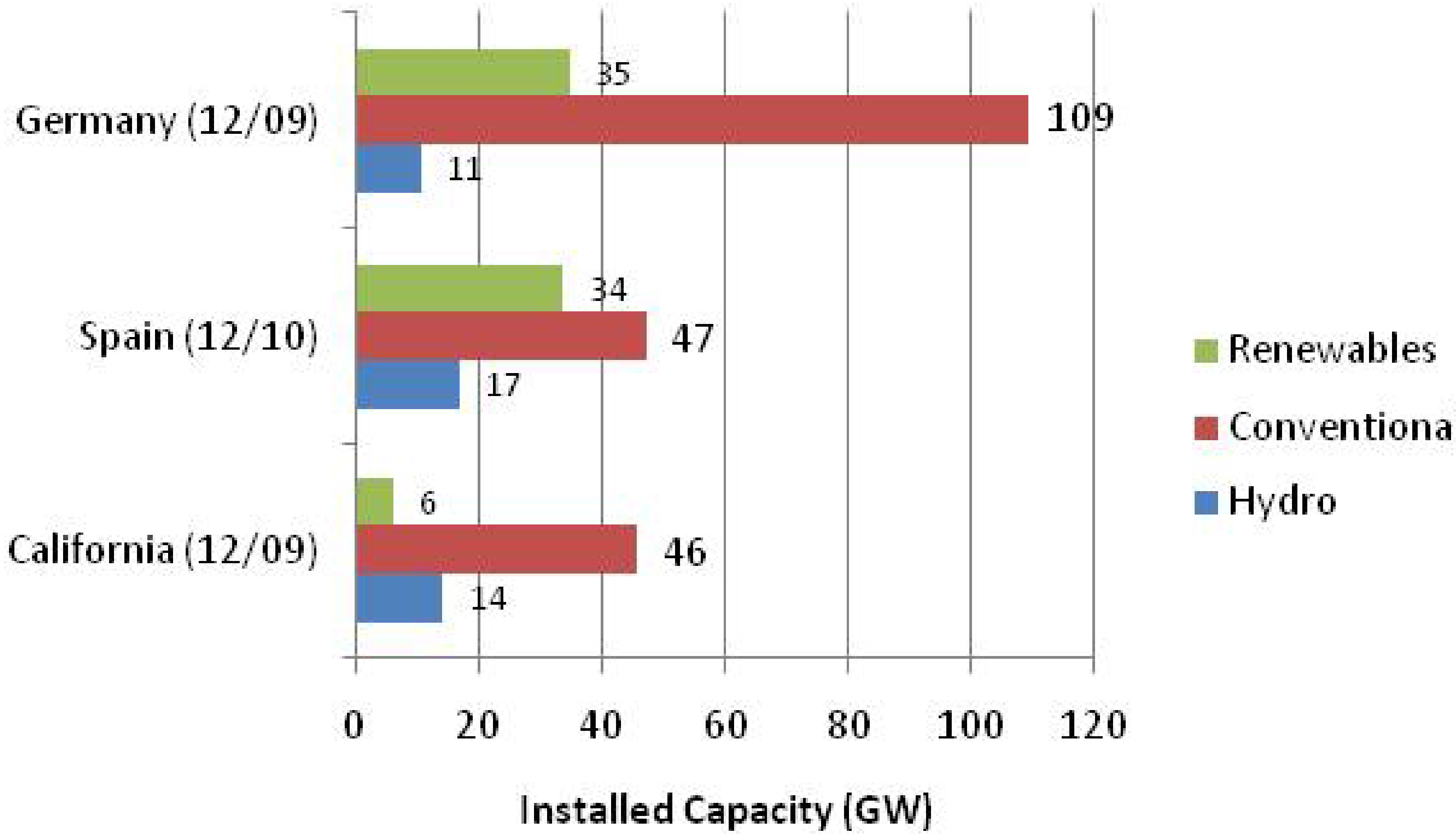
Both Germany and Spain characterized by high penetration of renewable energies

- Installed capacity of renewable energies (excluding hydro) represents approx. 50% of annual peak demand on both countries
- Note significant share of inflexible plants in Germany (nuclear, coal and lignite) vs. more flexible generation structure in Spain





Comparison of California to Germany & Spain



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AC Grid Voltage Levels in Germany and Spain comparable with Californian practice

- Using IEC Network Voltage Definitions (Phase-to-Phase)

