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WIND POWER TECHNOLOGY

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Introduction

- Driving forces for the future development of the electric energy systems:
  - 1) Environmental issues: meet Kyoto protocol targets (reduce emissions by replacing fossil generation by zero emission generation, reduce network losses), increase social responsibility and sustainability, minimize visual impacts and land use.
  - 2) Replacement of old infrastructures (generation and grid)
  - 3) Security of Supply
  - 4) Increase quality of service (more automation and remote control)
  - 5) Electricity market liberalization (energy and services)

  - 1) Increase renewable generation, exploit clean coal technologies, CCGT and others
  - 2) Increase Flexibility of Operation of Conventional Power Plants, Adopt CO2 Sequestration Techniques
  - 3) Demand Side Management (increase load consumption efficiency)

Introduction

- Targets on RE defined for EU (2010)
  - EU Directive on Renewable Energies CE/2001/77

	RES-E TWh 1977	RES- E % 1997	RES – E % 2010
Belgium	0,86	1,1	6,0
Denmark	3,21	8,7	29,0
Germany	24,91	4,5	12,5
Greece	3,94	8,6	20,1
Spain *	37,15	19,9	29,4
France	66,00	15,0	21,0
Ireland	0,84	3,6	13,2
Italy	46,46	16,0	25,0
Luxembourg	0,14	2,1	5,7
Netherlands	3,45	3,5	9,0
Austria	39,05	70,0	78,1
Portugal *	14,3	38,5	39,0
Finland	19,03	24,7	31,5
Sweden	72,03	49,1	60,0
United Kingdom	7,04	1,7	10,0
EU	338,41	13,9	22,0

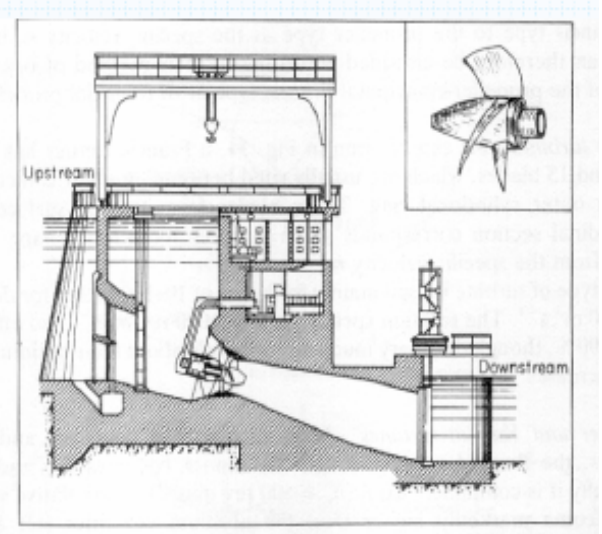
* - 1997 (very favourable year regarding hydro-electricity)

Introduction

- More recently European leaders have agreed to a legally binding objective to meet 20% of their energy needs with renewable such as wind power in a fresh drive to put the EU on track to a low-carbon economy by 2020.
  - This means intensive use of resources like: **biomass, hydro, wind (on-shore and off-shore), solar.**
  - The difficulty now lies in defining specific national targets to achieve the overall figure, taking into account each country's potential and point of departure.

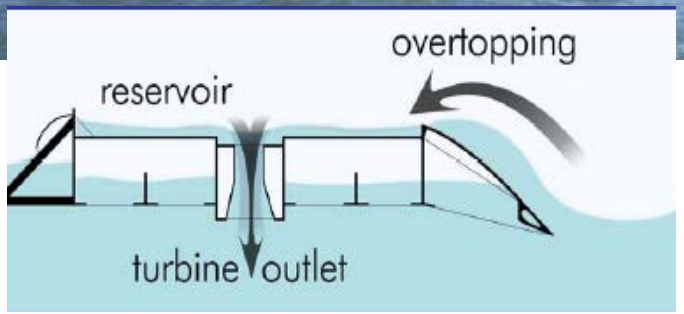
What has to change?: increasing renewable generation

- Stabilized technologies



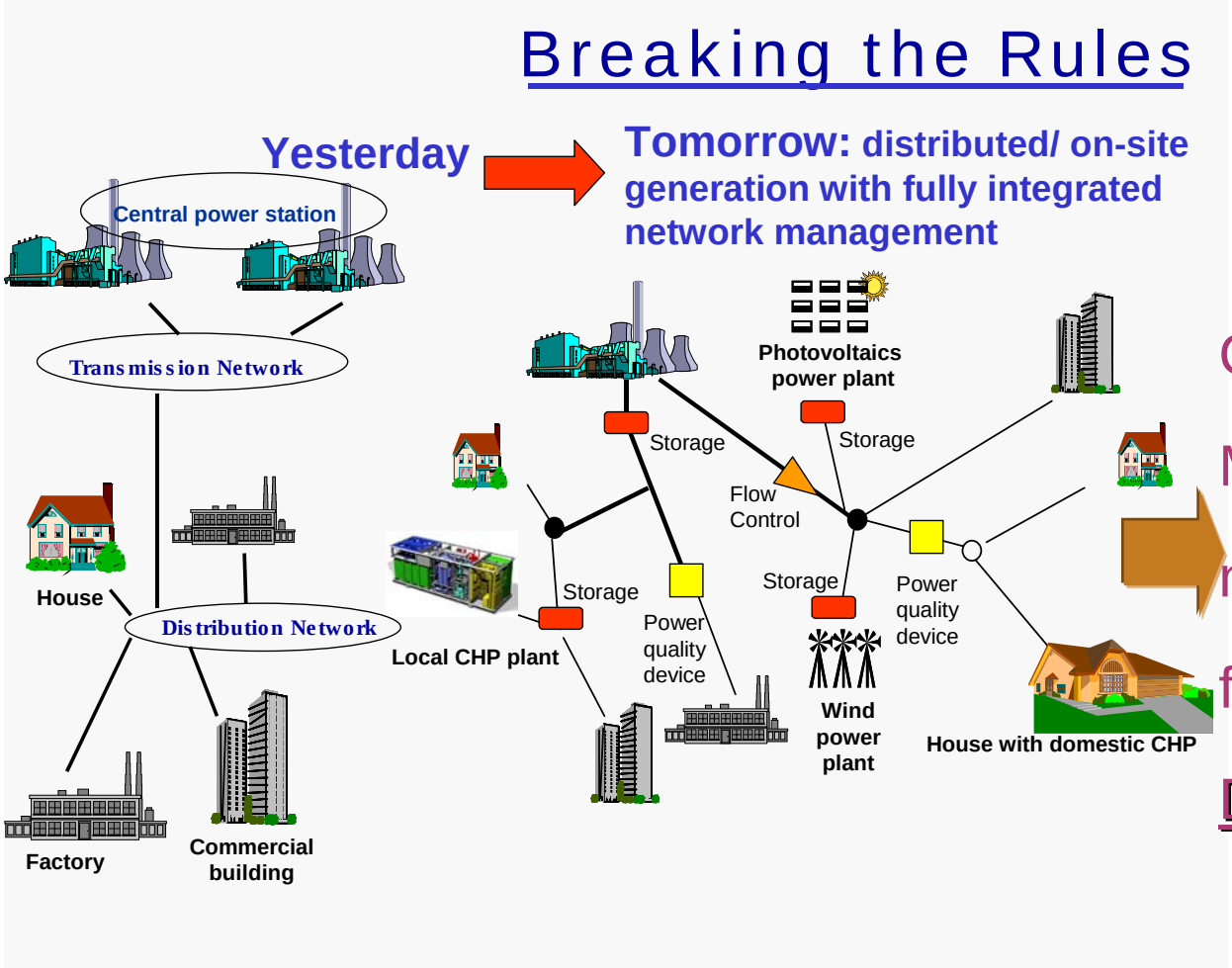
What has to change?: increasing renewable generation

