RED ELÉCTRICA DE ESPAÑA

Wind Energy: Control and operation management issues

Portland, 24th-25th July 2008

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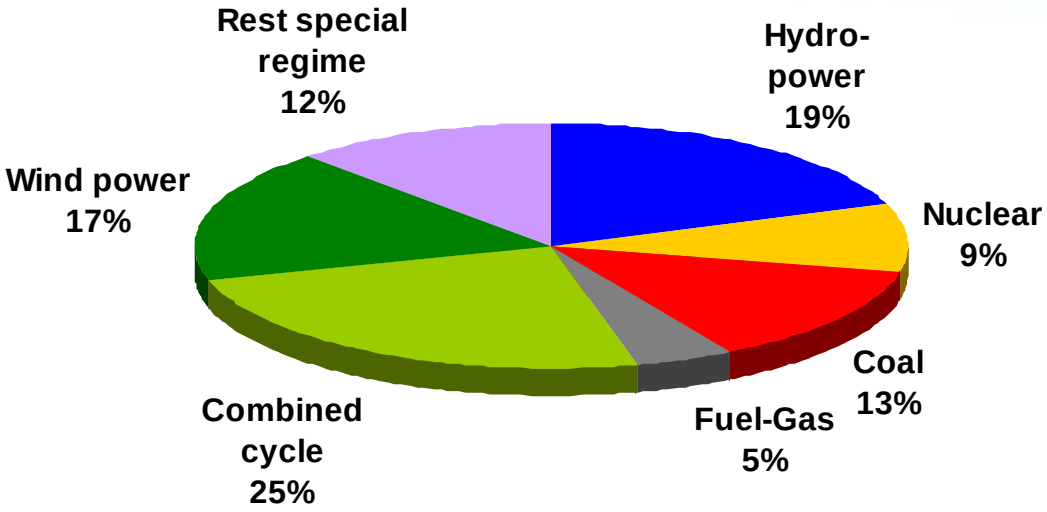
Conclusions

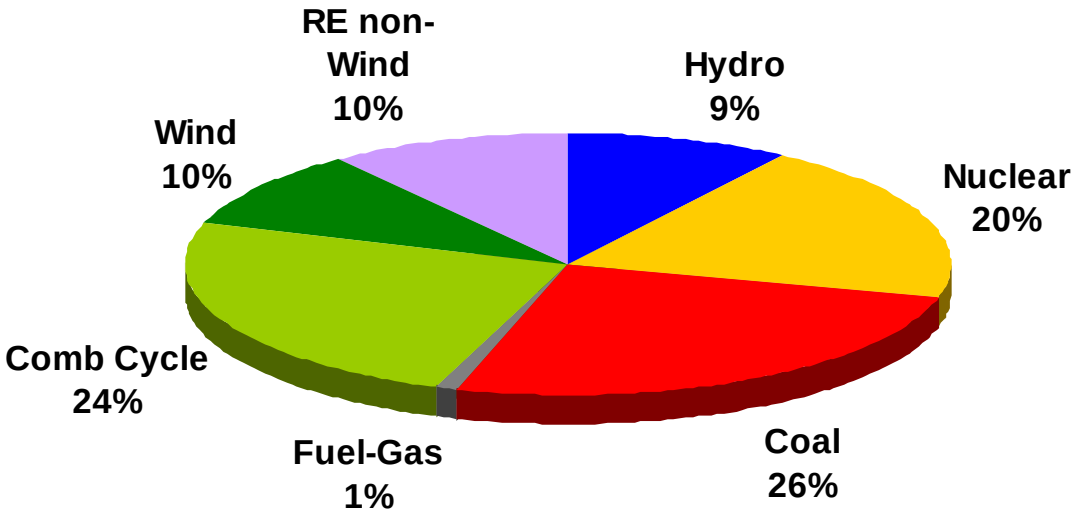
Installed power in May 2008



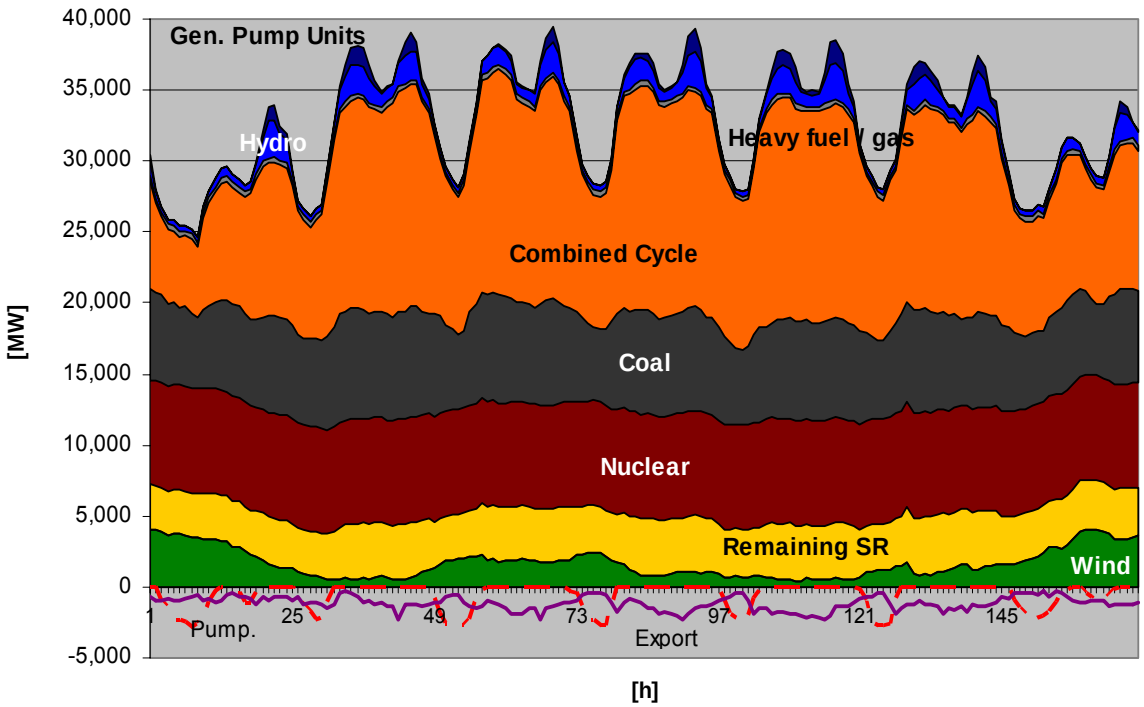
Technology	MW	%
Hydro-power	16 657	19,3
Nuclear	7 716	9,0
Coal	11 357	13,2
Fuel-Gas	3 933	4,6
Combined cycles	21 048*	24,5
Total (ordinary regime)	60 711	70,5
Wind power generation	14 875	17,3
Rest of special regime	10 499	12,2
Total (special regime)	25 215	29,5
Total	86 085	

*2 366 MW correspond to units in their trial period

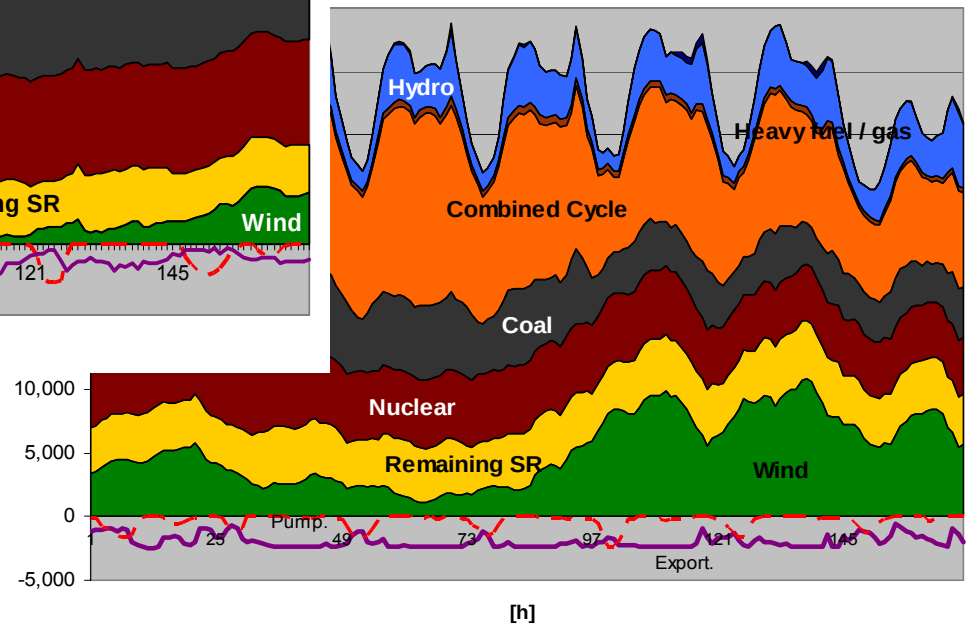
Demand coverage in 2007



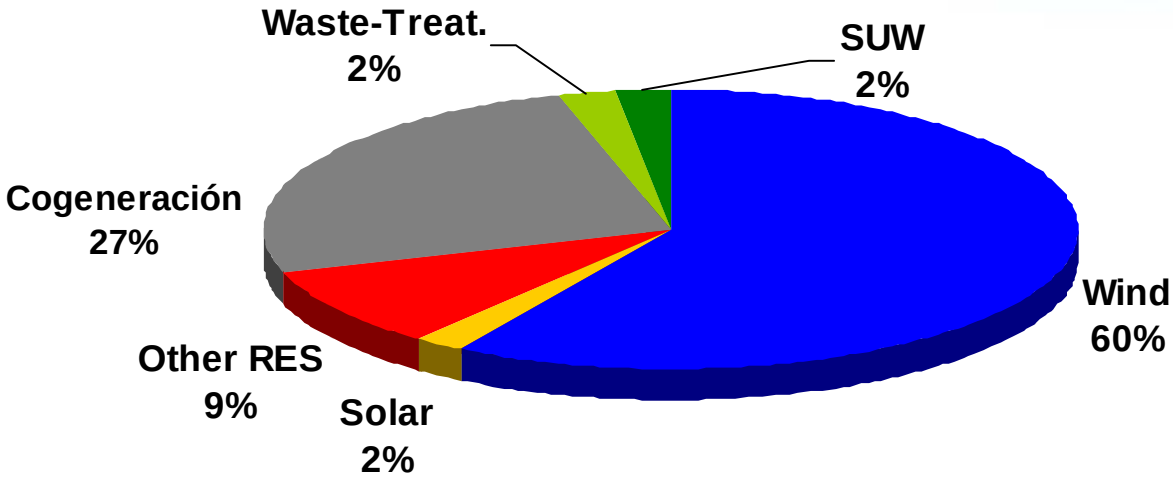
Spanish Demand Coverage - 24/02/2008 to 01/03/2008



Coverage - 13/04/2008 to 19/04/2008

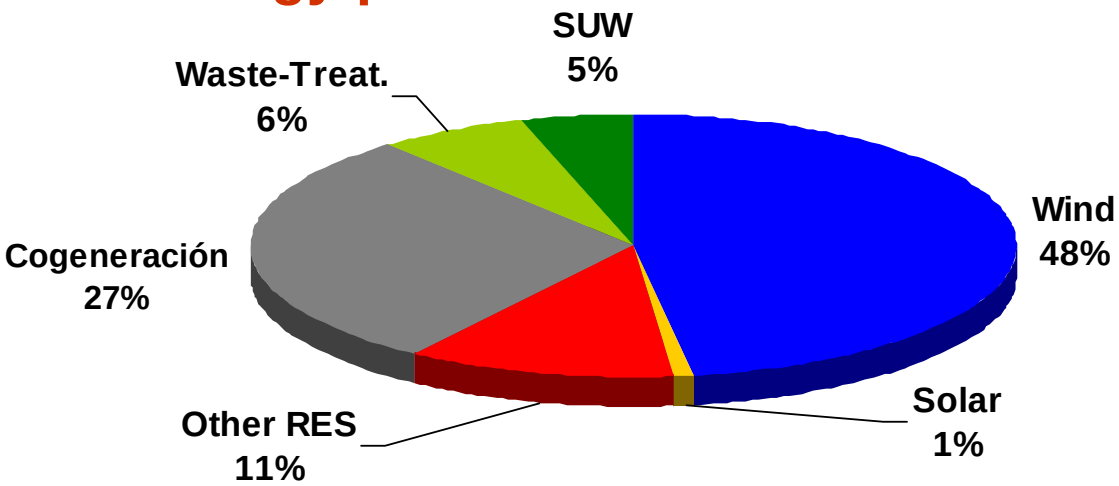


Installed Power Special Regime



Technology	Pow (MW)	%
Wind	14 875	58,6
Solar	516	2,0
Other Renewables	2 403	9,5
Cogeneration	6 437	25,4
Waste-Treatment	553	2,2
Solid Urban Waste	590	2,3
Total Special Regime	**25 374**	

