Japan Renewable Energy Foundation

Spanish experience on technical integration and incorporation of wind energy into the electric market
Traditional concepts:
- Centralized supply by large power plants.
- Power flow from high to low voltage levels.

Future scenarios:
- Increasing distributed power generation.
- Progressive substitution of conventional power plants.
- Bi-directional power flows.

→ Upgrading and reinforcement of the electrical grid: generation away of the consumption.
→ REs should be involved in regulation and ancillary services.
→ Technical requirements should take into consideration the technical characteristics of the equipments and the installations.

It is important to have standards and no retroactive GRID CODES.

Source: FHG/AEE
CRITICAL ELEMENTS OF THE INTEGRATION OF WIND POWER INTO THE ELECTRIC GRID, SYSTEM AND MARKET OPERATIONS

TECHNICAL REQUIREMENTS TO CONNECT WIND FARMS TO PUBLIC MAINS:
- Power quality: flicker, harmonics, …
  - Safety.
- Minimum requirements for later technical operations: permanent voltage control, f/P, LVRT, …

TECHNICAL SYSTEM OPERATION:
- Local voltage control.
  - Contribution to grid stability.
- Regulation and balancing power costs as low as possible.

WHOLESALE ELECTRIC MARKET:
- Wind power increases market liquidity.
  - Day-ahead offers are based on weather forecasting.
  - Deviations can be compensated in the intra-day markets.
NEVERTHELESS, WIND INTEGRATION CAN BE SEEN FROM DIFFERENT POINTS OF VIEW

**TRANSMISSION SYSTEM OPERATOR (TSO)**
- Grid Security
- Technical risk: GRID CODES

**MANUFACTURER**
- Standardization, costs, ...
- Technical risk: certification, ...

**DEVELOPER**
- Economic feasibility
- Technical risks: contracts
TRANSMISSION AND SYSTEM OPERATORS NEEDS TO INCORPORATE POWER FROM RES

Increasing penetration of RES

Problems of the system operator: are they real?

- Frequency stability
- Voltage regulation
- Dynamic stability

- Lacking involvement of RES in balancing power regulation
- Substitution of conventional power plants with voltage control availability
- Risk of voltage unstability in case of sudden low voltage

NEW GRID CODES/
Postulation of system services is mandatory

Source: FGH /AEE
CURRENT GRID CODE REQUIREMENTS FOR WIND POWER

Active Power

Fault Ride Through (FRT)

Grid Code requirements:

Reactive Power

Protection Concepts

System perturbation

Harmonics

Wirkleistung $P$ [MW]
Blindleistung $Q$ [MVAr]
Anlagenkennlinie am NAP
Anforderung nach BDEW MS

Fault Ride Through (FRT)

Source: Langstädtler | FGH – Certification
ONLY 5% OF THE WIND POWER INSTALLED IN SPAIN IS NOT ADAPTED TO THE LVRT GRID CODE

- All the TSOs are concerned by sudden voltage drops and the subsequent risks of instability.
- Wind farms cannot trip off the grid in case of sudden voltage dips (Grid Code O.P. 12.3).
- WTG and Wind Farms have integrated power electronics to fulfil those requirements.
- Certification and test procurement were jointly developed by AEE and the TSO.

Source: REE

![Map of Spain with voltage levels](image)

![Graph showing voltage response over time](image)
ALL WIND FARMS OVER 10 MW OF CAPACITY ARE CONTROLLED BY THE TSO

REASONS FOR CURTAILMENTS

- Overload risks in transmission and distribution grids.
- Risks of lost of power by transient instability (LVRT).
- Limited short circuit capacity of the installed wind farms which could restrict the operation of neighbourhood protections.
- Excess of generation which cannot be consumed by the demand (limited exchange capacity with France).
LOW WIND CONDITIONS AND DEMAND DECREASE REDUCE WIND FARM CURTAILMENTS

In 2011, only ~ 74,000 MWh were curtailed, 0.18% of all wind power generation in that year.
WIND FARMS FORECAST THEIR PRODUCTION FOR THE DAY MARKET TO OPTIMIZE THE BALANCING POWER OF CONVENTIONAL POWER PLANTS
Wind power could participate in all sessions of intra day markets and it is also affected by technical restrictions.

AVERAGE DEVATION OF WIND FARMS OFFERS IS BETWEEN -13% AND +11%

Wind deviations over the offer

Error (%) = \( \frac{\text{Programación} - \text{Producción real (medida)}}{\text{Producción real}} \)

Fuente: ESIOS
In absolute terms, the deviation of the demand is much more important than the wind generation one, which, moreover, tends to decrease.
While production has increased by 37.5%, secondary and tertiary regulation costs have decreased by 28% and 27% respectively.
ANCILLARY SERVICES PROGRAMMES MANAGED BY REE

**Market Operator**
- Daily Market

**System Operator**
- Previous information DM
- Reception of nominations
- Resolution of technical constraints
- Secondary Regulation
- Resolution of technical constraints
- Deviation management
- Tertiary Regulation
- Resolution of technical constraints

**Timeline**
- 9.00 h
- 11.00 h
- 12.00 h
- 14.00 h
- 16.00 h
- 18.30 h
- 19.20 h
- 21.00 h
- 15 min antes de h
- T. real

**PBC**
**PBF**
**PVP**
**PHF**
**P48**
DAILY ELECTRIC MARKET

Production offers not matched in Spain

Modification of programmes for complex offers
HOW DID WIND POWER INFLUENCE DAILY MARKET PRICE IN 2011
WIND POWER SIGNIFICANTLY REDUCES THE COST OF ENERGY

<table>
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<tr>
<th>TIME</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<td>SAVING €/1000 wind MWh</td>
<td>1,3</td>
<td>2,1</td>
<td>2,8</td>
<td>3,2</td>
<td>3,2</td>
<td>3,0</td>
<td>2,5</td>
<td>1,8</td>
<td>1,7</td>
<td>1,4</td>
<td>1,5</td>
<td>1,7</td>
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<td>Reduction (€) for the electric system due to wind integration in 2011</td>
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<td>90.503.927</td>
<td>86.471.058</td>
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<td>67.937.132</td>
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<table>
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<td>1,3</td>
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<td>1,1</td>
<td>1,2</td>
<td>0,9</td>
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Thanks to the wind power production of 2011, the system saved 1.5 b€ due to the reduction hourly price.
CONCLUSIONS

• Collaboration among utilities, the TSO and the wind sector is essential to increase and facilitate the integration of wind electricity into the grid.

• Grid codes for wind installations are more exacting than those for conventional power plants and their ancillary components. The wind sector has always shown great professionalism and technical skills to react to those requirements.

• Cost reduction and simplification of power electronics have allowed the finding of solutions to ensure the response of wind farms in case of sudden voltage dips as well as in steady permanent conditions.

• Active involvement in the electricity market, through the participation in different markets and extensive use of weather forecasting, maximizes the integration of wind power at the lowest possible cost.
THANK YOU VERY MUCH FOR YOUR ATTENTION

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