- Some promising technologies



What has to change?: New grid management

- New paradigmas are under development

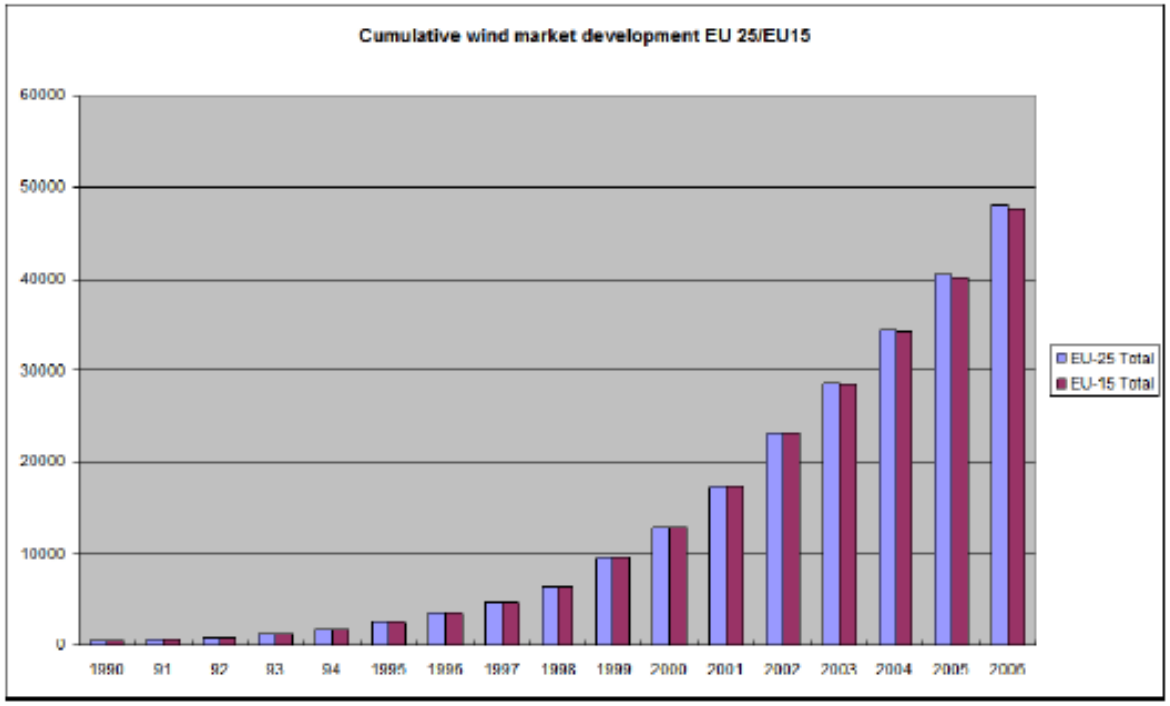


Current distribution grid Management practice needs to be changed from passive to active – DG control paradigm

Market Development of Wind Generation

Development of wind energy in Europe

Overall wind power 1990-2007



Source: EWEA

2007

- 56,535 MW
- 119 TWh
- 3.7% of EU power demand

EWEA Targets

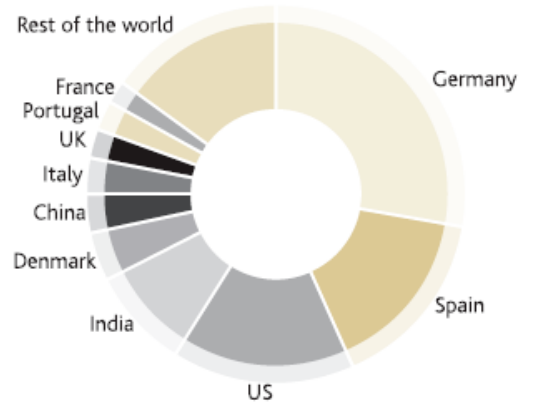
2010: 75 GW

2020: 180 GW

2030: 300 GW

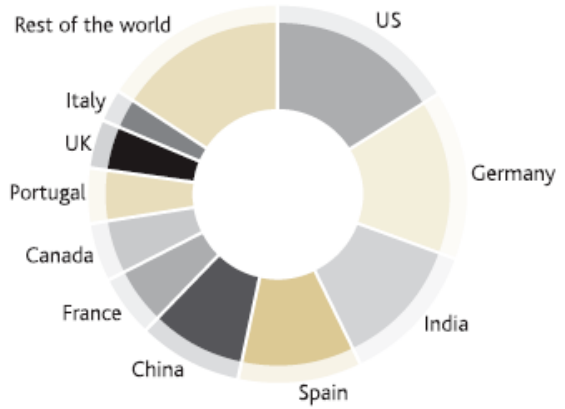
Market Development of Wind Generation

TOP 10 TOTAL INSTALLED CAPACITY



	MW	%
Germany	20,622	27.8
Spain	11,615	15.6
US	11,603	15.6
India	6,270	8.4
Denmark	3,136	4.2
China	2,604	3.5
Italy	2,123	2.9
UK	1,963	2.6
Portugal	1,716	2.3
France	1,567	2.1
Rest of the world	11,005	14.8
Total top 10	**63,218**	**85.2**
Total	**74,223**	