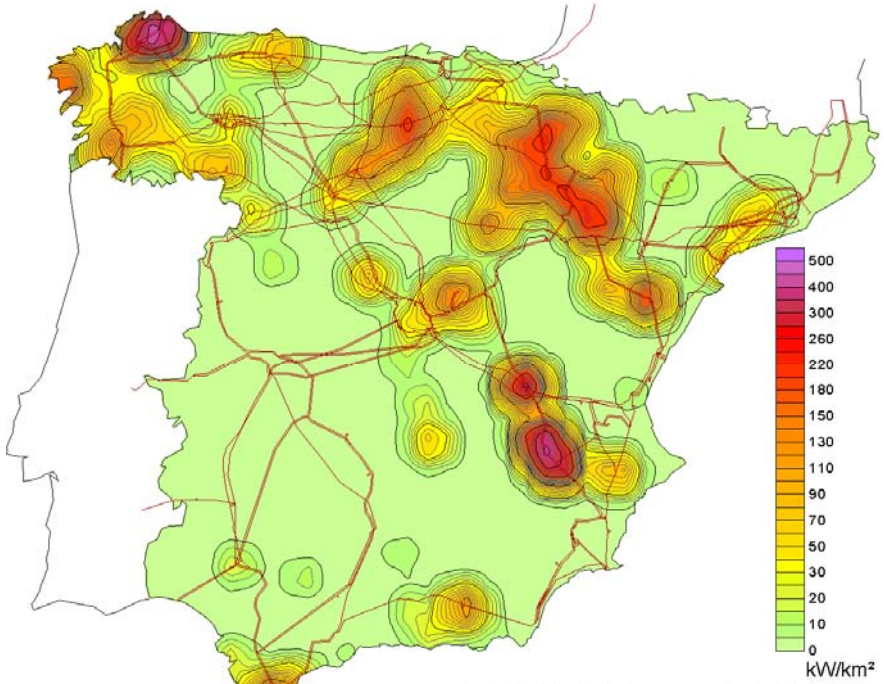
Energy produced in 2007



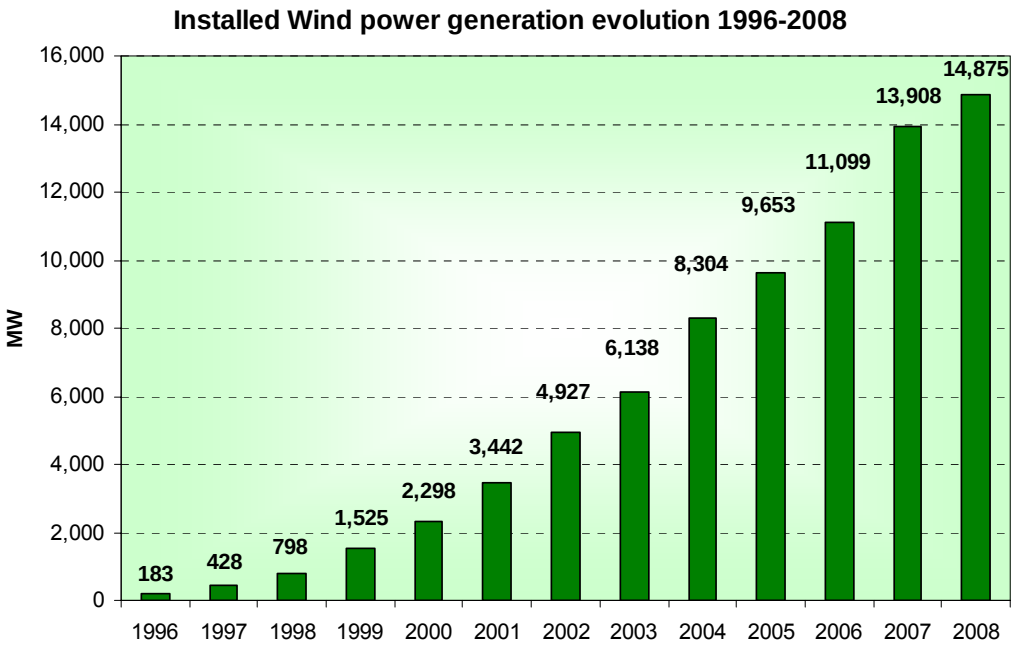
Technology	En. (GWh)	%
Wind	23 195	47,6
Solar	363	0,7
Other Renewables	5 509	11,3
Cogeneration	14 272	29,3
Waste-Treatment	3 089	6,3
Solid Urban Wast	2 309	4,7
Total Special Regime	**48 736**	

Source CNE y REE. April 2008.

Wind Power Capacity and Evolution



Installed Wind Capacity April 2008



Renewable Energies' Plan for Spain (August 2005): ~20,000 MW by the year 2010.
Further increase expected for compliance with proposed EC initiatives.

Targets

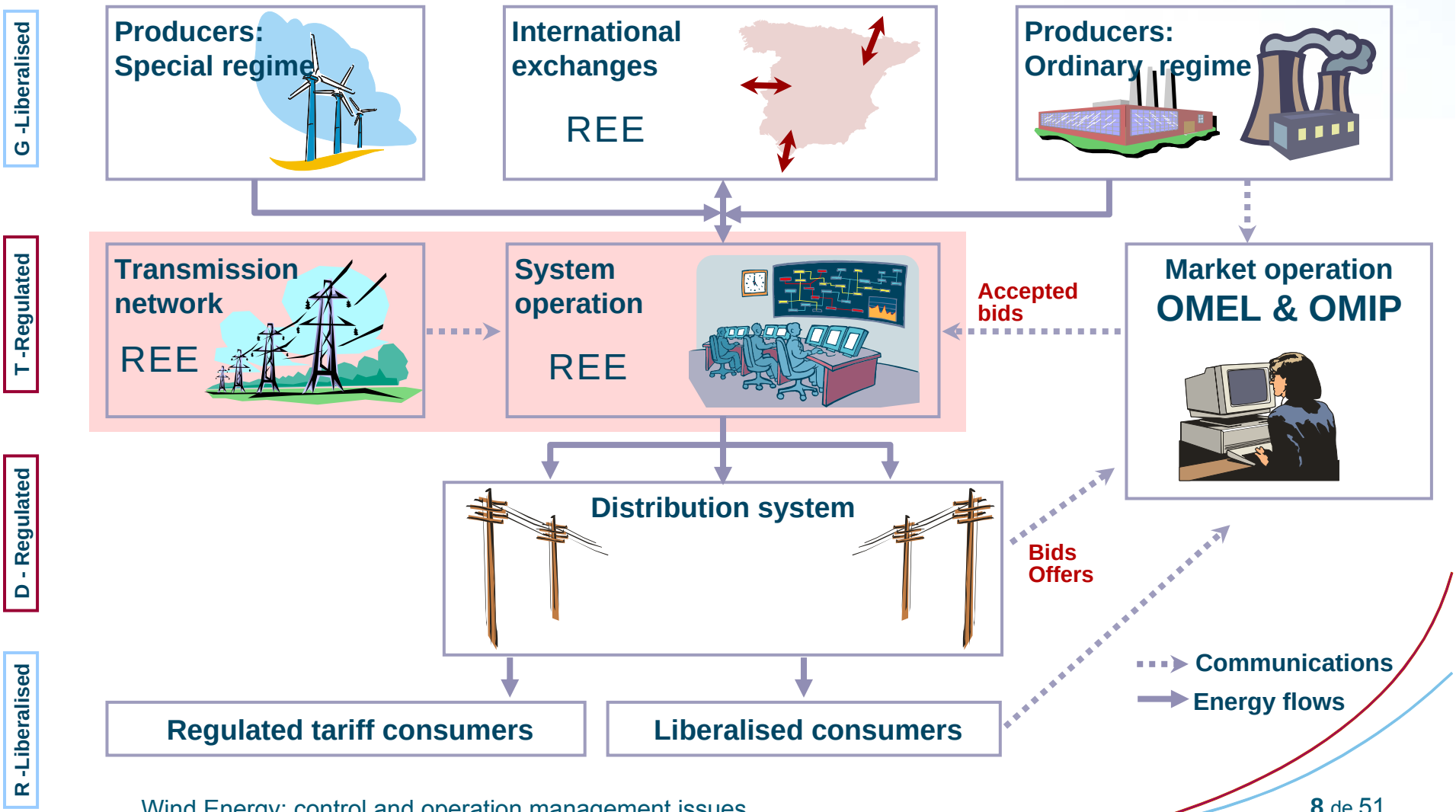
Wind: 20.000 MW in 2011, 29% of electricity production from renewables in 2010. Up to 29.000 MW installed in 2016. 40% of RE in 2020.

Solar (photovoltaic): ~1000 MW end of 2008. Industry claims capacity to have 10.000 MW in 2016. Remuneration under discussion.

Thermal solar (combined with gas): >500 MW in 2009

European Union: 20% of renewable and 20% CO2 emission reduction in 2020

Spanish electric sector organisation



Participation in the Market

- Generation
  - Daily power pool in OMEL (Spain), day-ahead + 6 intraday sessions
  - Long term contracts in OMIP (Portugal)
  - Bilateral contracts with consumers

- Wind Energy
  - Option A: No participation in the market, and fixed payment/Mwh
  - Option B: Normal participation in the market + bonus (with cap and floor).
  - Most chose Option B
  - They can participate in intraday sessions, but not the balancing markets
  - They receive an additional bonus according to their power factor

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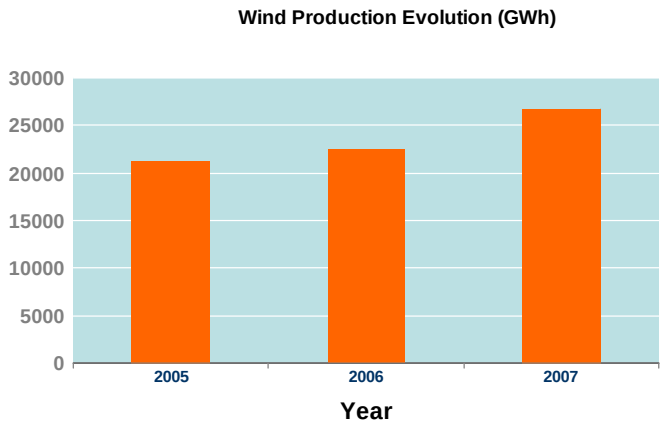
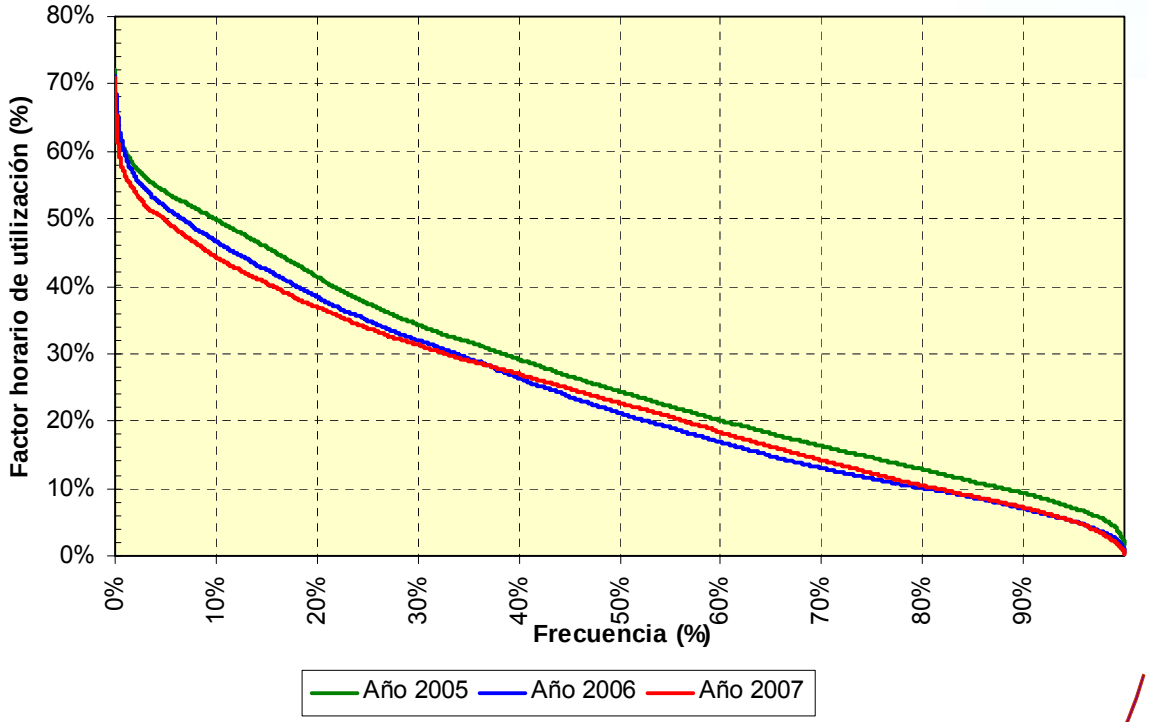
Wind Production and Evolution