Network Level	Germany	Spain	California
Extra-high voltage (EHV)	380 kV, 220 kV	400 kV, 220 kV	500 kV, 345 kV, 287 kV, 230 kV, 220 kV
High voltage (HV)	110 kV	132 kV, 110 kV 66 kV, 45 kV	138 kV, 115 kV, 69 kV, 66 kV
Medium voltage (MV)	30 kV, 20 kV, 15 kV, 10 kV	30 kV, 20 kV, 15 kV, 13.2 kV, 11 kV	34.5 kV, 13.8 kV, 12.47 kV, 4.8 kV, 4 kV
Low voltage (LV)	400 V	400 V	480 V, 208 V

Connection level of renewable DG typically defined by size of installation(s)

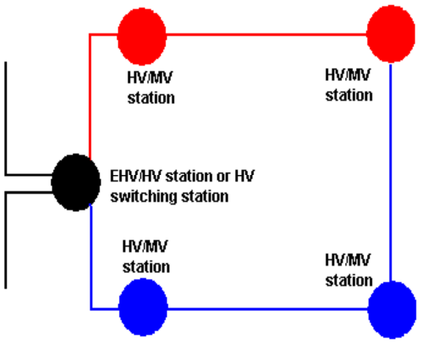
- Example:
  General Rules for Selecting the Voltage Level of the Point of Common Coupling, according to the Rated Power of Generation Plants (Germany)

Rated power of the generation plant	Voltage level of grid connection
Up to 30 kW	LV grid without verification
30 to 200 kW	LV or MV grid
0.15 to 20 MW	MV grid
15 to 80 MW	HV grid
80 to 400 MW	EHV grid

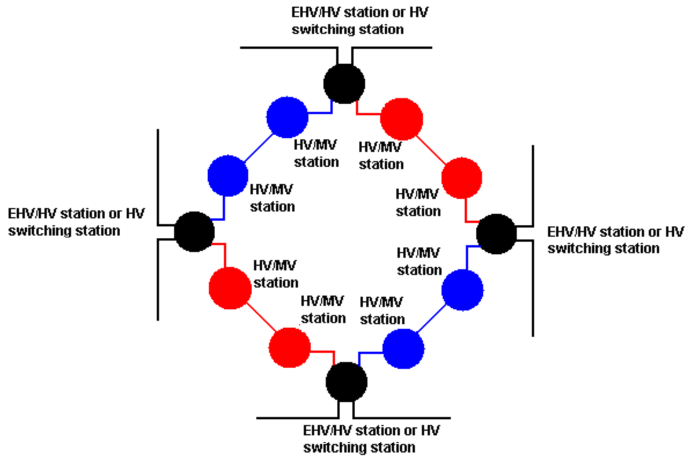
Similar to California, HV / MV are generally designed to provide for alternative sources of supply

- Example:
  Typical HV grid configurations in Spain

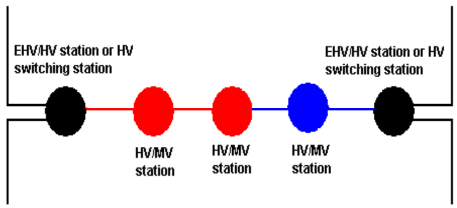
Looped HV Grid (Single Source Point)