TOP 10 NEW CAPACITY

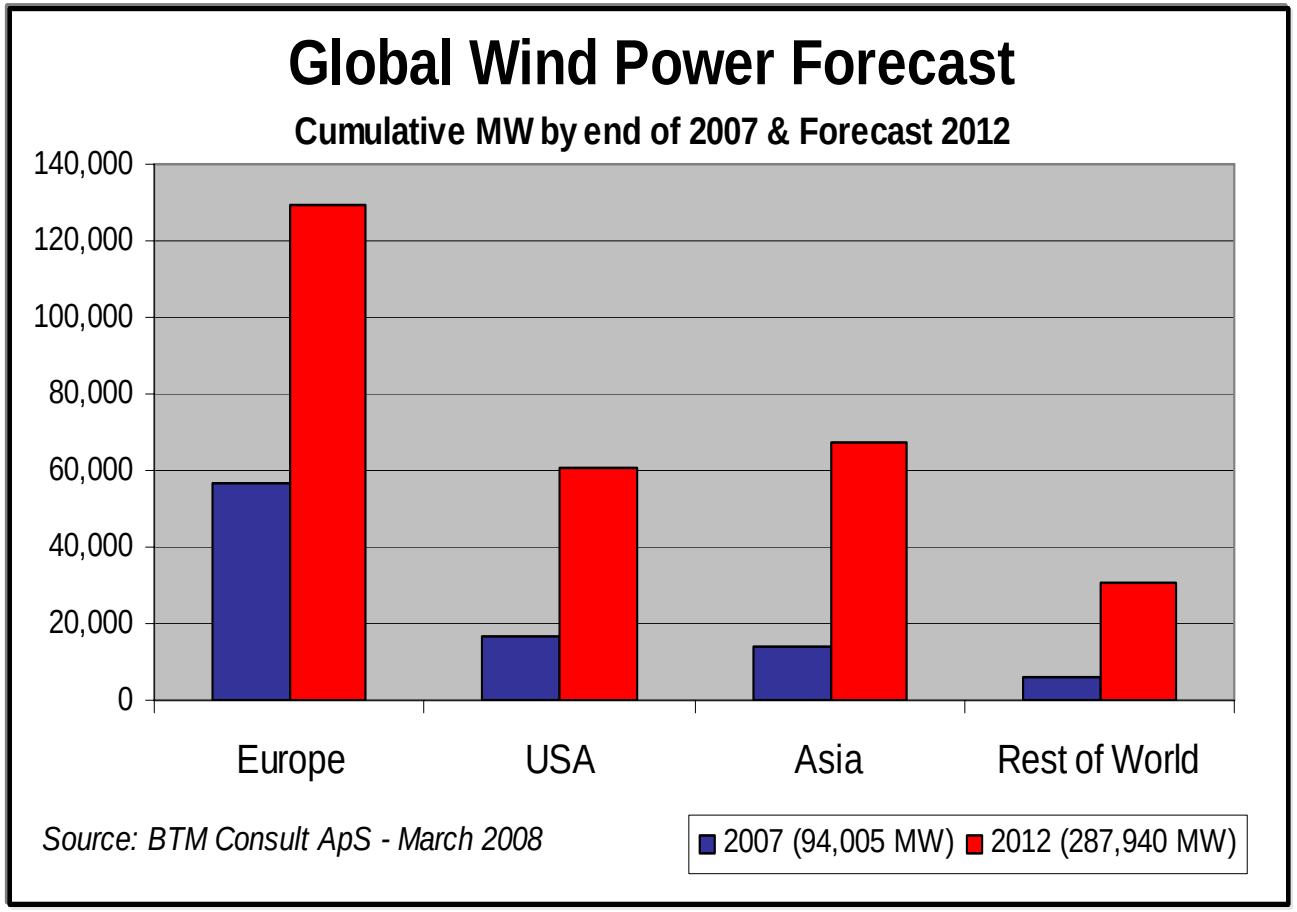


	MW	%
US	2,454	16.1
Germany	2,233	14.7
India	1,840	12.1
Spain	1,587	10.4
China	1,347	8.9
France	810	5.3
Canada	776	5.1
Portugal	694	4.6
UK	634	4.2
Italy	417	2.7
Rest of the world	2,405	15.8
Total top 10	**12,792**	**84.2**
Total	**15,197**	

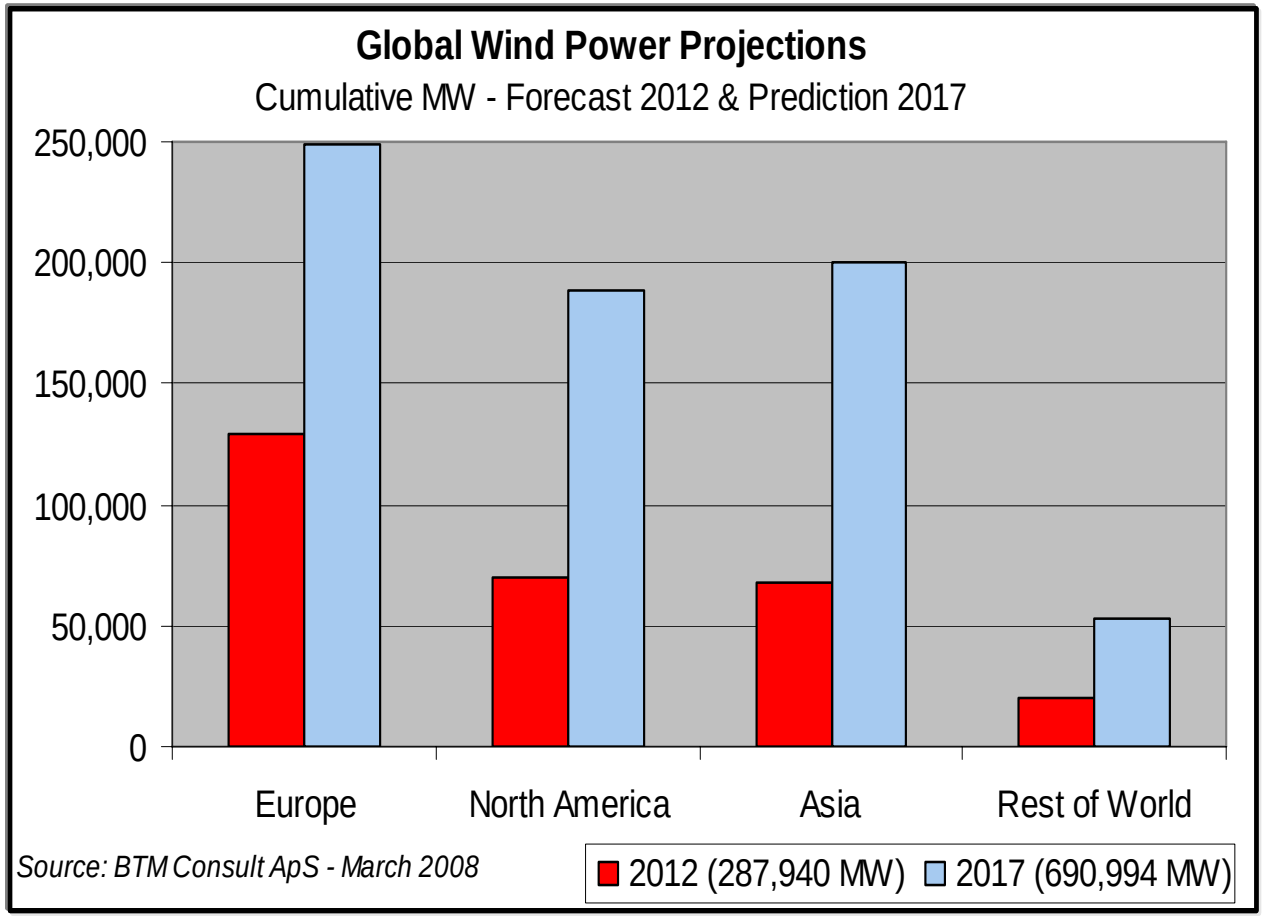
2010:
Portugal – 4500 MW
Spain – 20000 MW

Source: EWEA

Future Market Development of Wind Generation



Future Market Developments of Wind Generation



Future Market Developments of Wind Generation

	2005-2010	2011-2020	2021-2030
Wind power's share of new capacity	39%	32%	46%
New generating capacity (GW)	117	368	404
New wind generating capacity (GW)	46	117	187

Source: EWEA

Developments in Wind Power Technology

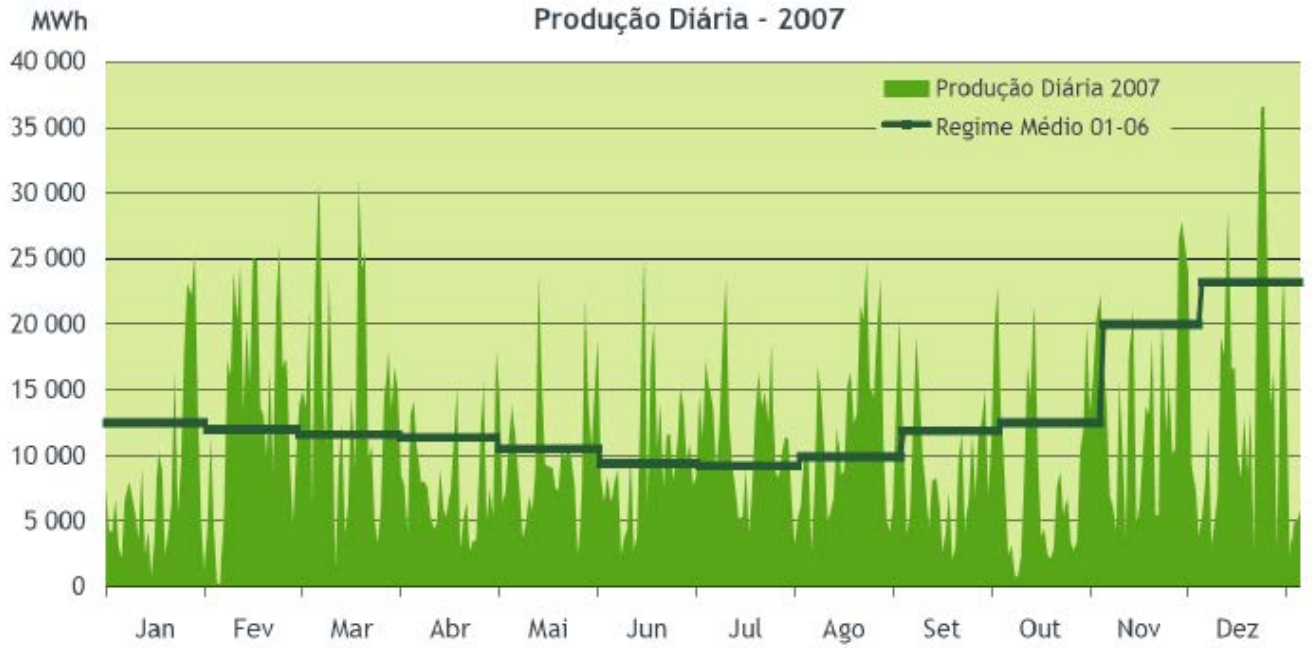
- Such a large deployment of a renewable energy source with specific characteristics requires several technological developments:
  - Wind Energy converters
    - Additional control capabilities to provide ancillary services and robustness of operation (Fault ride through, Damping oscillations)
  - System level
    - Grid Codes
    - New management and control architectures
    - Wind Power Forecasting
    - Combined operation with storage
    - Smart metering
  - Studies
    - Security of Supply
    - Reserves Management, Congestion Management
    - Transmission Expansion Planning