- **Absolute Wind Production Evolution**



	Wind Production (GWh)
2005	21.239
2006	22.437
2007	26.643

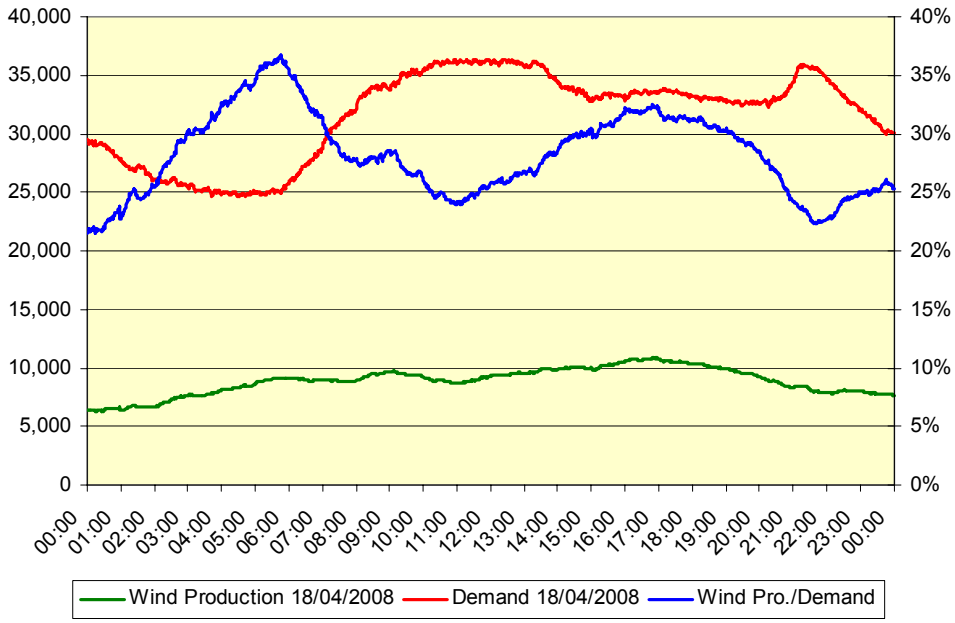
- **Monotonous curve of relative wind production**



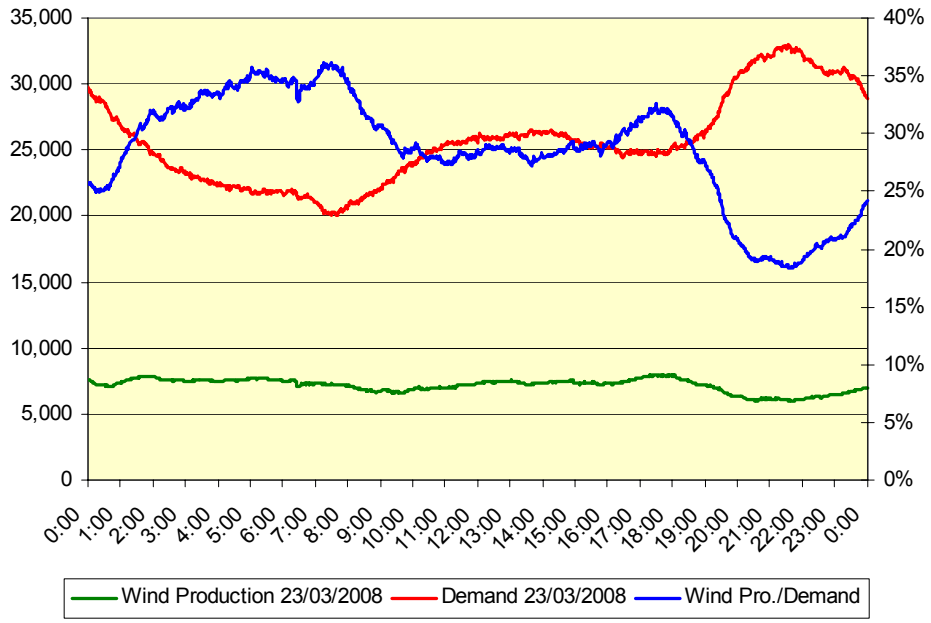
- **Absolute production increases as result of the increase of installed capacity**
- **Relative wind production remains "constant" for long periods of time**

Wind Energy Characteristics

MAXIMUM PRODUCTION



DEMAND vs. WIND PRODUCTION

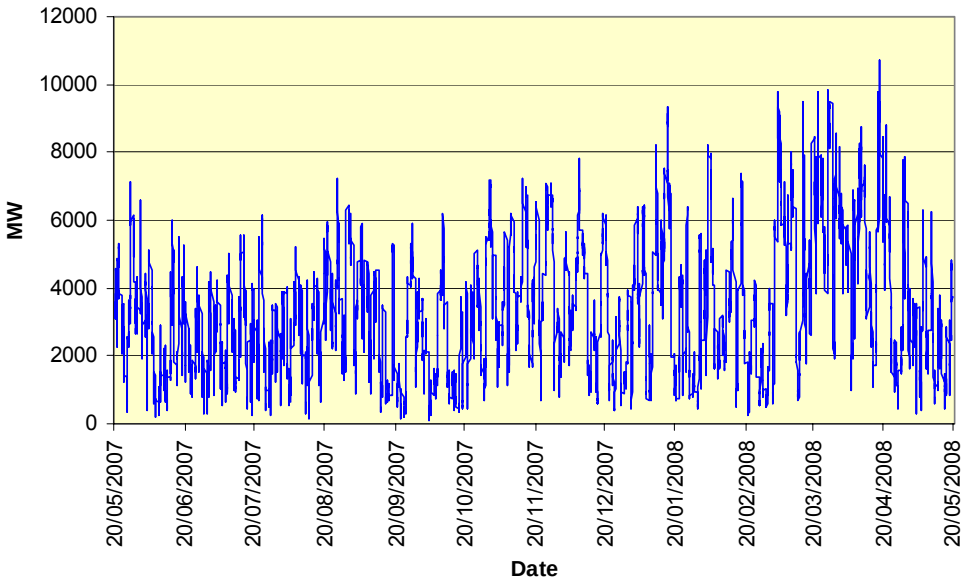


- **Maximum production: 10.879 MW (18/04/2008)**
- **Minimum production: 26 MW (4/2/2007)**

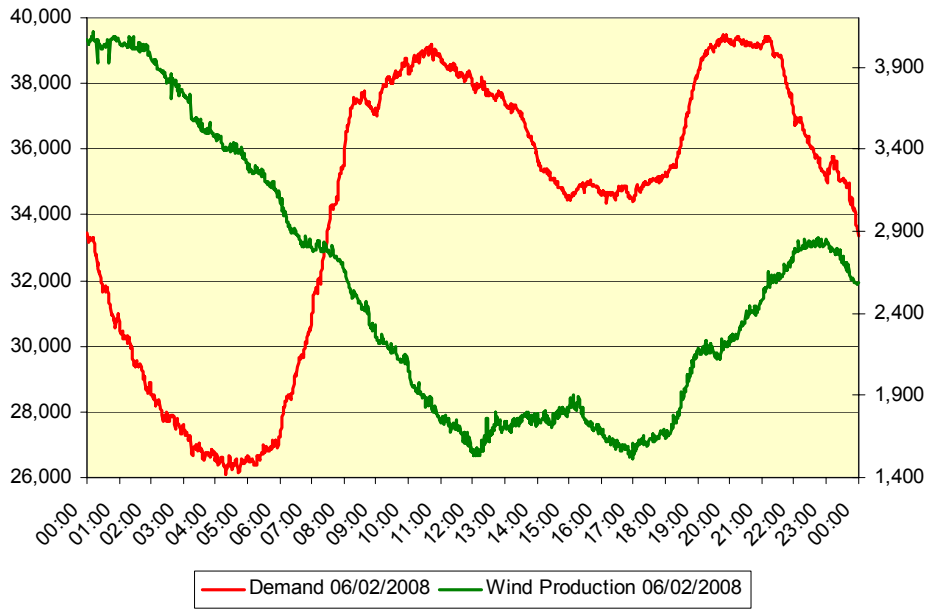
- **Wind production peak : 7.996 MW**
- **Demand peak: 32.953 MW**
- **37% of demand coverage by wind energy**

Wind Energy Characteristics

WIND PRODUCTION DURING A YEAR



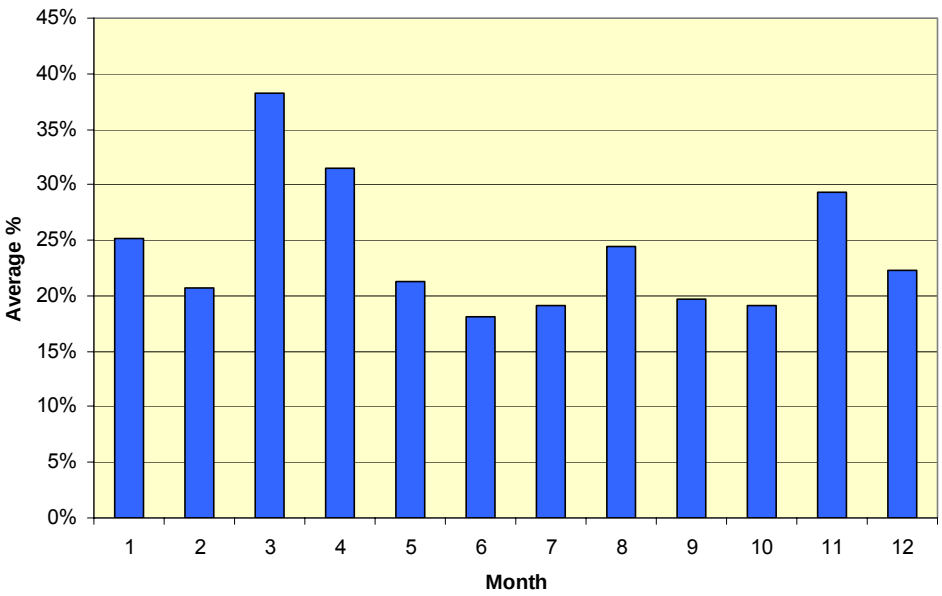
DEMAND vs. WIND PRODUCTION



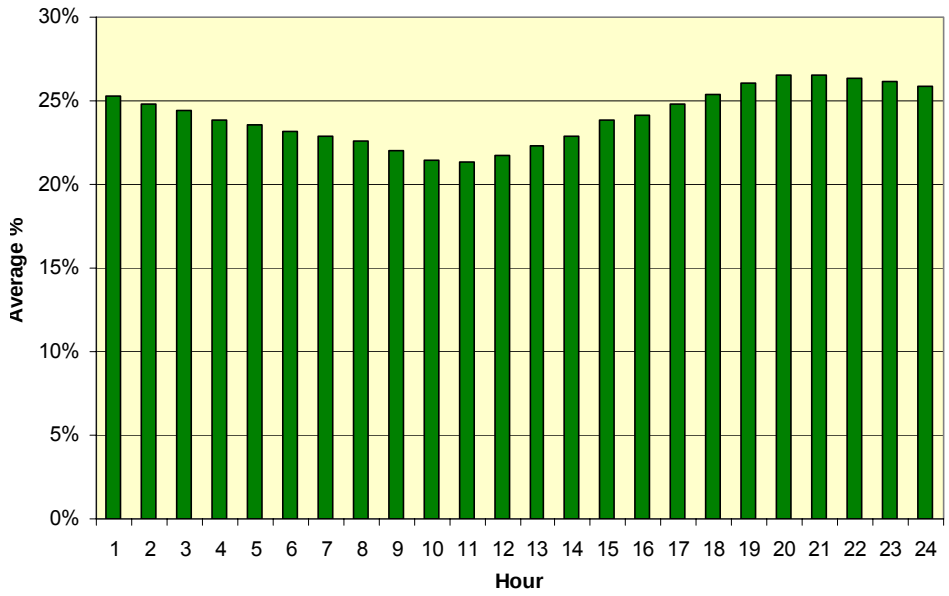
- **Non manageable primary energy.**
- **Very variable production output.**
- **Downward ramps in wind production in the mornings often increase morning ramps of conventional generation.**

Wind Energy Characteristics

MONTHLY PRODUCTION DISTRIBUTION



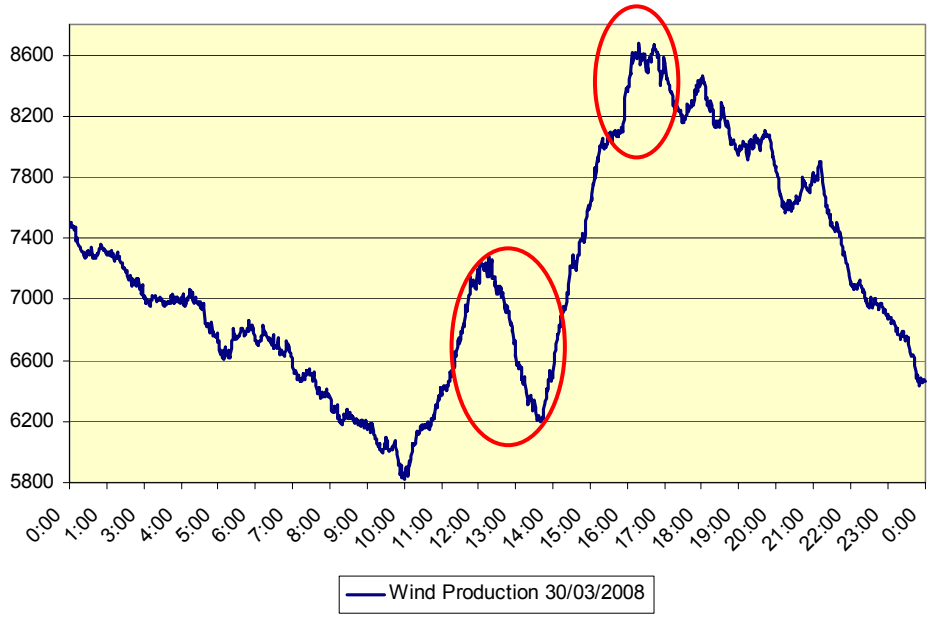
HOURLY PRODUCTION DISTRIBUTION



- **Data corresponds to one year (20/05/2007-19/05/2008)**
- **Wind production differs sometimes from demand requirements, specially in summer.**