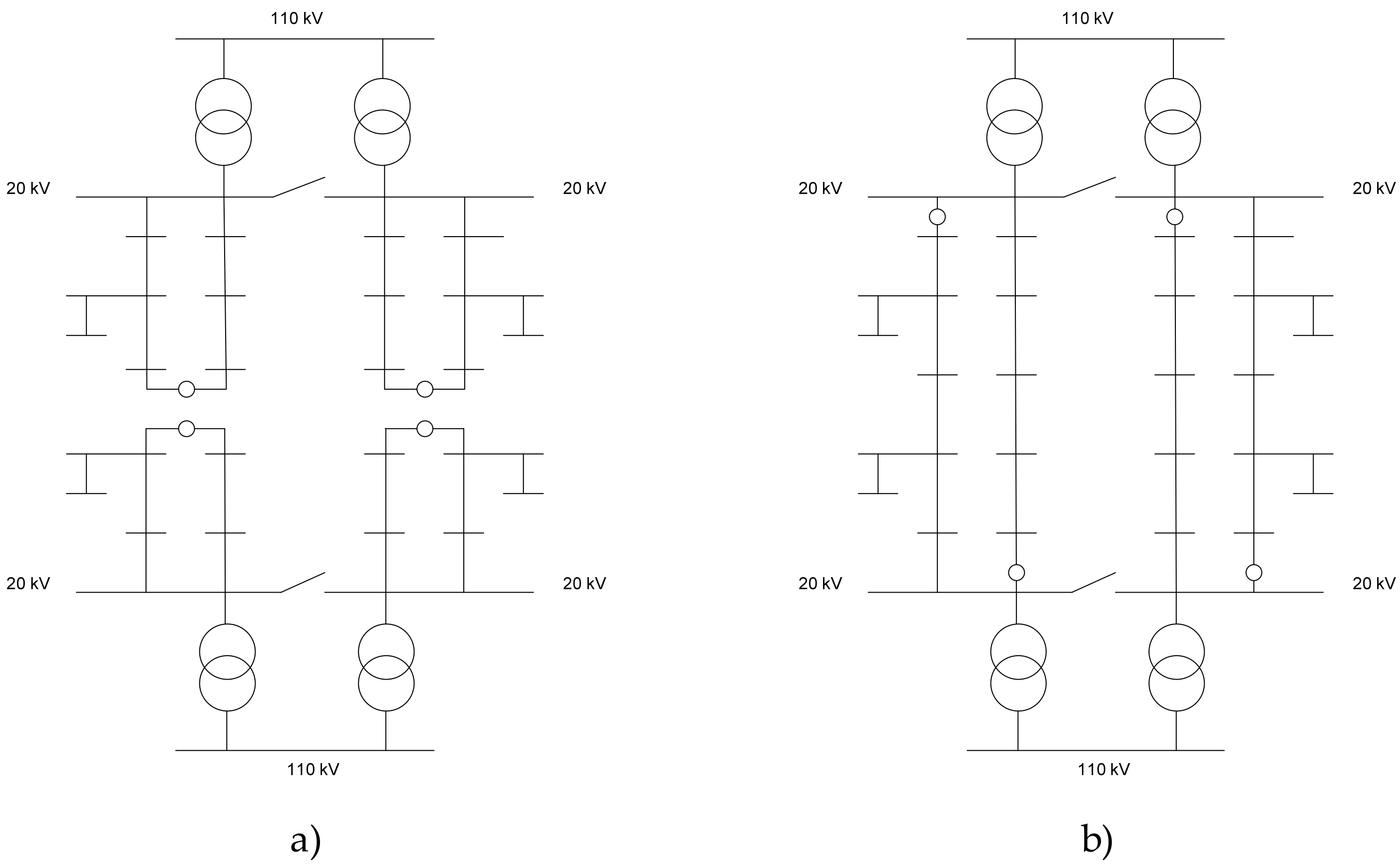
Meshed HV Configuration



"Bridge" Configuration (HV Grid Fed from Two Points)



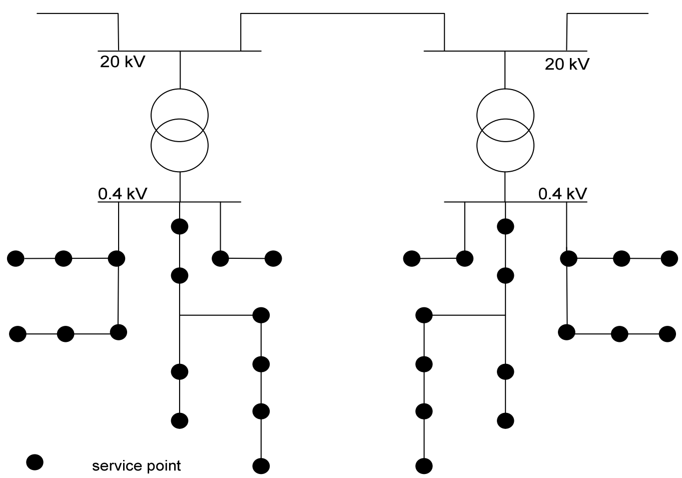
MV distribution grids in Germany operate radially (with normally open backup tie points)