Characterization of the wind power resource

Portugal 2007

Power (MW) - Wind

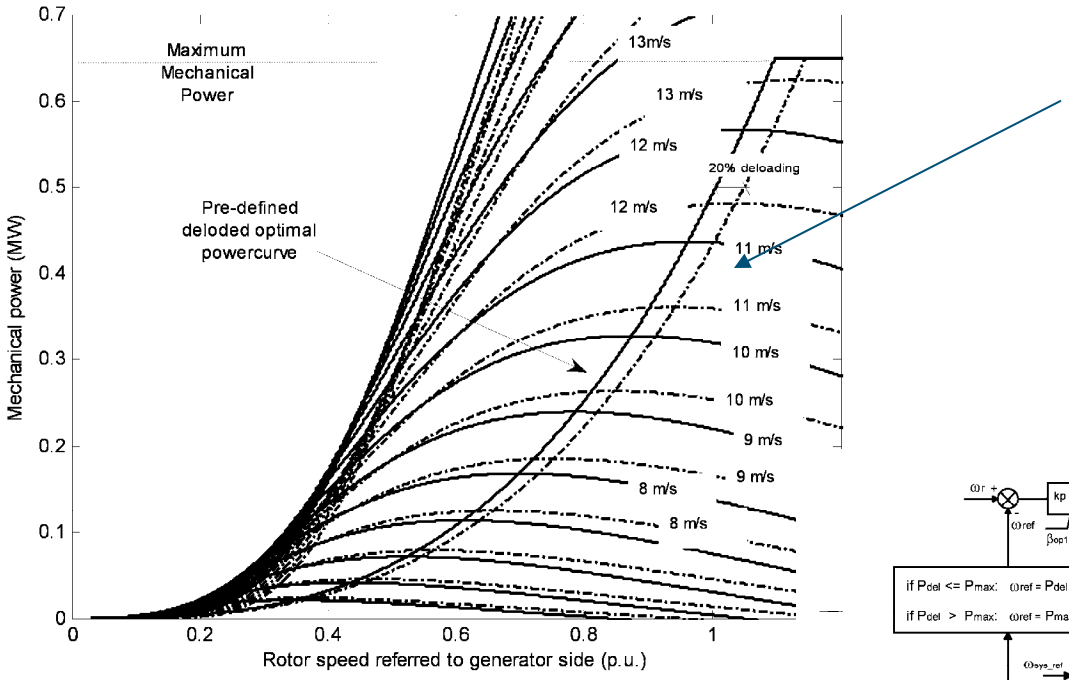
- Great volatility

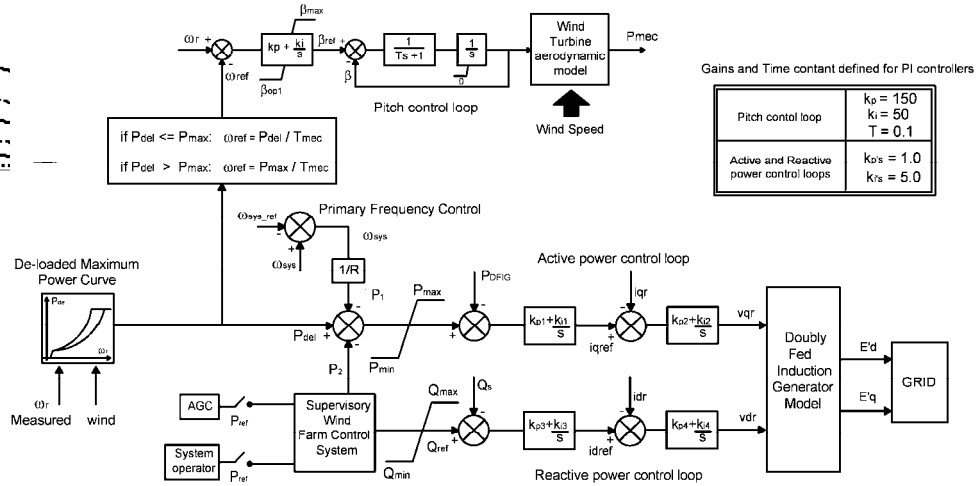


Source: REN

Additional Control Capabilities

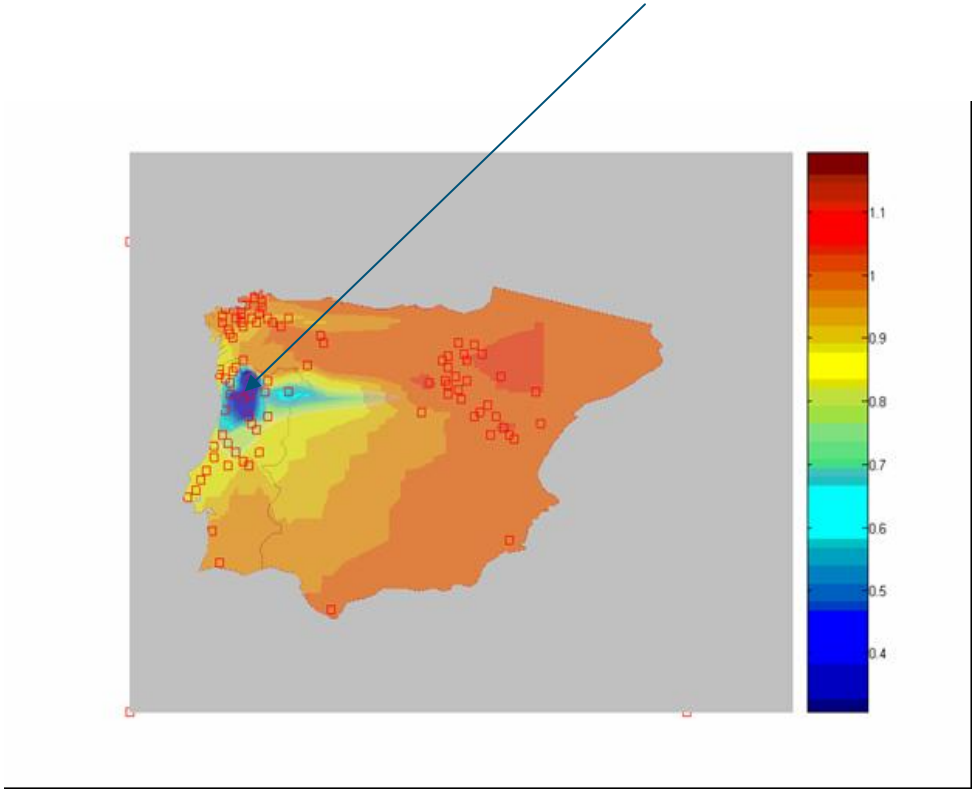
- Primary frequency control participation (Ex: with a 5% deload) → to be managed by the TSO.