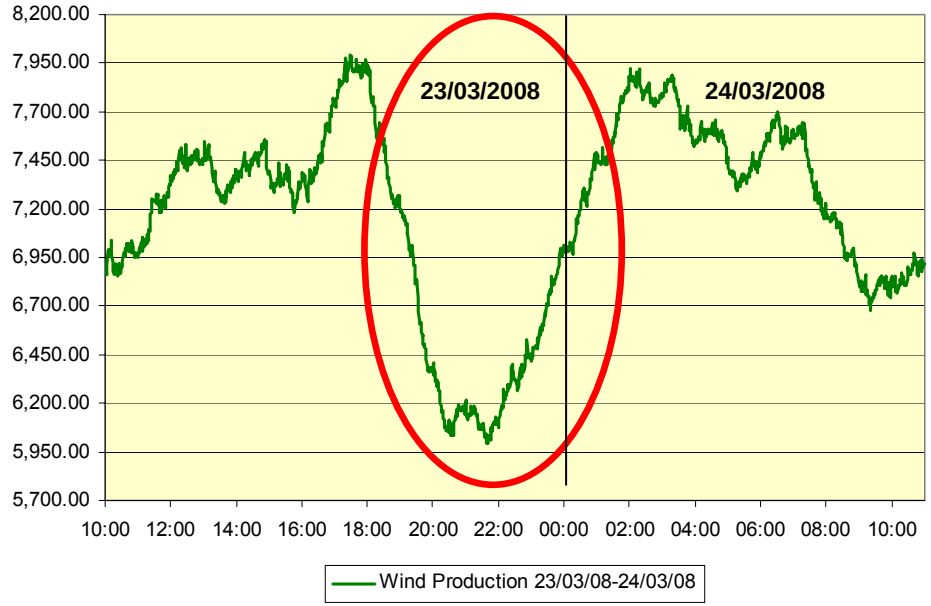
Wind Energy Characteristics

Wind production variability



- Increase of 586 MW in 30 min. Gradient: 1172 MW/h
- Decrease of 1110 MW in 1 h 25 min. Gradient: -785 MW/h

Wind turbines technology



- Wind generation trippings if wind speed higher than 25 m/s.
- Wind power variation on this day: 1 800 MW

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Operational challenges of distributed generation

- **Myriad of plants each belonging to different companies with different policies for operation, switching and maintenance and hidden from the System Operator.**
- **Very slow contact in case of emergency reductions, outages or maintenance planning of the transmission assets next to connection points for generation.**
- **SO actions had to be always manual leading to longer execution times.**
- **If actions and supervision takes longer and risks are higher, stricter limitations must be in place and planned further in advance reducing RES production and installation.**
- **Right now, there are around 575 wind parks installed in the peninsular system.**

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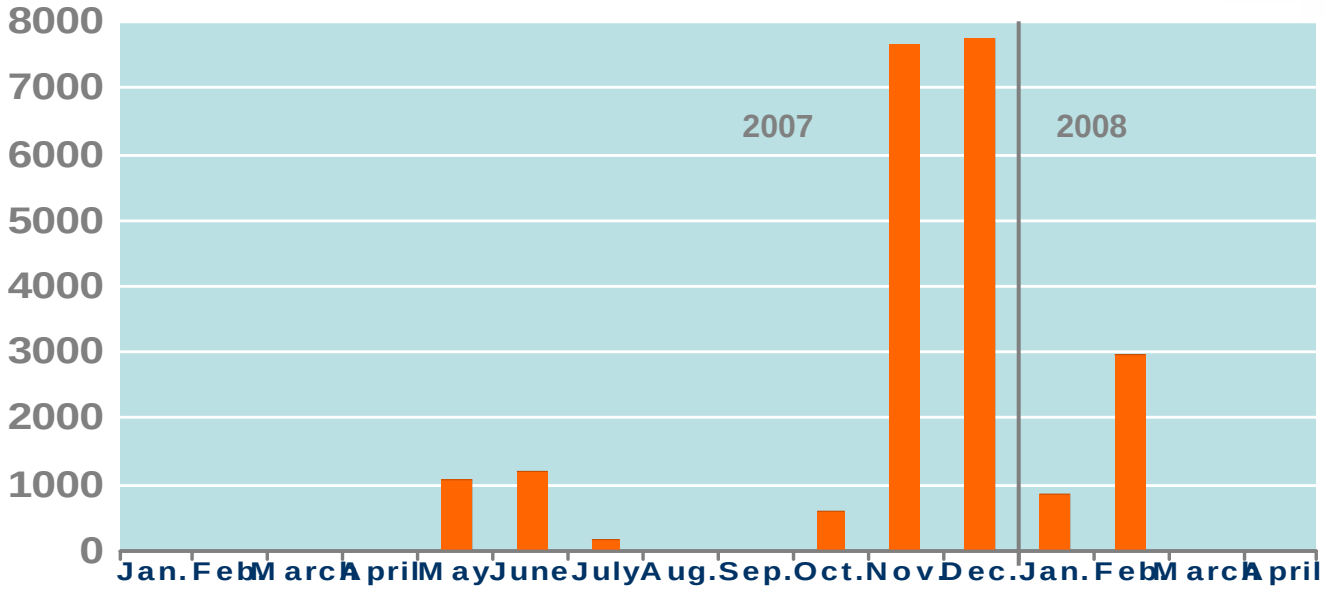
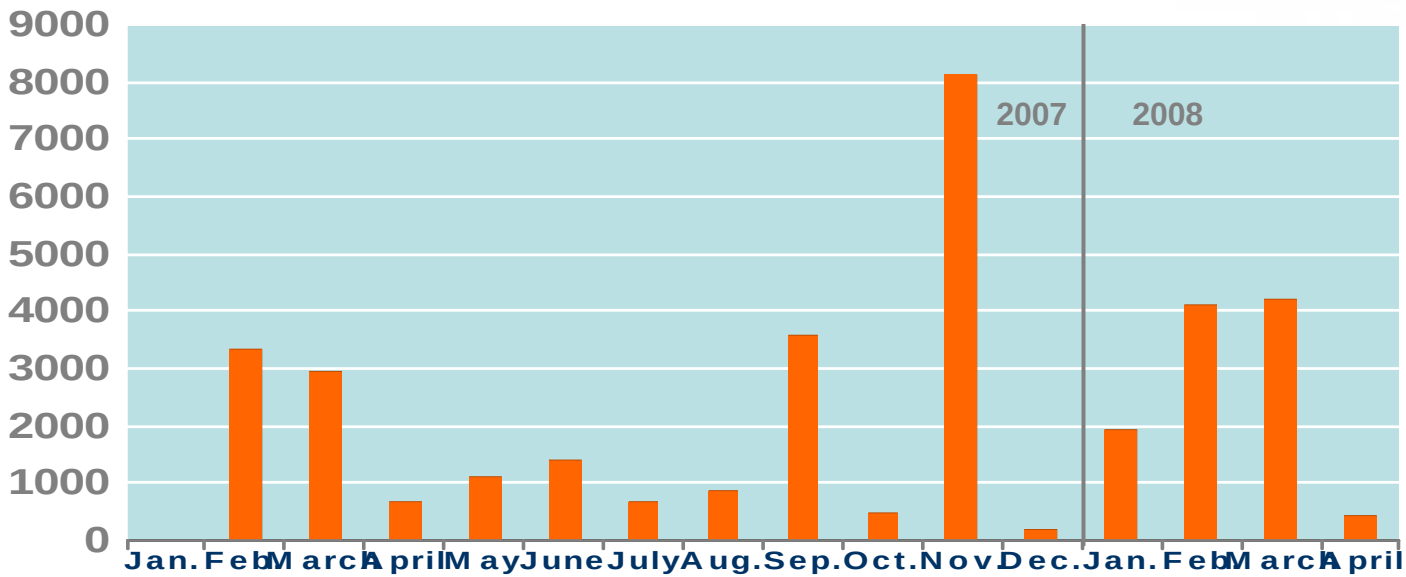
Wind power congestion management after day-ahead market



Congestions in the distribution network mainly due to social and environmental delays in the development of the transmission network and to over-installation of wind parks.

Congestions in the transmission network were due to maintenance works or unexpected outages.

Wind power congestion management in real time



Operational Procedure PO 3.7 and RD661/2007 regulate how these congestions must be managed. Wind parks must adapt their production to the given set-point within 15 minutes.

DSOs may also request limitations to the special regime facilities via SO in order to solve congestions in their networks.

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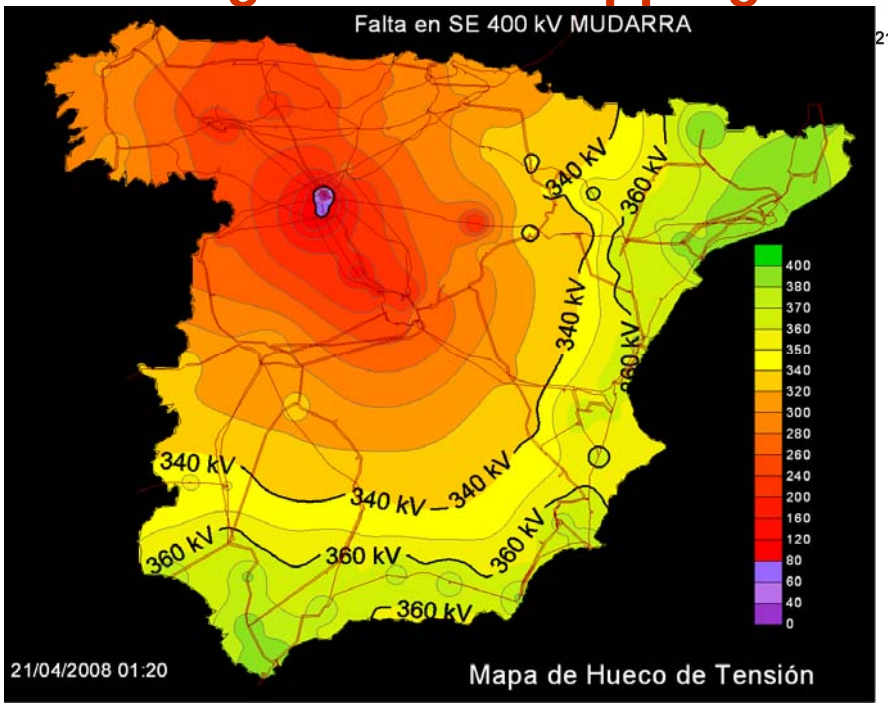
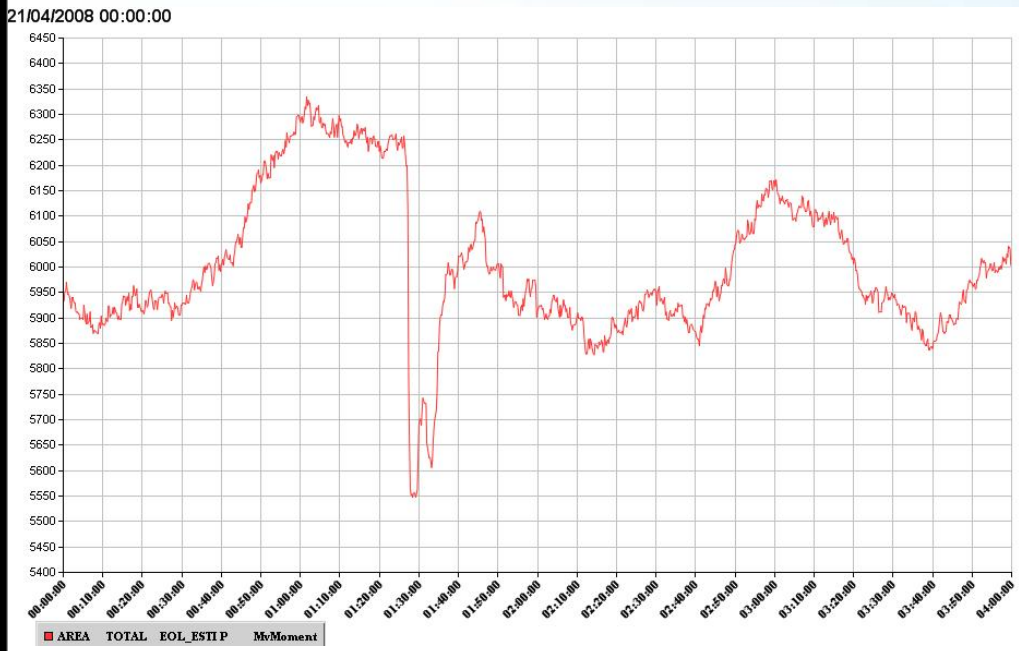
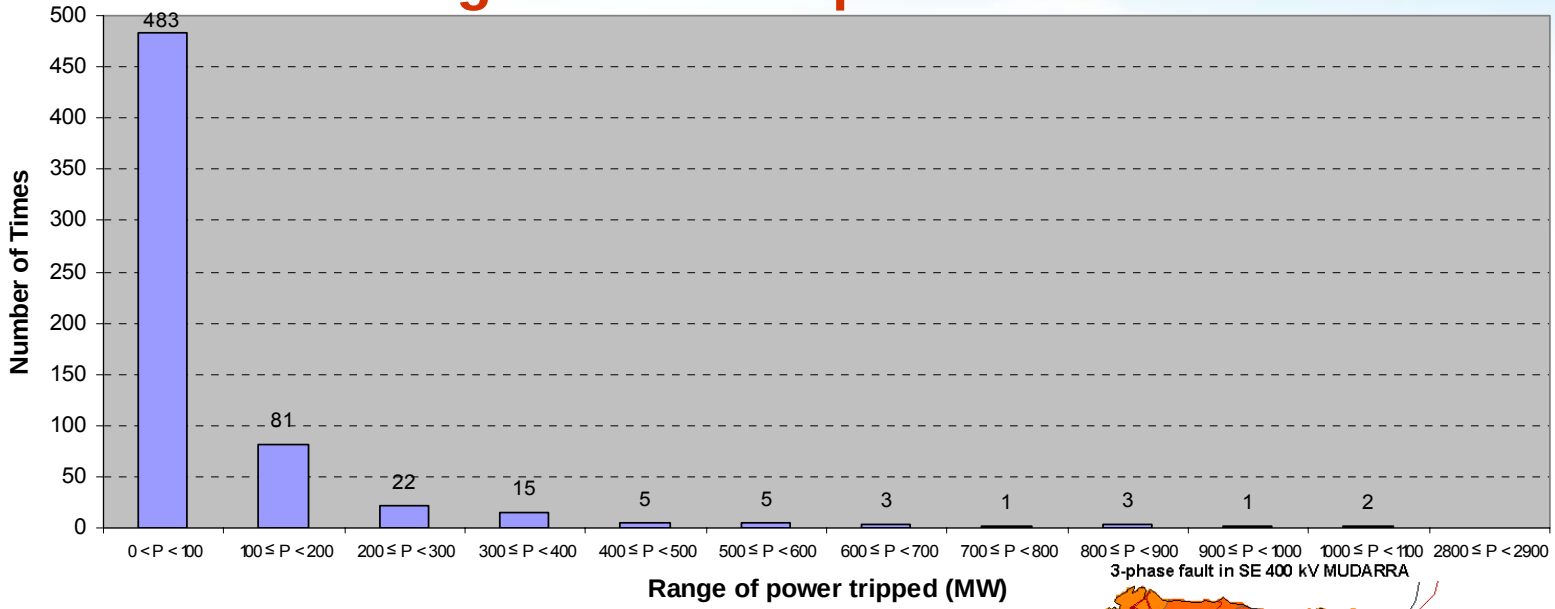
Wind generation tripping due to voltage dips.