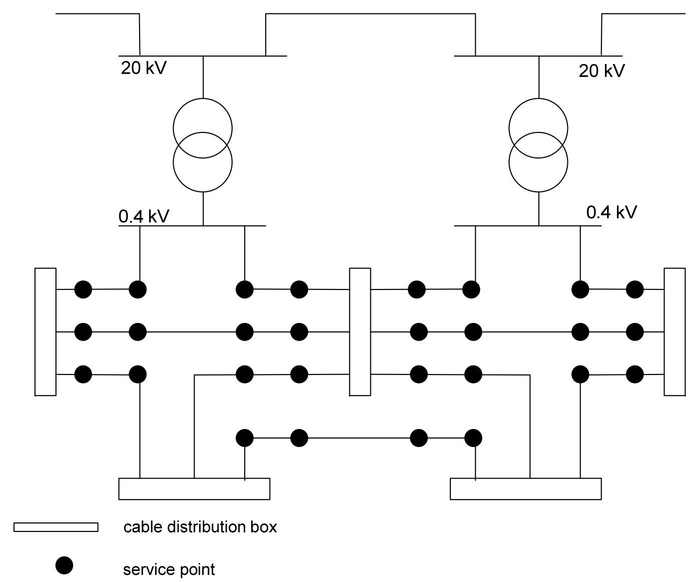
Spanish LV networks are based on a radial structure, in contrast to meshed LV urban grids in Germany

- Note: European LV networks typically based on three-phase circuit configuations down to the customer connection point

Radial LV grid structure in rural Germany and most of Spain

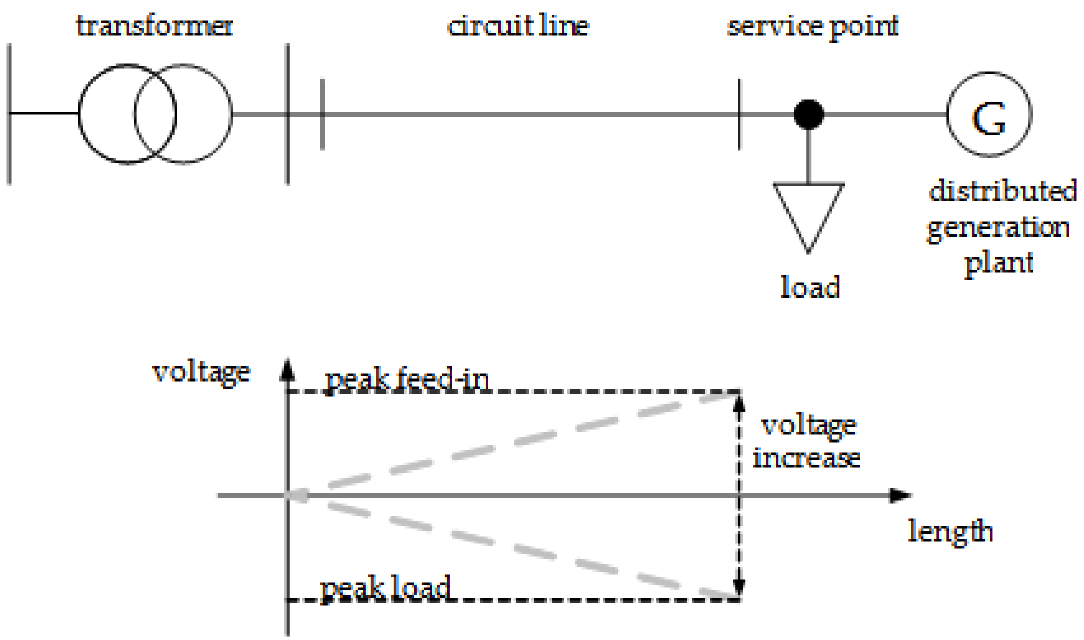


Typical layout of urban LV grid in Germany



German power quality rules, mainly in rural areas with long lines, often impact a DG plan of service

- Grid upgrades or change in PCC can occur due to 2-3% limit on steady-state voltage rise from PCC to substation (e.g., off-peak load vs. high DG infeed), flicker levels, thermal overloads, etc.
- Due to use of 4-quadrant relays, Back-feed is generally allowable.