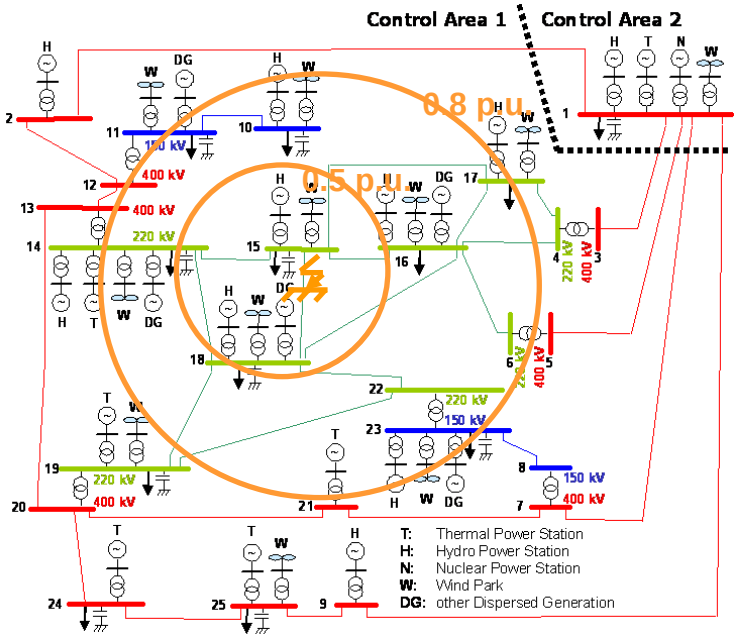




Additional Control Capabilities

- Low voltages due to short-circuits may lead to the disconnection of large shares of wind power production:

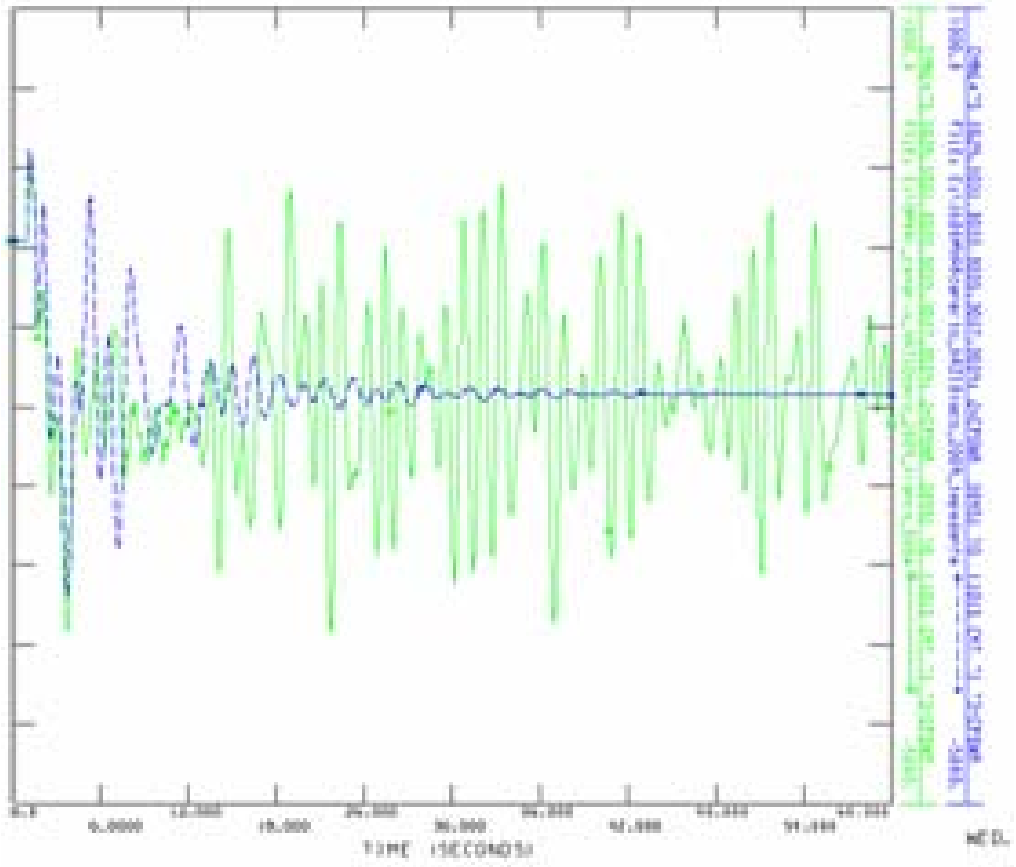




Ride through default capabilities will attenuate the problem

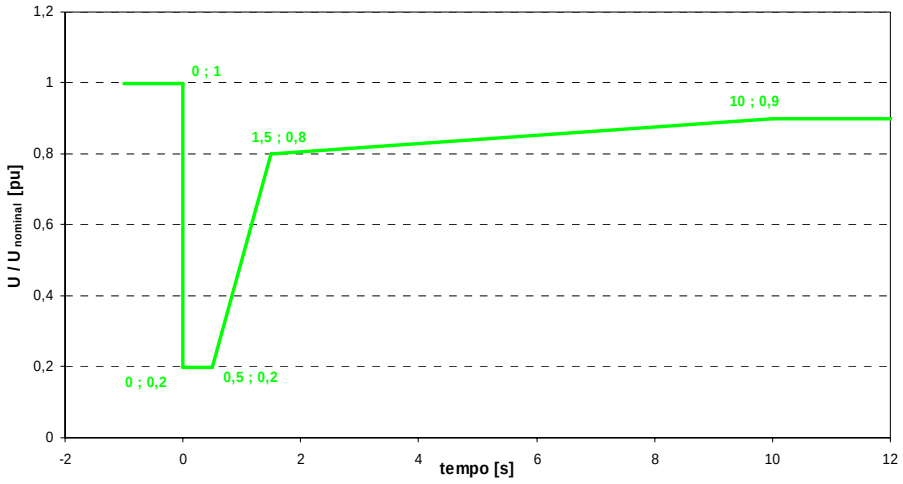
Additional Control Capabilities

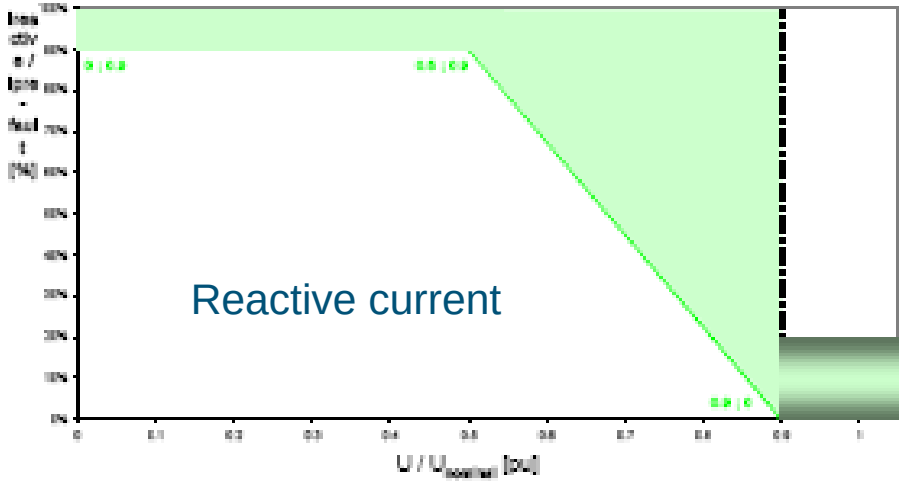
- Stability problems –interconnection with France