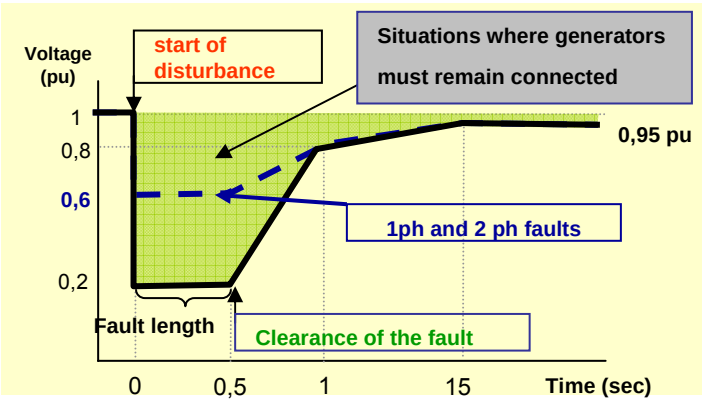


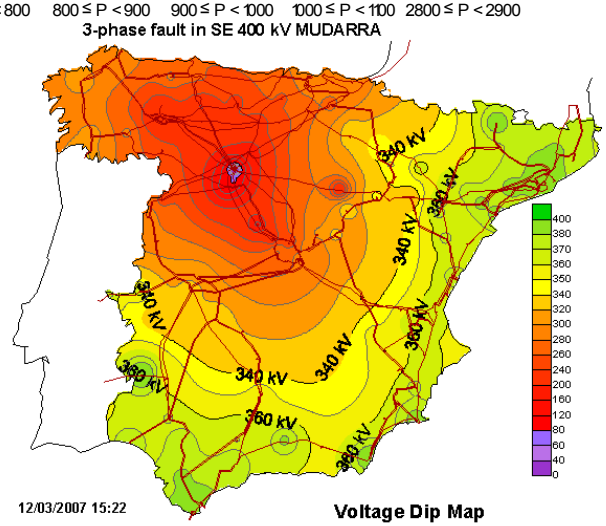


- The voltage dip which would be generated by a three-phase dead fault in some 400 kV substations affects most of the system.
- From January 1st 2008 all new wind facilities must comply with PO 12.3. Of the parks that were on-line prior to this date 2 670 MW have been also certified.
- Still 6 000 MW of installed wind turbines have no fault-ride-through capabilities for faults shorter than 100ms and voltages lower than 85% p.u.

Observation of wind generation trips





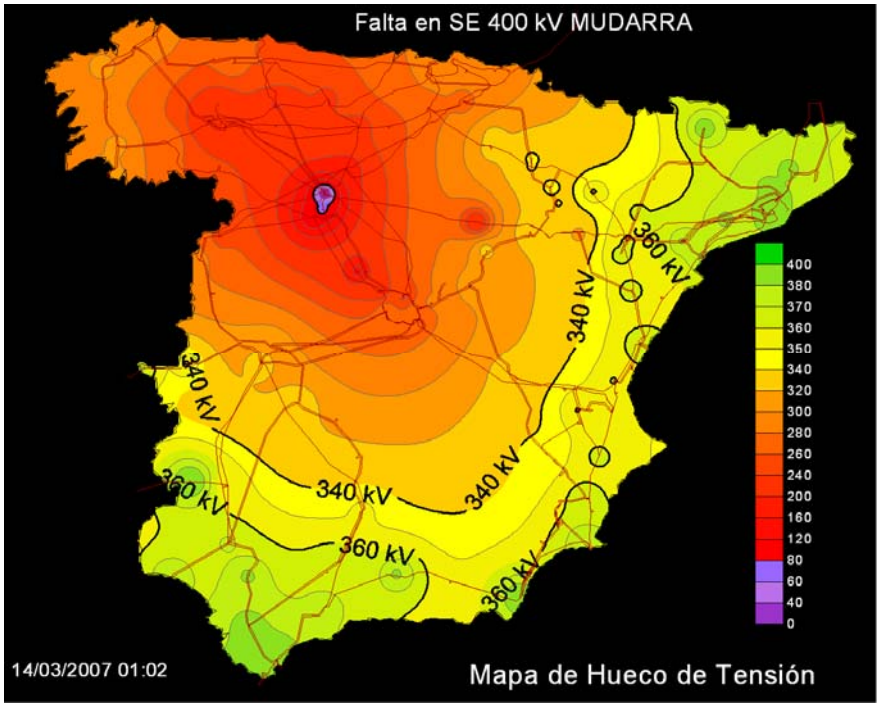


New "grid code". Operational Procedure 12.3

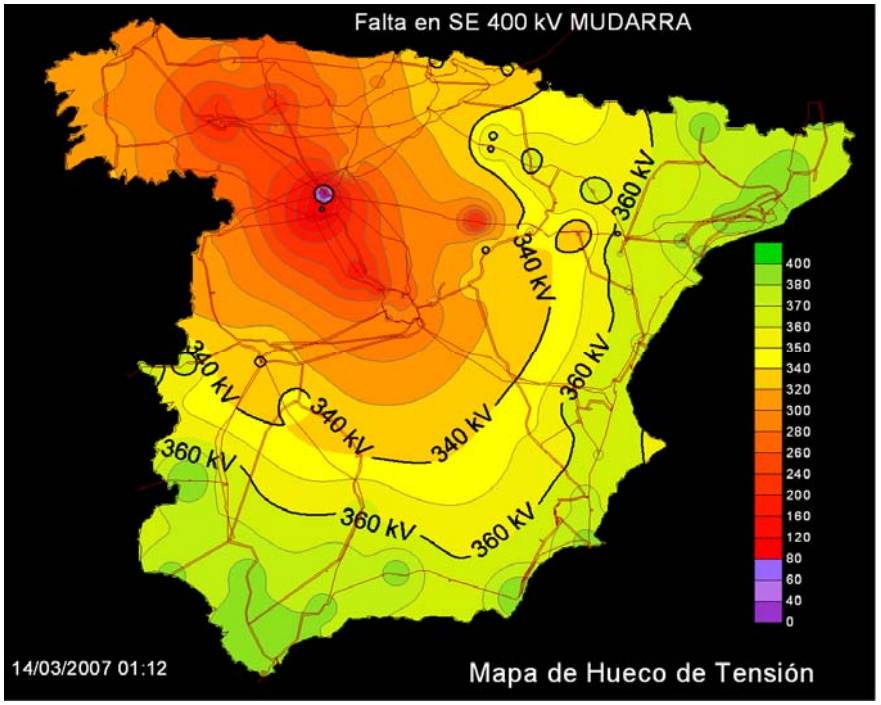
Real Time Risk Assesment

Network Topology Measures

Fault in SE 400 kV MUDARRA with L-400 kV MUDARRA-GRIJOTA in service. Wind Generation Tripping → 1,514 MW



Fault in SE 400 kV MUDARRA with L-400 kV MUDARRA-GRIJOTA opened. Wind Generation Tripping → 1,318 MW



This manoeuvre was performed 94 times in 2007 accounting a total of 2,573 hours out of service due to this reason. Before manoeuvring an N-1 contingency analysis with open line is performed.

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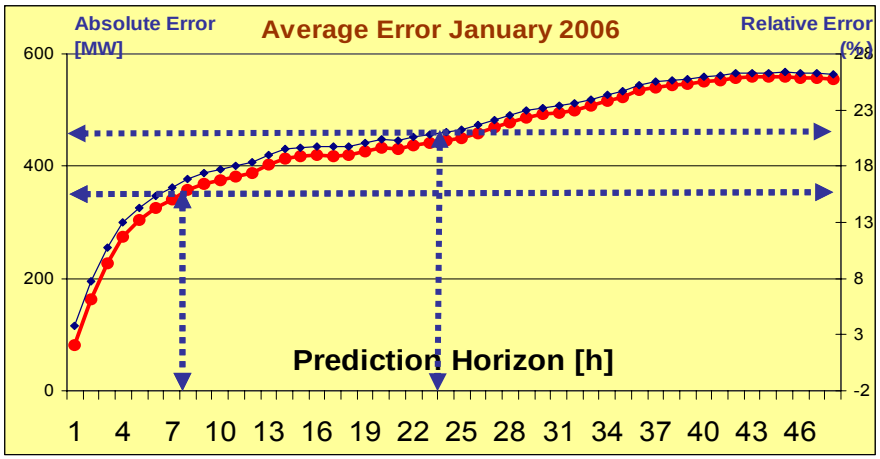
- **Each wind park (individually or in groups) performs a wind forecast to make day-ahead and intraday sales. Individual forecast errors are higher.**
- **Red Eléctrica performs its own forecast for all the territory, in order to ensure system security, power balance and reserve margins**

- Forecast of wind speed (HIRLAM Model)
- Information of wind farm characteristics
- Curves Power .vs. Wind speed
- Real time data
- Historic data