Typical “least cost“ grid planning upgrade options used by German network operators to integrate DG

Option	Grid overload	Critical voltage variation	Power quality issues
Direct connection to substation (e.g., change in Point of Common Coupling)		•	•
Upgrade of grid circuit conductors	•	•	•
Upgrade upstream transformer bank	•	•	•
Reduction of the grid circuit length		•	•
Relocation of a normally-open loop disconnect point	•	•	
Adjust set point of HV/MV transformer auto tap changer		•	
Using reactive power capabilities of DG project		•	
Construction of a new substation	•		

Despite DG priority access to the grid, both countries apply different approaches to interconnection rights

- In both Germany and Spain, renewable DG has a legal right to be granted access to the grid
- In Germany, a DG‘s costs for interconnection are based on the calculated costs of connecting to the closest possible PCC (even if connection at this point would violate grid technical rules)
  - Any incremental costs needed to comply with grid technical rules are borne by the network operator (i.e., socialized)
- In contrast, Spanish network operators have been able to impose limits on the volume of DG to 50% of load in any area or branch
  - As a result, back-feed situations and the need for network upgrades are much less common in Spain than in Germany
  - Cost sharing rules for upgrades in Spain are also less defined

Germany expects significant costs for further integration of renewables at EHV, HV and MV

- Two recent studies have investigated the expected impact of continued renewable expansion on grid expansion needs:
  – To transport power from future offshore wind power plants in the North to load centers in the South
    – need 3,000 km of new EHV lines by 2020 at an *annual carrying cost* of €1 billion/yr
  – For forecasted growth of solar PV in Germany (e.g., 33 – 52 GW of new PV by 2020)
    – from 195,000 km to 380,000 km of new HV and MV lines may be required
    – estimated installed capital cost of €13 billion to €27 billion
- In other words, most of the “ low hanging fruit“ has been picked!

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Spanish and German TSOs have taken several steps to facilitate the integration of renewable DG

- Requirements for remote control and monitoring by TSO
  - Remote control required for all projects ≥ 100 kW in Germany and for all projects ≥ 10 MW in Spain (national control center)
- Technical rules in both countries have been adjusted in recent years to mandate fault-ride-through capabilities for new wind power plants
- In Germany, a bonus is being paid to renewable DG that can provide reactive power control to the grid
- Similarly, Spain pays a bonus for older wind power plants with fault-ride-through capabilities

Establishment of dedicated wind control centers in Spain

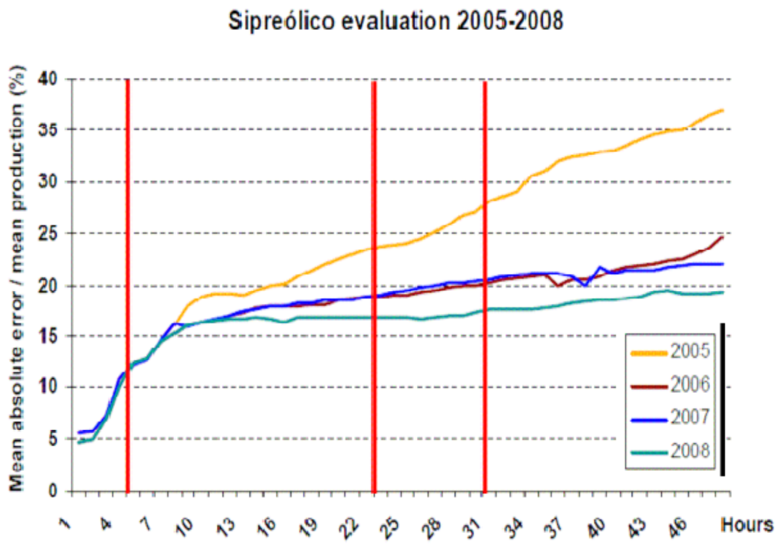
- The Spanish TSO (REE) has a national Control Center for Renewable Energy (CECRE), which includes:
  - Real-time communication and control of all wind farms ≥ 10 MW (via 14 regional control centers)
  - Advanced forecasting systems
  - Continuous real-time simulations of grid faults and related wind farm outage impacts for grid reliability assessment

Frequency Control and Balancing Services

- Control Performance Standards in ENTSO-E (formerly UTCE) appear to be comparable to NERC/WECC
- Balancing services for intermittent renewables
  - Germany has allowed explicit regulating reserves for renewables until 2011 (up to +/- 600 MW)
  - Originally, a significant increase in reserve requirement as a result of growing wind power was expected in the future
  - However, latest studies have concluded that improved wind forecasts will not require any additional reserves until 2020
- In NERC/WECC impact of intermittent renewables is lumped with other regulating reserves and cannot deploy “contingency reserves” for renewable ramps

Both Germany and Spain have made major advances in the forecasting of wind (and solar) power

- Solar power forecasts in Germany have reached a similar quality level as for wind power
- A recent study in Germany has estimated that the quality of wind power forecasts may improve by another 50% by 2020