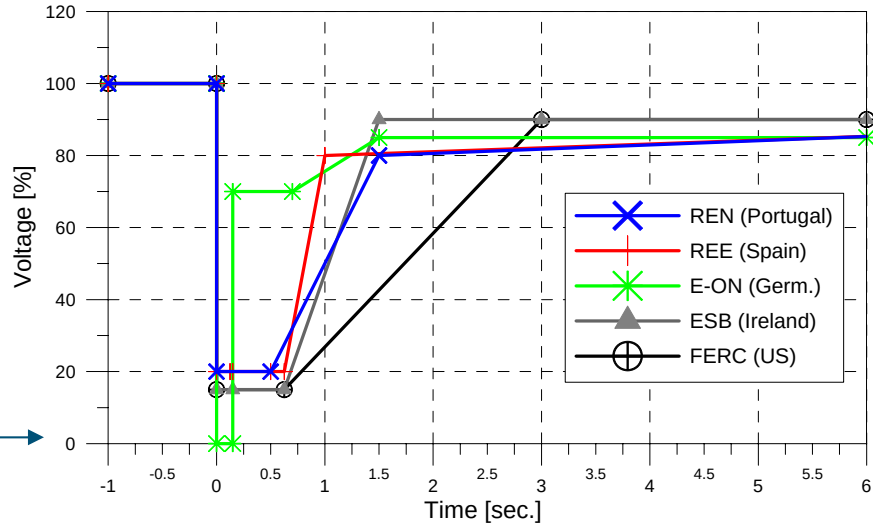
Additional Control Capabilities

- Ride through fault requirements



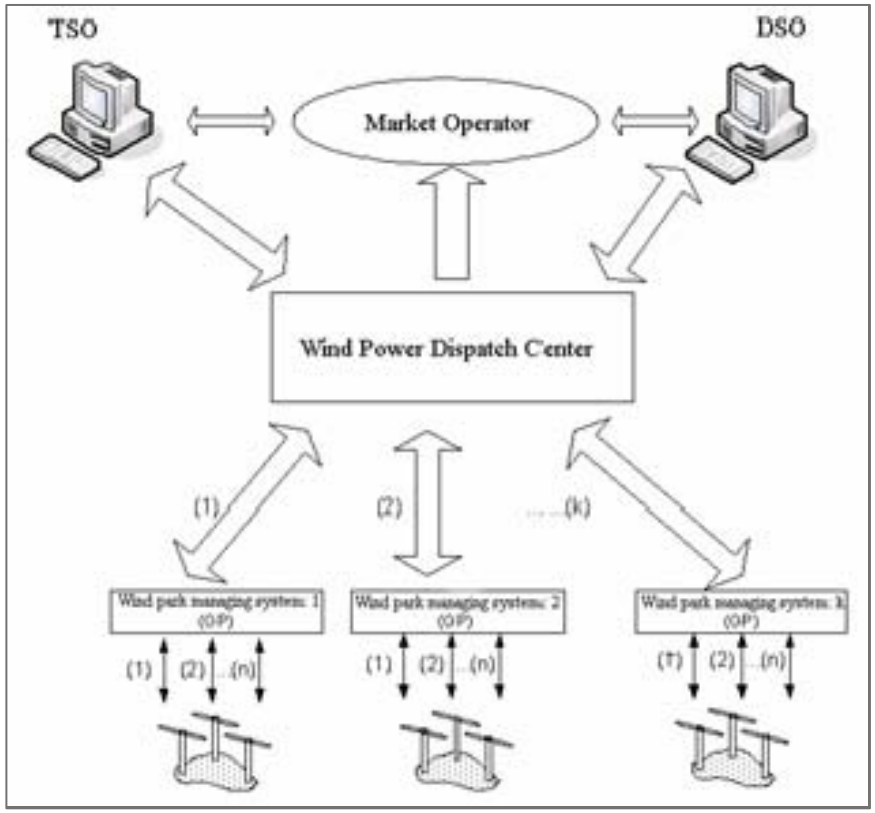


Comparing solutions



New Solutions: New management / control structures

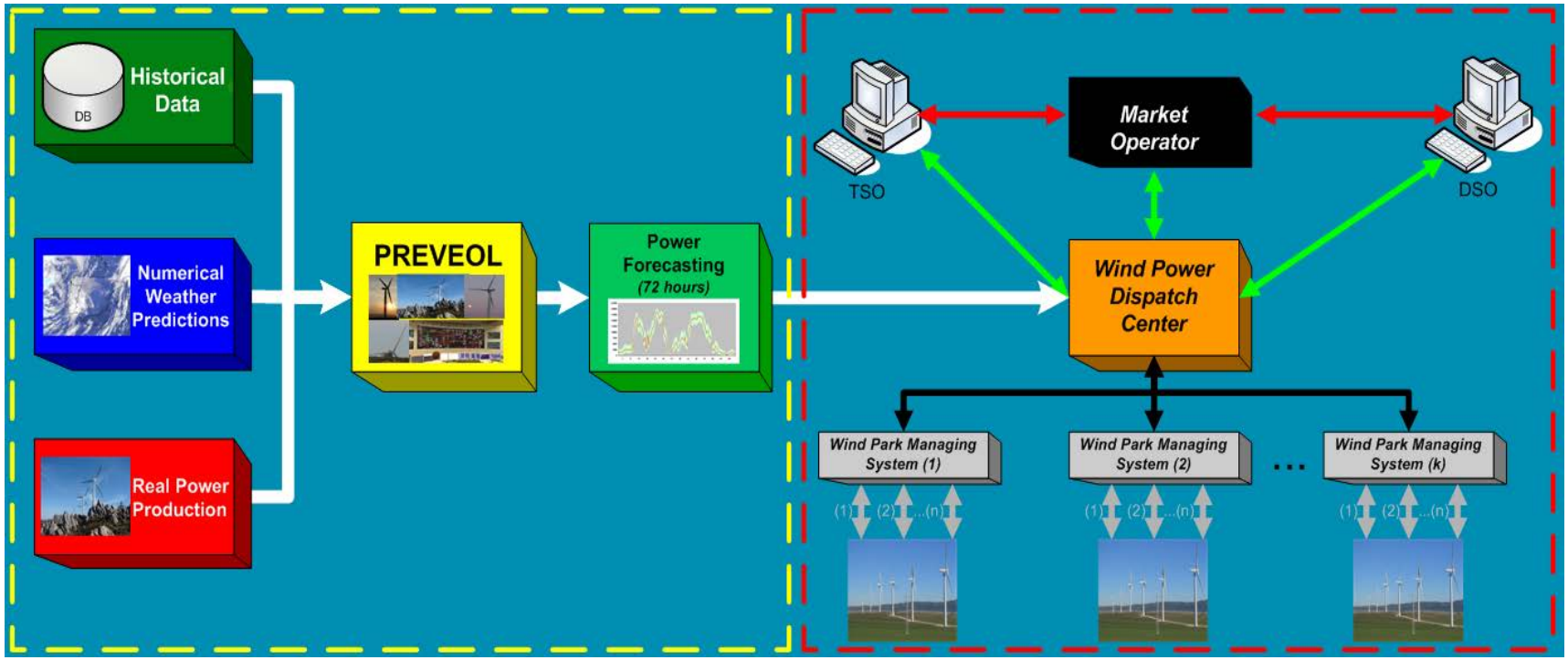
- Wind park dispatch centers acting as virtual power plants should be developed and installed