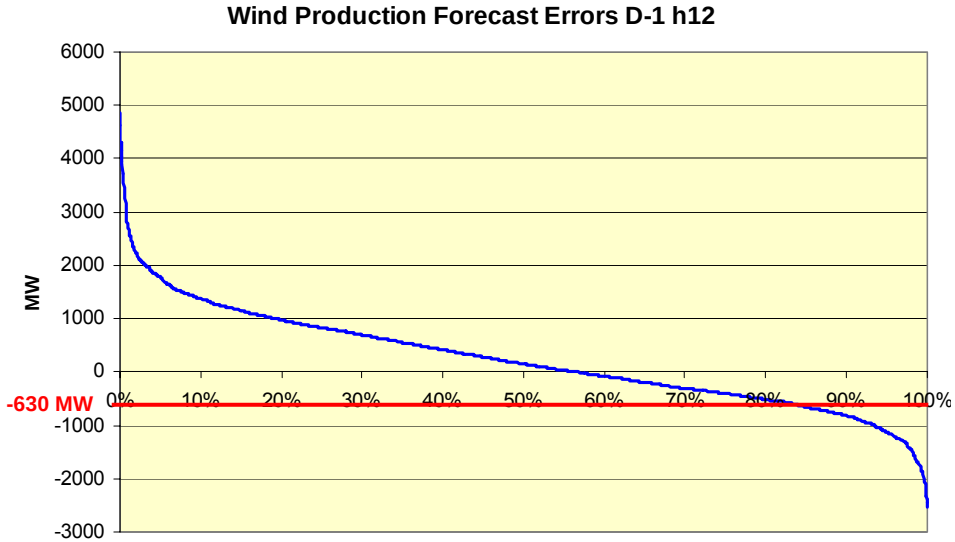
Algorithms

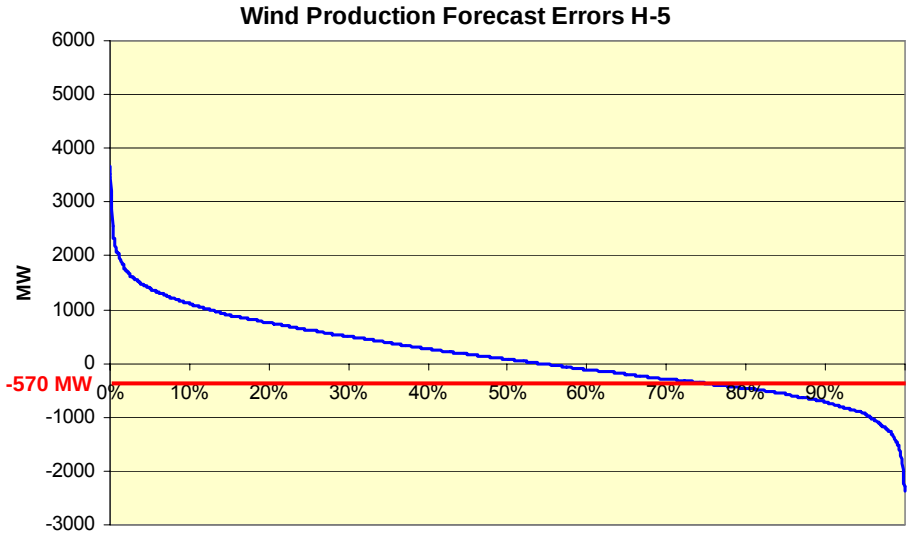
- Every 15 minutes hourly forecast for up to **24 - 48 h**
- Global and individual production forecasts
- Statistical treatment of two algorithms
- Provides expected values, plus probabilistic exceedance intervals



- **Mean relative error of ~20% for 24h forecast**
- **Normalised mean square error of ~5% for 24h forecast**

Impact of forecast errors in the demand coverage





- **In D-1 at hour 12 when the daily congestion management studies are conducted there is a 15% possibility that wind production is 630 MW lower than predicted.**
- **Within start-up time of thermal power units (5 hours in advance) there is still a 15% possibility that wind production is 570 MW lower than predicted.**
- **Reserves are checked within these time scopes and the uncertainties must be translated into further running reserves. Additional thermal groups might be needed to guarantee demand coverage.**

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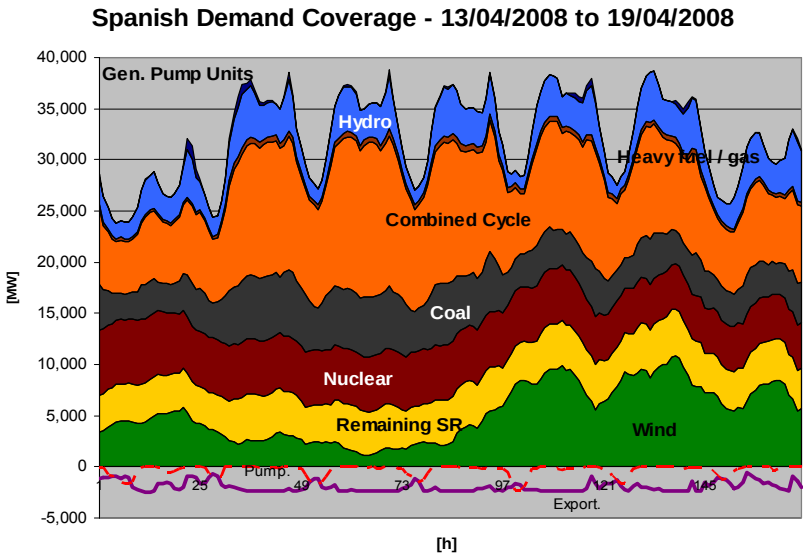
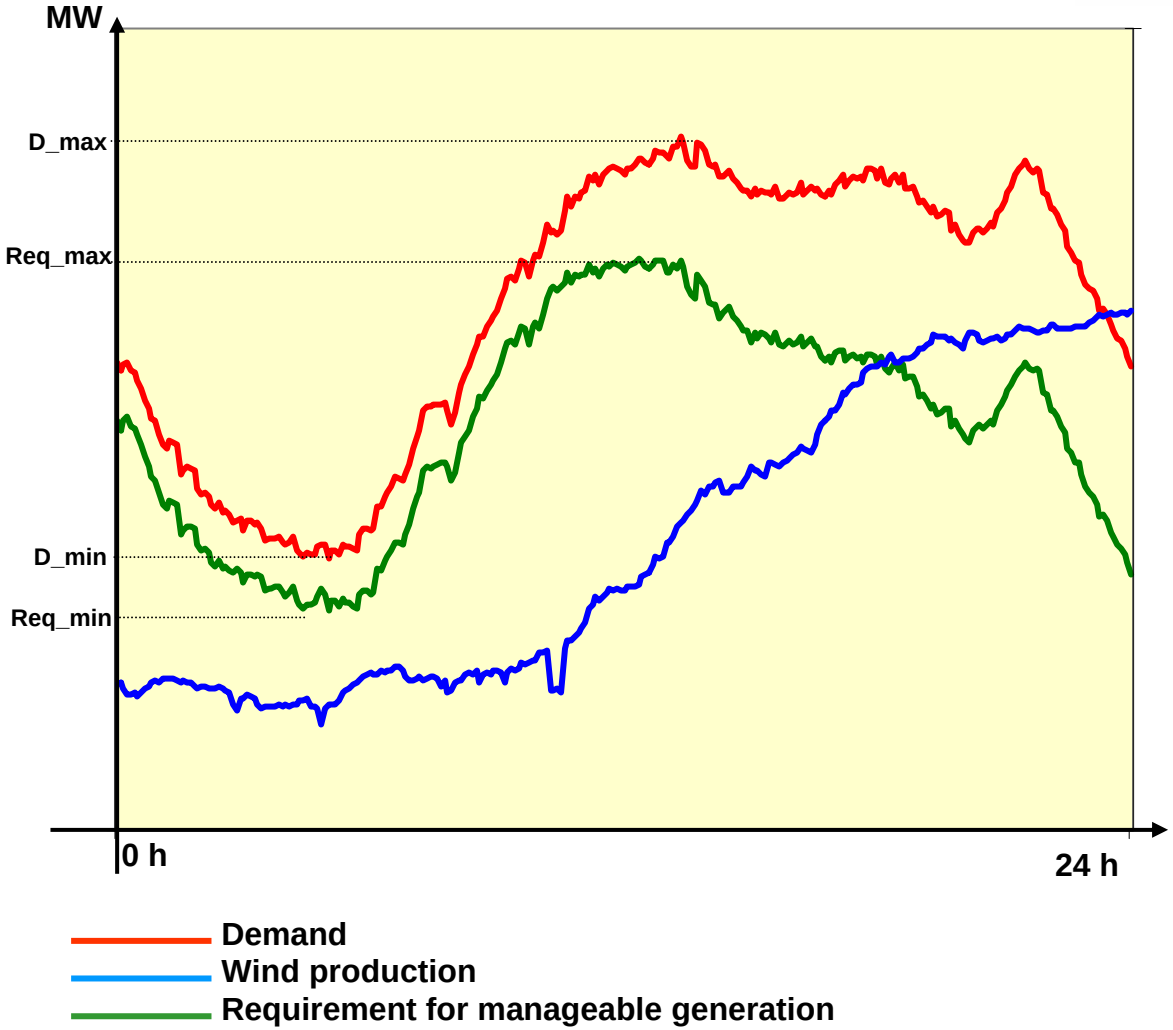
Power Balance feasibility



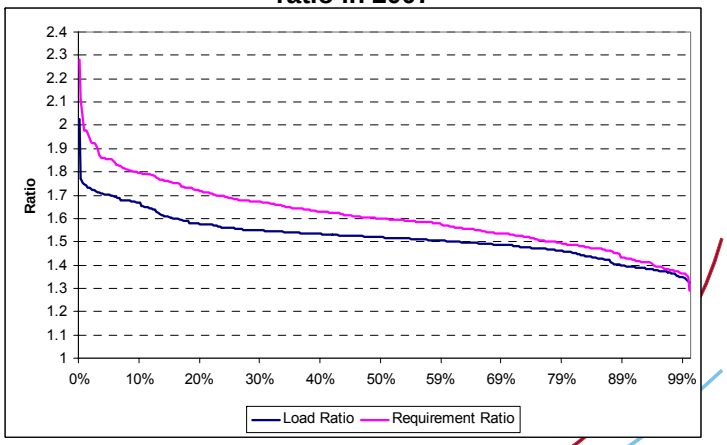
- Cover peak hour with reserve margin
- Avoid curtailments of wind energy during off-peak hours
- Cover the worst requirement: highest demand upward slope with the highest wind downward slope

Requirement for Manageable Generation (I)

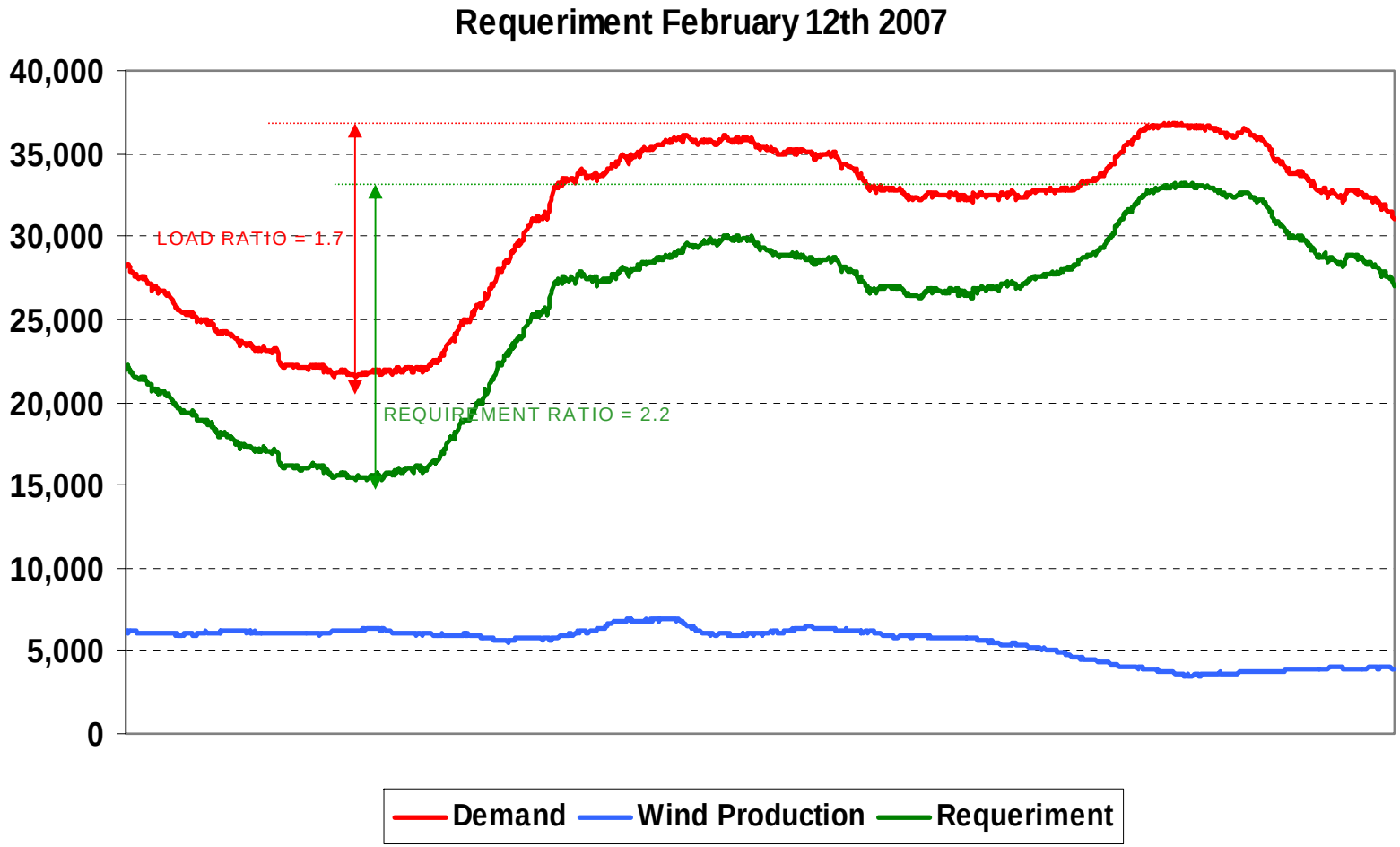


- Demand Ratio = D_max/D_min
- Requirement Ratio = Req_max/Req_min
- Due to wind energy and its behavior during peak and off-peak hours:
  - Requirement Ratio > Demand Ratio
  - Steeper slopes (from off-peak hours to peak hours)