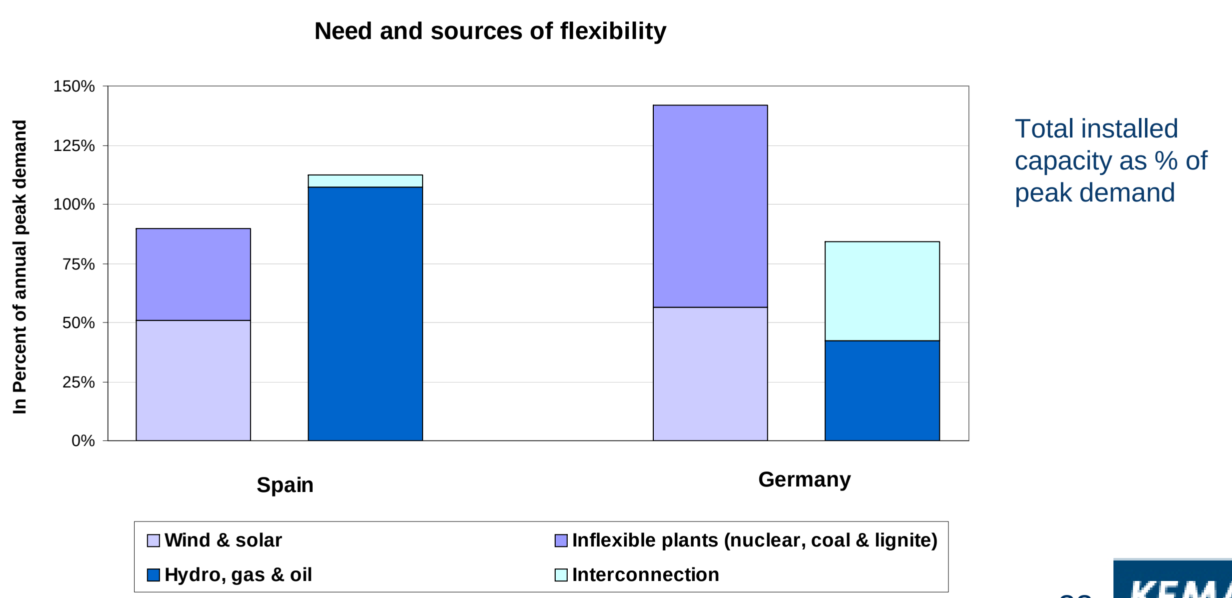


RMSE Renewables Forecast Error	Germany, Spain[2]	California[1]
Day-Ahead	< 5%	< 15%
1 Hour-Ahead	1.5%	<10%

[1] Revised Analysis of June 2008 – June 2009 Forecast Service Provider RFB Performance, March 25 2010. CA ISO (http://www.caiso.com/2765/2765e6ad327c0.pdf).
[2] Note that the statistics for Germany and Spain differ from Memo # 2. The numbers reported in the memo for Spain indicated maximum allowable forecast error rather than actual forecast error.

Dispatchable resources and tie capacity have been essential to renewable integration in Germany/Spain

- Both countries have high ratio of intermittent generation, but Spain benefits from a relatively larger share of dispatchable resources (hydro, gas and oil generation) to provide balancing/regulation
- Germany relies more on access to dispatchable resources via ties to neighbouring countries (including hydro-rich Austria, etc.)