Solution already adopted for Portugal: Wind GenerationTender

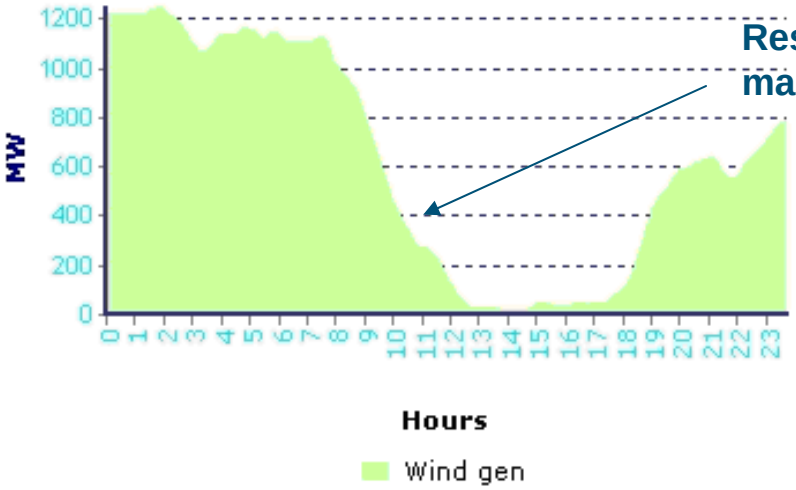
New Solutions: new management tools

- Wind Power Forecasting Tools

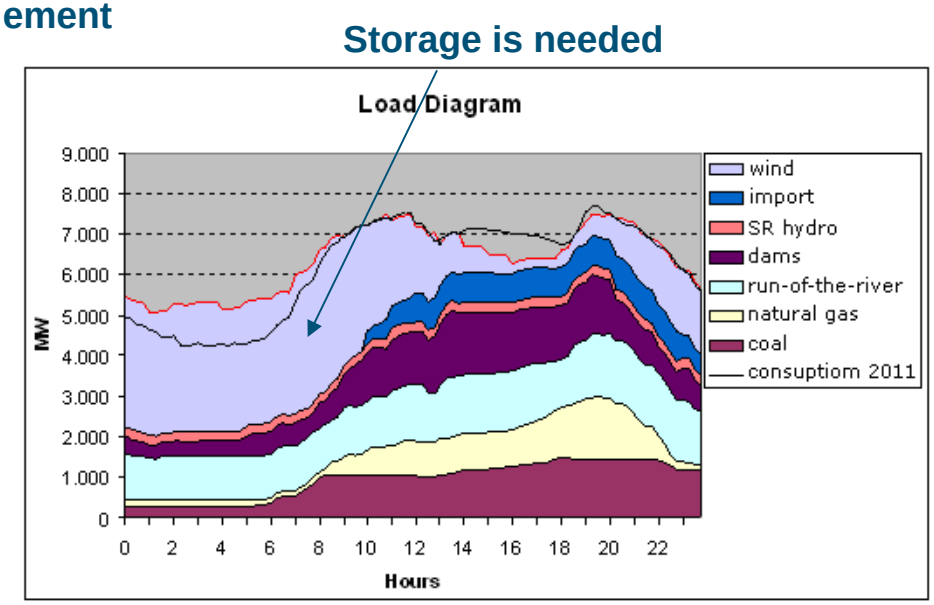


Combined operation with storage

- Storage and Reserve management



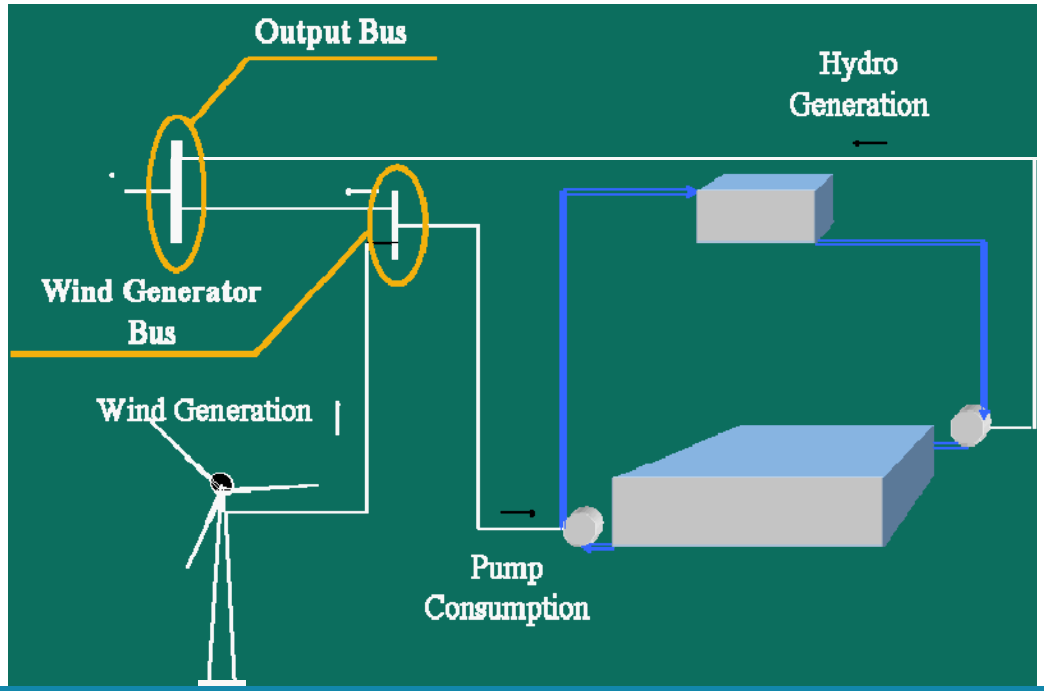
Wind Generation of 14 th February 2007
Source: REN (Portuguese TSO); http://ww.ren.pt



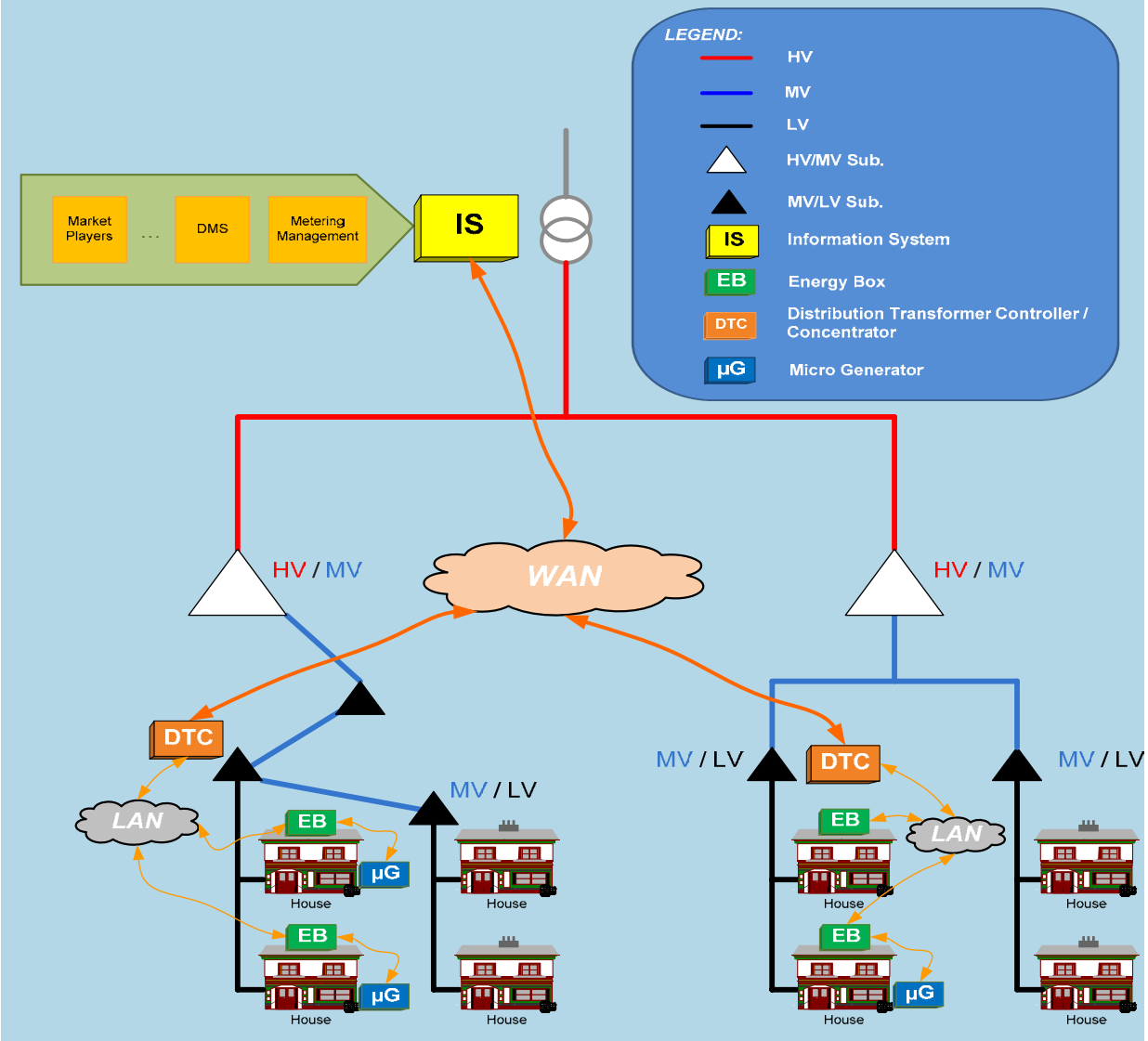
Prospective generation allocation in a winter windy wet day (2011)