Monotonous curve for demand and requirement ratio in 2007

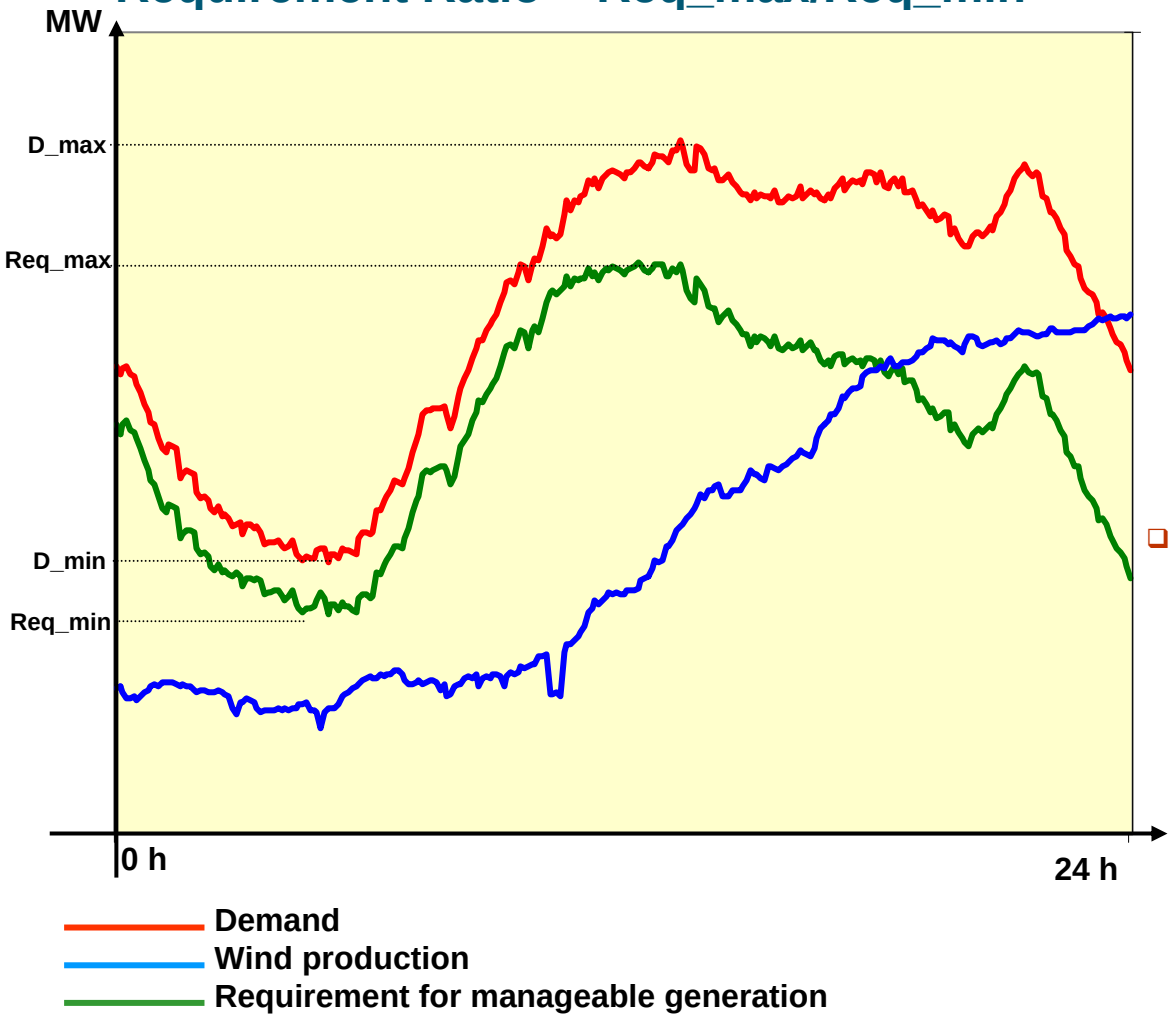


Requirement for Manageable Generation (III)



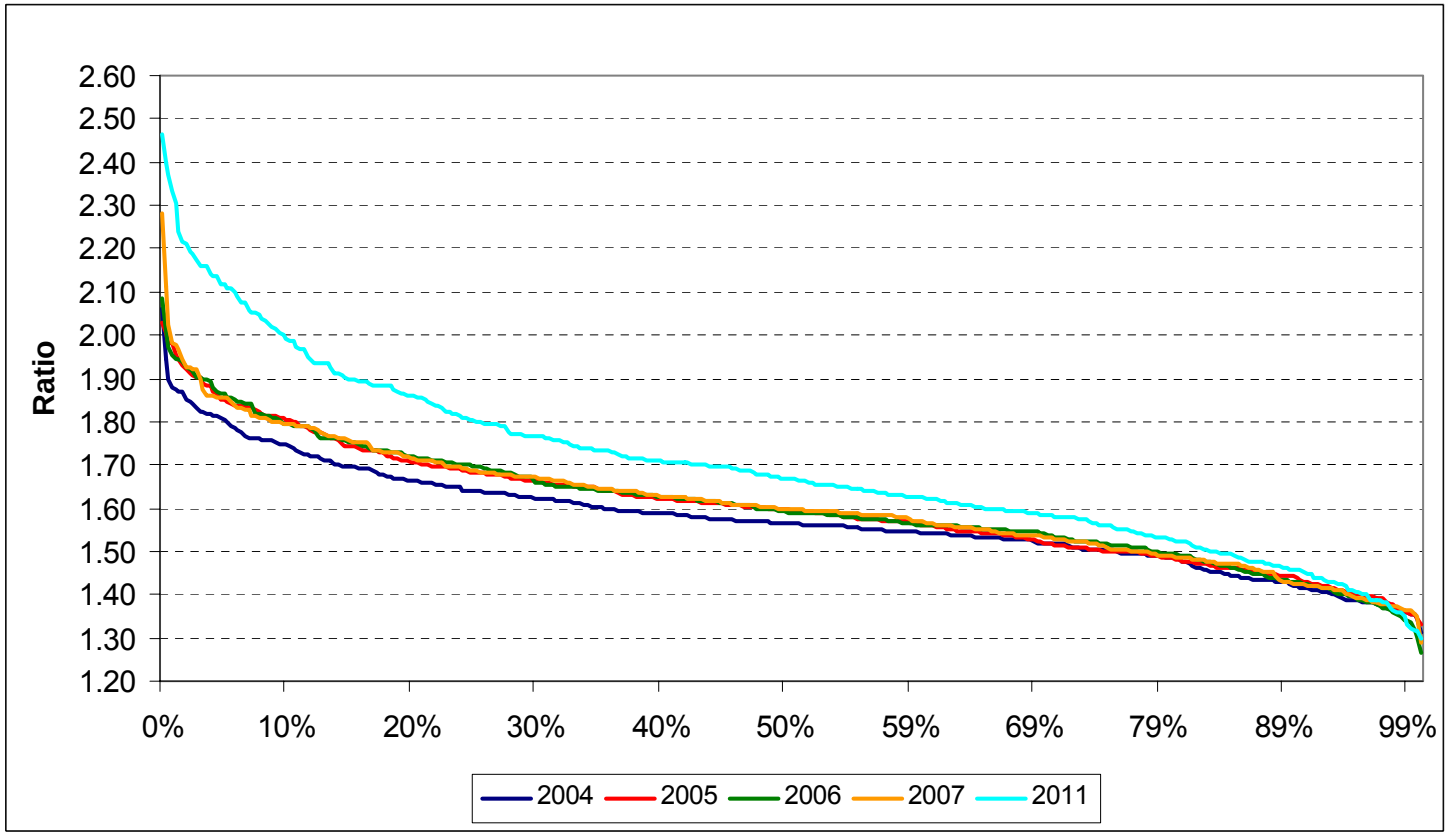
Requirement for Manageable Generation (II)

Requirement Ratio = Req_max/Req_min



- Since there is a minimum value for manageable generation (technical minimum power output of generating units, run-of-river hydro power plants…) there is a ratio over which it is necessary to shut down conventional power generation during off-peak hours to connect it back several hours later in real time (8 times since 2006).
- Due to the need of keeping connected power plants during off-peak periods that are necessary for the daily peak loads (with long start up times) and to provide ancillary services there is also a ratio above which wind power reduction is unavoidable.

Requirement : = Demand – Wind Generation



- **2004-2007: Few days with requirement ratio > 2**
- **2011 (20.000 MW of wind energy): 10% of the time requirement ratio > 2**
- **Possible solution: Additions hydro pump storage in the system**

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Voltage Control

- **Contribution of wind parks is necessary for the network's voltage profile. Wind parks receive a premium according to their power factor and time of the day.**

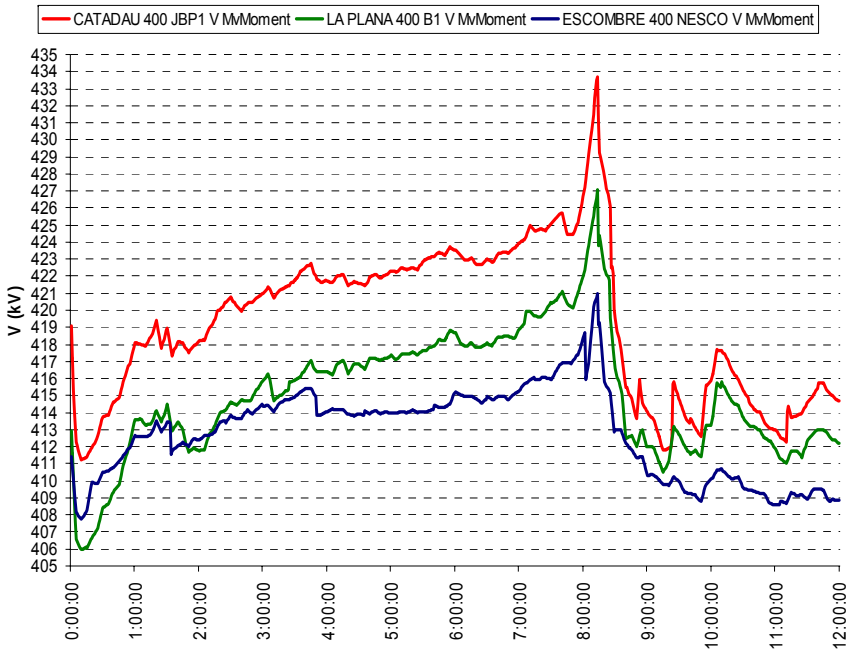
Reactive Power Bonus

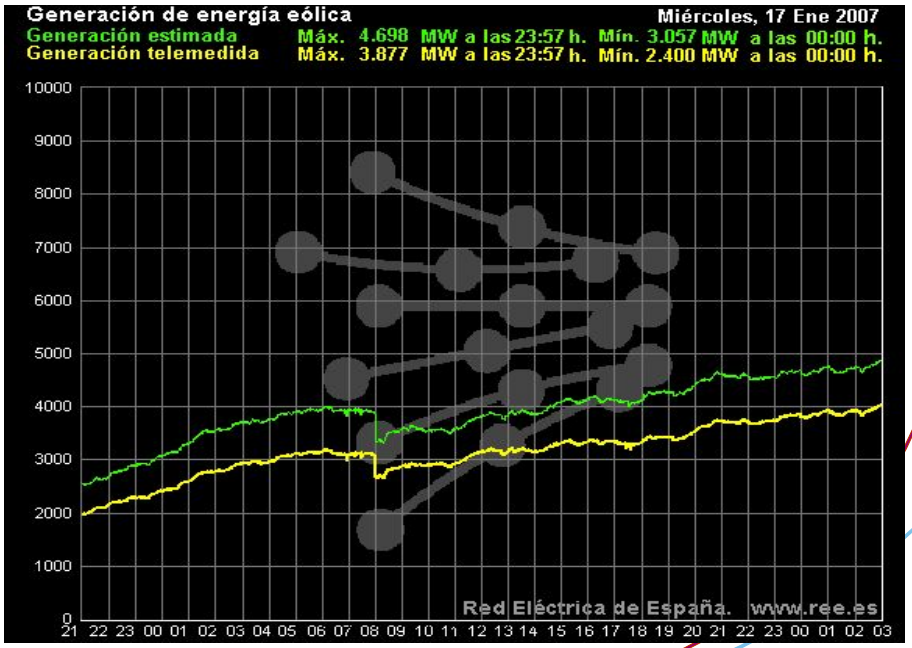
Type of	Power Factor	Bonus (%)		
		Peak	Inter	Off-Peak
Inductive	< 0,95	-4	-4	8
	< 0,96 y ≥ 0,95	-3	0	6
	< 0,97 y ≥ 0,96	-2	0	4
	< 0,98 y ≥ 0,97	-1	0	2
	< 1 y ≥ 0,98	0	2	0
	1	0	4	0
Capacitive	< 1 y ≥ 0,98	0	2	0
	< 0,98 y ≥ 0,97	2	0	-1
	< 0,97 y ≥ 0,96	4	0	-2
	< 0,96 y ≥ 0,95	6	0	-3
	< 0,95	8	-4	-4

