RE Integration at High Penetration Levels. RE in Spain
Content

Energy Generation Context in Spain

RE Integration issues

CECRE. Real Time Monitor.

A glance to the future
Energy Generation Context in Spain
ENERGY GENERATION CONTEXT IN SPAIN

✅ Size: 505,992 km²
✅ Population: 40,847,371
✅ Currency: Euro
✅ GDP: $1,407 trillion
✅ GDP per capita: $30,412
✅ Annual energy: 255,179 GWh
**Law 54/1997: Liberalization of Electricity sector**

**Law 17/2007: Amends last law, erasing integral tariff and introducing TUR**

**RD 661/2007: Regulates renewable generation activity**

**RD 1578/2008: New remuneration for PV plants**

**RD 485/2009: Established how to set up TUR**

**CNE 4/2009: Regulated how to set up Equivalent bonuses other incentives addressed to renewable plants**

**ENERGY GENERATION CONTEXT IN SPAIN. Regulation**
Generation mix 2012

ENERGY GENERATION CONTEXT IN SPAIN
ENERGY GENERATION CONTEXT IN SPAIN

PERCENTAGE OF ENERGY DEMANDED COVERED BY RENEWABLE SOURCES

- Austria: 60.6% (2009), 66.4% (2010)
- Sweden: 54.7% (2009), 60% (2010)
- Portugal: 50.9% (2009), 50.9% (2010)
- Latvia: 49.2% (2009), 49.3% (2010)
- Slovenia: 36.8% (2009), 36.6% (2010)
- Denmark: 27.5% (2009), 29% (2010)
- Spain: 25.9% (2009), 29.4% (2010)
- Romania: 27.9% (2009), 28.4% (2010)
- Finland: 25.8% (2009), 26.6% (2010)
- Italy: 20.5% (2009), 22.5% (2010)
- Slovakia: 17.9% (2009), 21.2% (2010)
- Germany: 16.1% (2009), 17% (2010)
- Ireland: 14.2% (2009), 15.1% (2010)
- Greece: 12.5% (2009), 14.4% (2010)
- France: 13.5% (2009), 14.4% (2010)
- Estonia: 6.1% (2009), 10.7% (2010)

2010 target from the 2001/77/EC Directive

Eurostat, 2007
ENERGY GENERATION CONTEXT IN SPAIN. Nameplate capacity

Evolution of Wind Installed Capacity (MW)

Evolution of Solar PV Installed Capacity

Evolution of CSP Installed Capacity

RE installed capacity Dec-2011 (MW)
Some records in Spain

<table>
<thead>
<tr>
<th></th>
<th>Date</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Wind Generation</td>
<td>April 19th, 2012</td>
<td>14,889 MWh</td>
</tr>
<tr>
<td>Maximum Coverage Wind</td>
<td>Sept 24th, 2012</td>
<td>64.25%</td>
</tr>
<tr>
<td>Maximum CSP Generation</td>
<td>July 10th, 2012</td>
<td>1,363 MWh</td>
</tr>
<tr>
<td>Maximum Coverage CSP</td>
<td>July 10th, 2012</td>
<td>4%</td>
</tr>
</tbody>
</table>
REE is Spanish TSO

- Grid Operator: assure power supply
- Transport Grid Design, Planification and Maintenance.

<table>
<thead>
<tr>
<th>TN</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lines (HV)</td>
<td>18.576</td>
</tr>
<tr>
<td>Lines (MV)</td>
<td>17.221</td>
</tr>
<tr>
<td>Subs.</td>
<td>3500</td>
</tr>
<tr>
<td>Trans.</td>
<td>69.059</td>
</tr>
</tbody>
</table>
Renewable Energy Integration Issue
**TSO must balance generation and consumption**

- Stability of grid parameters: frequency, power, etc.
- Unbalance may lead whether to disconnection or to extra generation costs.

**Demand**

- Varies along time
- Depends on
  - Meteorology
  - Labor/Non-labor day
  - Day of week
  - Special events
  - Random data
RENEWABLE INTEGRATION ISSUES. Demand Variability

Cloudiness

Labor or Non-Labor days

Seasons
RENEWABLE INTEGRATION ISSUES. Demand Variability

Special events!
Evolution of energy demand in Spain
**Renewable Energy Sources**

- Availability depends on natural resource
- Intermittent vs non-intermittent
- Dispatchable vs non-dispatchable

*Generation not correlated to demand*
Wind energy: typical situations

- Wind ramps -> High gradients of energy -> Scheduling efforts.
- Wind energy fall due to over-speed protection, wind speed is higher than 25 m/s.
- Forecasts can mitigate the effects of wind variability for System Operation.
- Larger forecast errors imply the use of reserves -> Increasing system costs.
CECRE