Storage as way to help managing the system

- Storage technologies:
  - Medium term storage (to keep energy balance, help in frequency control, costumer peak shaving): Compressed air, flow batteries, hydro pumping storage
  - **Long term storage** (transferring energy from one period to another): hydro pumping storage

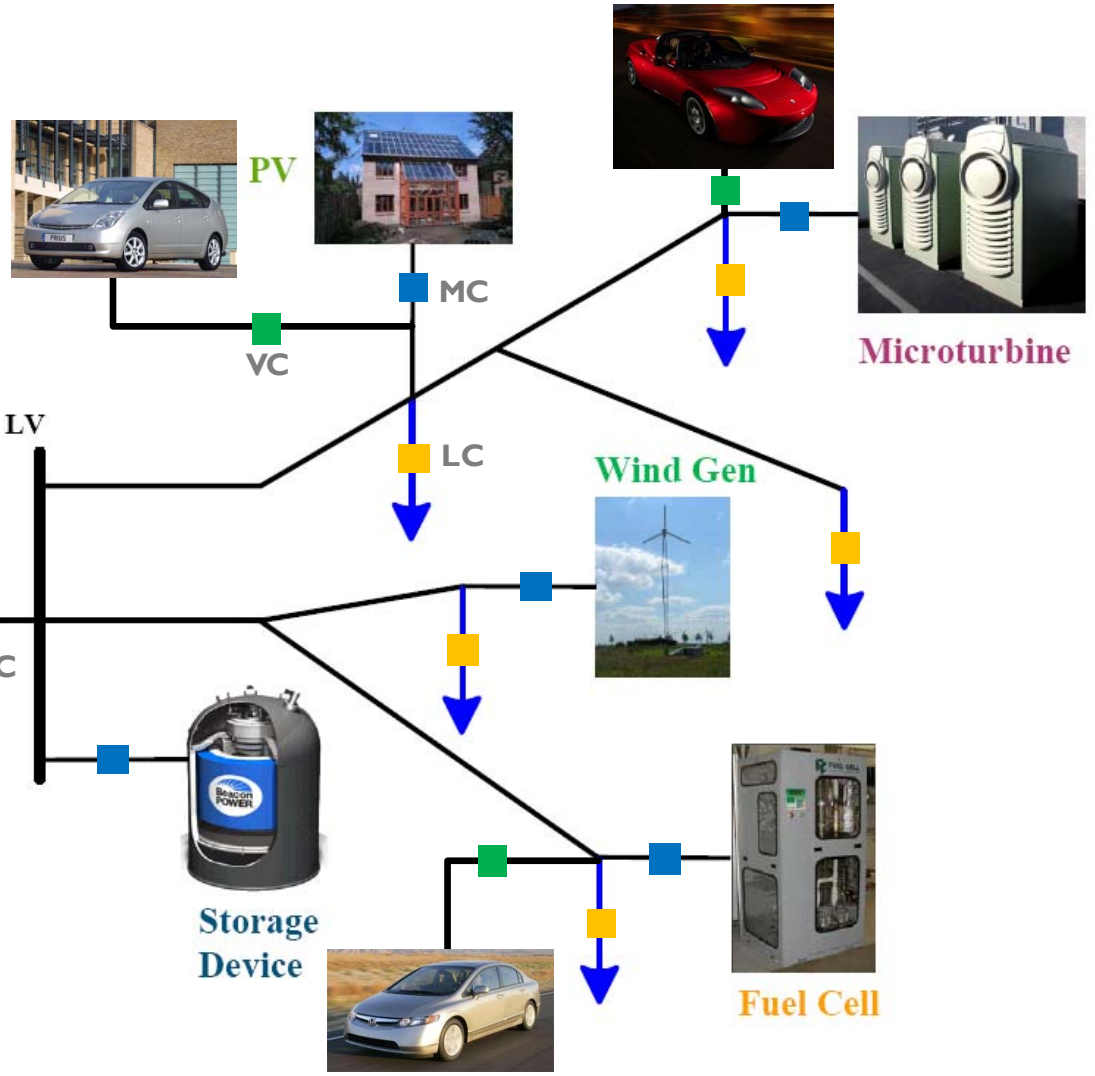


Metering and Smart Metering – A way no manage load



The Future: Wind Power and the Vehicle-2-Grid (V2G) Concept

- Electric vehicles plugged in a dispersed manner over the LV grid
- The Vehicle Controller (VC) has to regard the vehicle as a storage device that responds to both technical and economic signals → constrained use



- Electric Vehicles used as storage and loads for wind power
- Bidirectional power exchange with the grid
- Charging can be controlled accordingly with the markets and wind power availability
- Provision of ancillary services

Advanced Technical Measures adopted in Portugal

- Technical measures adopted by the public tender:
  - Allow 20% overcapacity installation in the wind parks → local control of wind power production at each wind park level.
  - Wind farms shall not disconnect during disturbances in the network → ride through fault requirement.
  - Grouping of generator under dispatching centers.
  - Require wind production forecasts up to 48 h ahead.
  - Participation of wind farms in ancillary services provision (reactive power generation [$-0.2 < \text{tg}\,\phi < 0.2$] and participation in primary frequency control when required by the system operator).
  - Allow interruptability of wind farms during valley hours (50h / year).
  - Require storage capabilities in the amount of 1h x wind park capacity (MWh)

Fostering National / Regional Economic Development

- Economic benefits (new economic activities, increase in job creation, improvements in social cohesion and environmental sustainability).
- In Portugal:
  - Total investment: 162 + 66 M€ (direct investment)
  - Total employment: 1700 + 1300 new jobs (direct investment) + 7000 new jobs related to indirect investment
- National incorporation
  - Initially: 20% of national incorporation
  - Nowadays: 95% of national incorporation (60% export)

Conclusions

- The integration, in an efficient way, of large shares of renewable energy sources requires a set of new technical solutions and operational rules, where IT technologies will play a key role.
  - A wise level of central management and decision regarding network reinforcements and operation planning is needed
  - Cooperation among TSO, DSO and wind park developers is required;
  - Definition of new technical requirements for robust and safe system operation.
- Society benefits (less tangible benefits related to energy policy):
  - diversification of primary energy sources / reduction on energy external dependence),
  - potential economic benefits (new economic activities, increase in job creation, improvements in social cohesion and environmental sustainability).
- Additional opportunities for electric power manufacturers will be created
- Competitiveness in the electric power industry will increase