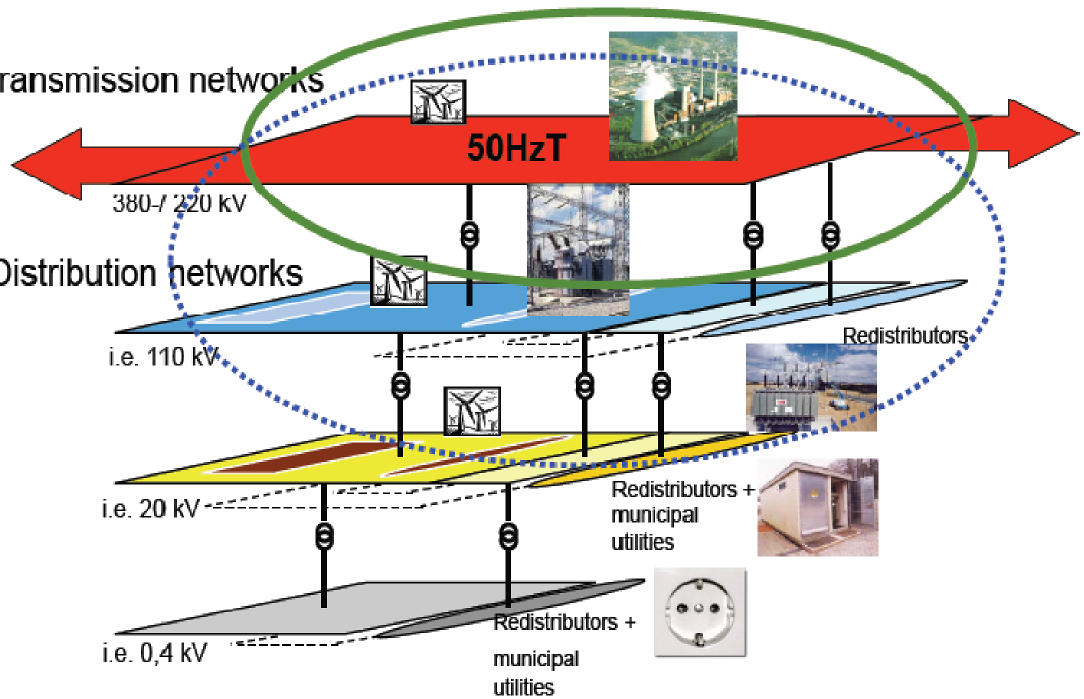


Curtailment of Renewables

- CECRE in Spain curtails renewables if needed for grid security due to real-time grid fault event assessment simulations (including loss of intertie with France)
  - However, for congestion relief, renewables are the last tier curtailed under Royal Decree
- In Germany, all projects over 100 kW equipped with TSO remote control capability
  - TSOs can initiate step-wise reduction in output of any plant >100 kW if needed for congestion relief
  - However, TSOs exhaust all market-based options before taking such curtailments

German network operators have invested in two key dispatcher training and simulation centers

- The existing training facilities with renewable simulation capability:
  - DuTrain (Inter-TSO as well as distribution operator training)
  - Cottbus (Eastern German grid operators)



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Summary of Observations

- "DG" loosely defined as projects connecting at MV grid or below (<80MW in Germany and <50MW in Spain).
- Network configurations and voltages are comparable to California
- LV networks in Germany and Spain do not enhance DG additions
- German/Spain grid planners implement the "lowest cost" network upgrade plan to interconnect DGs. Similar upgrade options are used by planners in California.
- Grid upgrade costs for DG/renewables are socialized nearly 100% in Germany; but at a much lower percentage in Spain.
- No sweeping changes in German or Spanish grids so far for DGs
  - However, German "DENA" study shows major grid impacts coming by 2020 due to projected renewable expansion.

Summary of Observations (cont.)

- “German and Spanish grid rules regarding reliability impacts of DG are at least as strict as CA
  - higher level risks are not accepted
  - German rules limit steady-state voltage impact of a DG to 2-3% as compared to 5% limit at PCC under standard CA Rule 21
- “Four-quadrant” protection systems, standard in German MV substations, allow for back-feed conditions
  - This approach allows any combination of +/- MW & Mvar flows
  - Older protection systems in CA may need to be replaced, but newer solid-state relays may just need to be “reprogrammed”

Summary of Observations (cont.)

- German TSOs have telemetry and remote control for all generating projects >100 kW
- Spain's CECRE has full visibility and control for all renewable projects >10 MW
- German and Spanish TSOs can curtail renewable/DGs for grid reliability issues, but usually the final tier of curtailment (and only after market-based options are exhausted in Germany for congestion relief)
- Per revised German rules as of April 2011, all DG > 100kW must provide reactive power to grid (e.g., new inverter technology)

Summary of Observations (cont.)

- Similar analytical methods and tools are used for DG/renewable integration and operation in Germany, Spain and California.
  - However, better renewable forecasting in Germany and Spain
- NERC/WECC frequency “control performance requirements” are similar to western Europe
  - More conventional/hydro resources available to manage renewable resource variability in Spain
  - Similar to California, Germany relies more heavily on market based regulating services
- Germany and Spain have more advanced specialized grid operator training in regard to renewables.
- No use of ancillary technologies (e.g., storage) for renewable integration to date in Spain or Germany, but may be in future.

Question and Answer Session

Thank you for your attention.

Email Contact info:
christian.hewicker@kema.com
david.korinek@kema.com
karin.corfee@kema.com

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