Operación del Sistema Eléctrico Español
• 149 facilities
• Nameplate capacity: 430 MW
• Multitechnology: wind, PV, CSP, biomass, cogeneration.
• 24 x 7 x 365
• HW High availability
• Multiprotocol: IEC-104, Modbus TCP
• 2 ICCP redundant point-to-point links to CECORE y CECOEL (REE TSO)
Signals sent to CECRE:

- **P ≤ 10 MW**
  - Active Power

- **P > 10 MW**
  - Active Power
  - Reactive Power
  - Connection Status
  - Voltage

**Wind Farms**

- Wind speed
- Temperature

- Signals are sent every 12 seconds
- P>10, Control Signals to limit to a Max Operation Power in 15 minutes.
A glance to the future
“A Smart Grid is an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies”
### A GLANCE TO THE FUTURE. Smart Grids

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Today’s Grid</th>
<th>Smart Grid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enables active participation by consumers</td>
<td>Consumers are uninformed and non-participative with power system</td>
<td>Informed, involved, and active consumers - demand response and distributed energy resources.</td>
</tr>
<tr>
<td>Enables new products, service and markets</td>
<td>Limited wholesale markets, not well integrated - limited opportunities for consumers</td>
<td>Mature, well-integrated wholesale markets, growth of new electricity markets for consumers</td>
</tr>
<tr>
<td>Operates resiliently against attack and natural disaster</td>
<td>Vulnerable to malicious acts of terror and natural disasters</td>
<td>Resilient to attack and natural disasters with rapid restoration capabilities</td>
</tr>
</tbody>
</table>
A GLANCE TO THE FUTURE. Investments on Smart Grids

- **FORECAST SMART GRID INVESTMENTS**
  - €56 billion by 2020

- **FUNDING FOR SMART GRID DEVELOPMENT**
  - €384 million

- **NUMBER OF SMART METERS DEPLOYED AND/OR PLANNED**
  - 45 million installed
  - 240 million by 2020

- **FORECAST SMART GRID INVESTMENTS**
  - €71 billion

- **FUNDING FOR SMART GRID DEVELOPMENT**
  - €5.1 billion

- **NUMBER OF SMART METERS DEPLOYED AND/OR PLANNED**
  - 360 million installed by 2030

- **FORECAST SMART GRID INVESTMENTS**
  - €238-334 billion by 2020

- **FUNDING FOR SMART GRID DEVELOPMENT**
  - €4.9 billion

- **NUMBER OF SMART METERS DEPLOYED AND/OR PLANNED**
  - 8 million installed
  - 60 million by 2030
A GLANCE TO THE FUTURE. Smart Grid Projects

SMART GRID PROJECTS IN US MAP
### City of Fort Collins
- Supported by DOE seeks to transform electrical distribution system, integrating a system of mixed distributed resources and including renewables, improving efficiency and reliability, achieving Zero Energy District.
- 30 distributed generation, 5 customer locations, 3.5 MW.

### Beach Cities Microgrid by San Diego Gas & Electric
- Will prove the effectiveness of integrating multiple distributed energy resources with advanced controls and communications.
- Integrates PV, Biodiesel-fuel, energy storage along AMI.
- 50MW.

### Distributed Management System, University of Hawaii
- Will integrate AMI as a home portal for demand response.
- Home automation for energy conservation.
- Optimal dispatch of distributed generation, storage, and loads in the distribution system.
- Controls to make the distribution system a dispatchable entity to collaborate with other entities in the bulk grid.

### Washington Olympic Peninsula
- DOE demonstration project. Sophisticated system that responded to simple instructions set in place by a consumer in their preference profile.
- Consumers saved 10% on their bills.
- Peak of load reduced 15%.
A GLANCE TO THE FUTURE. Smart Grid Projects

WEB2ENERGY PROJECT

- Connects small producers, storage and controllable loads (smart meters) through remote terminals units with a Control Center
- Platform connected components: 11 MW intermittent power, 300 MW controllable power
- Domestic consumer has access to variable tariffs

MINI-BERLIN PROJECT

- Electric vehicle integration project
- 50 customers and 100 recharging stations (50 public stations and 50 home stations) pursues an open access approach...
- Electric vehicles are used as storage devices to provide ancillary services in presence of a high level of

ENCOURAGE PROJECT

- Develops embedded intelligence and integration technologies that will directly optimize energy use in buildings and enable active participation in the future smart grid environment
- Integrate energy brokerage module

- 5 countries participating
- 11 companies (small, large, universities)
- 4 demonstration locations
- €6.3 million budget
- 20% less energy needed
- 20% savings
Thank You!