	Invierno			Verano		
Zona	Punta	Llano	Valle	Punta	Llano	Valle
Zona 1	16-22	8-16 22-24	0-8	8-14	14-24	0-8
Zona 2	17-23	8-17 23-24	0-8	9-15	8- 9 15-24	0-8
Zona 3	16-22	8-16 22-24	0-8	9-15	8- 9 15-24	0-8
Zona 4	17-23	8-17 23-24	0-8	10-16	8-10 16-24	0-8
Zona 5	16-22	7-16 22-23	0- 7 23-24	17-23	0- 1 9-17 23-24	1-9
Zona 6	16-22	7-16 22-23	0- 7 23-24	17-23	8-17 23-24	0-8
Zona 7	17-23	8-17 23-24	0-8	18-24	0- 1 9-18	1-9

Voltage Control

- Such scheme leads to simultaneous connection/disconnection of capacitors, and variations of up to 18 kV in Transmission substations
- SO may issue instructions to modify these table values if voltage problems are detected. This is done regularly in 6 wind power evacuation nodes.
- This regulation will probably be revised in the future, in order to improve their active contribution to the voltage profile (continuous voltage control from the CECRE)





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Control centre for renewable energies (CECRE)

Real Time production control (GEMAS)

Conclusions

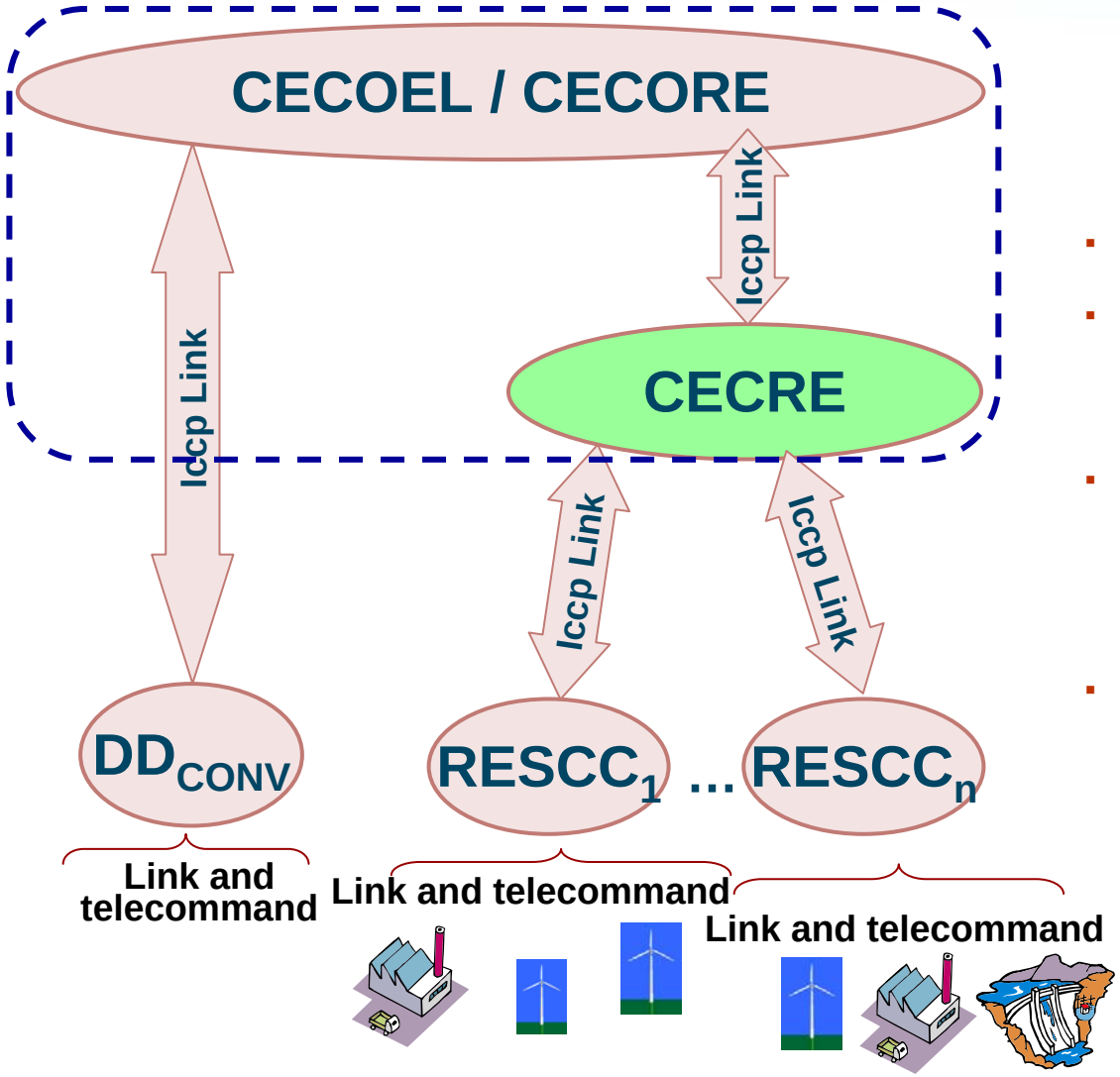
Renewable Energies in System Operation

- **Facilitate the maximum possible non-managed generation integration.**
  - **Proposal to establish system operation measures which allow the secure and stable operation of the whole electric system.**
  - **Creation of the Control Centre for Renewable Energies (CECRE)**
    - **Control and supervision of special regime generation.**
    - **Maximize RES production, but always keeping the electric system in a secure state.**

CECRE: purpose and targets

- **Target: achieve the highest level of integration for renewable energy sources without compromising system security.**
- **Main function: Organise special regime electric production according to the needs of the electric system.**
  - **Be the only real time communication channel with CECOEL and with the Control Centres (RESCC), which would be the entities in charge of switching operations in the facilities.**
  - **Receive the relevant production information of generation units in real time and send it to CECOEL.**
  - **Coordinate, control and supervise all generation units by grouping them in Control Centres.**
  - **Contribute with security and effectiveness in System Operation.**
  - **Change zone simultaneous production hypothesis and preventive criteria (conservative) by real-time production control and therefore allowing:**
    - **Higher energy production**
    - **Higher installed power (agent decision)**

CECRE: functional scheme



CECRE is a control centre devoted to special regime generation and specially to Wind Power:

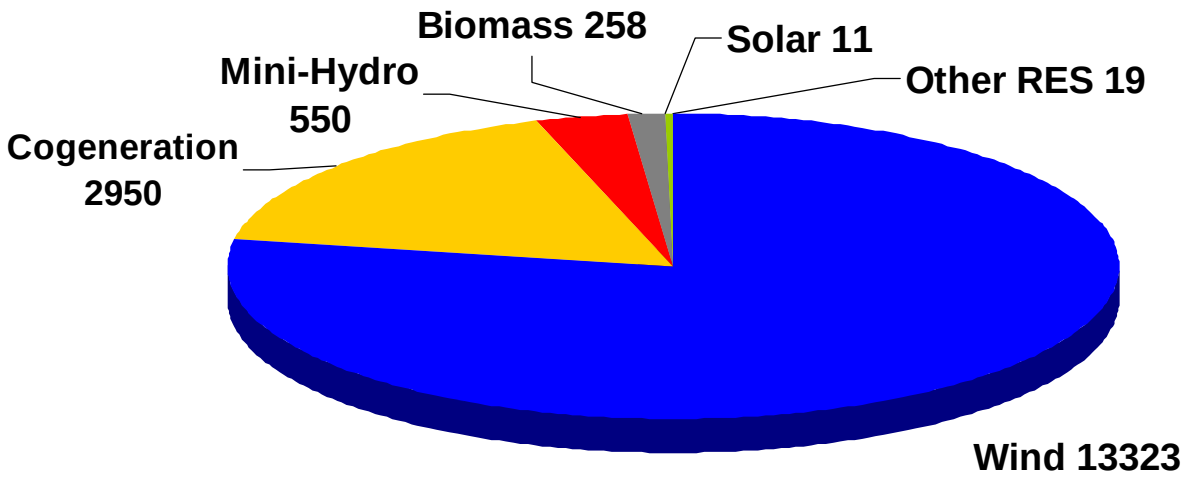
- Integrated in REE's control structure
- Communication with generation Control Centres for supervision and control instructions.
- CECRE does not telecommand generation equipment; this function is done by generation Control Centres.
- CECRE issues generation limitations through the SCADA system to the Control Centres.

RESCC: Renewable Energy Source Control Centre

DD: Delegate Dispatch for conventional generation

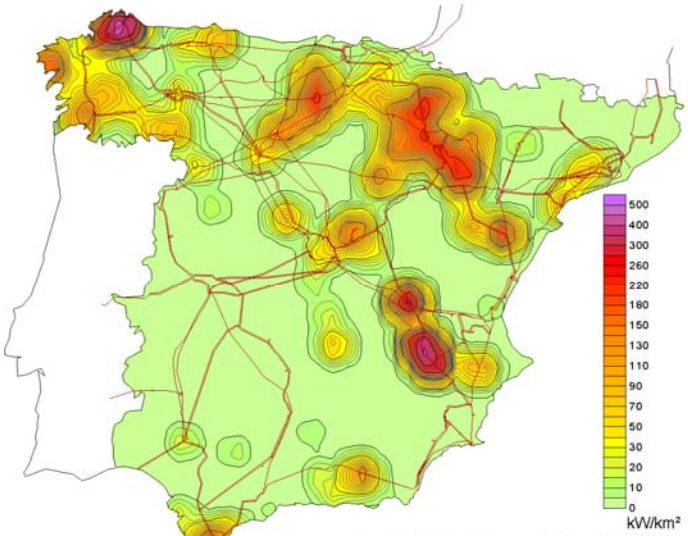
RES power connected to the CECRE via RESCC

RES power connected to RESCC (MW)

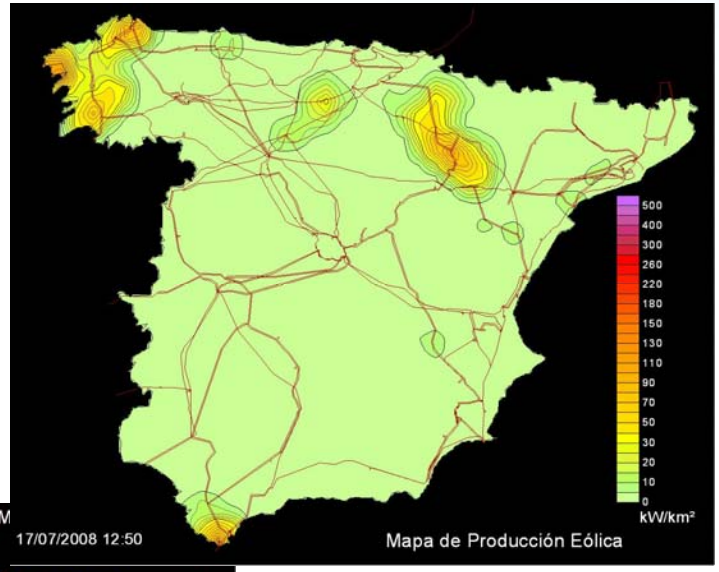


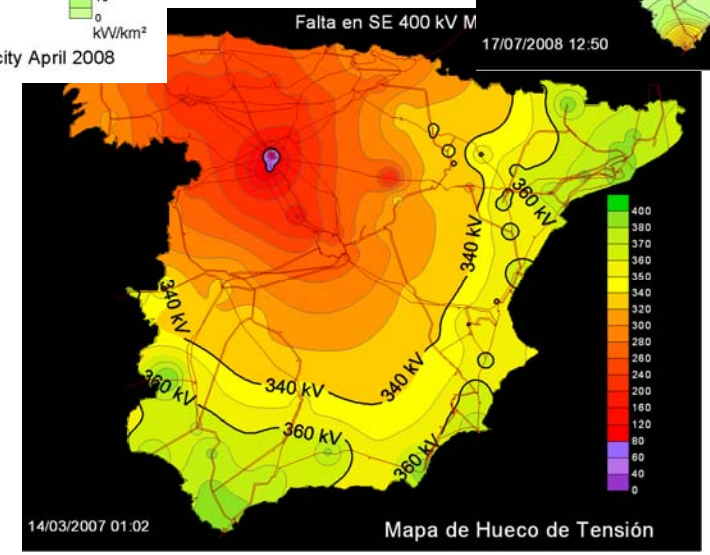
- **According to RD661/2007 all special regime facilities >10 MW must be connected to a RESCC.**
- **Facilities that don't comply with this requirement loose the Special Regime status regarding the prime received.**

Wind visualization



Installed Wind Capacity April 2008





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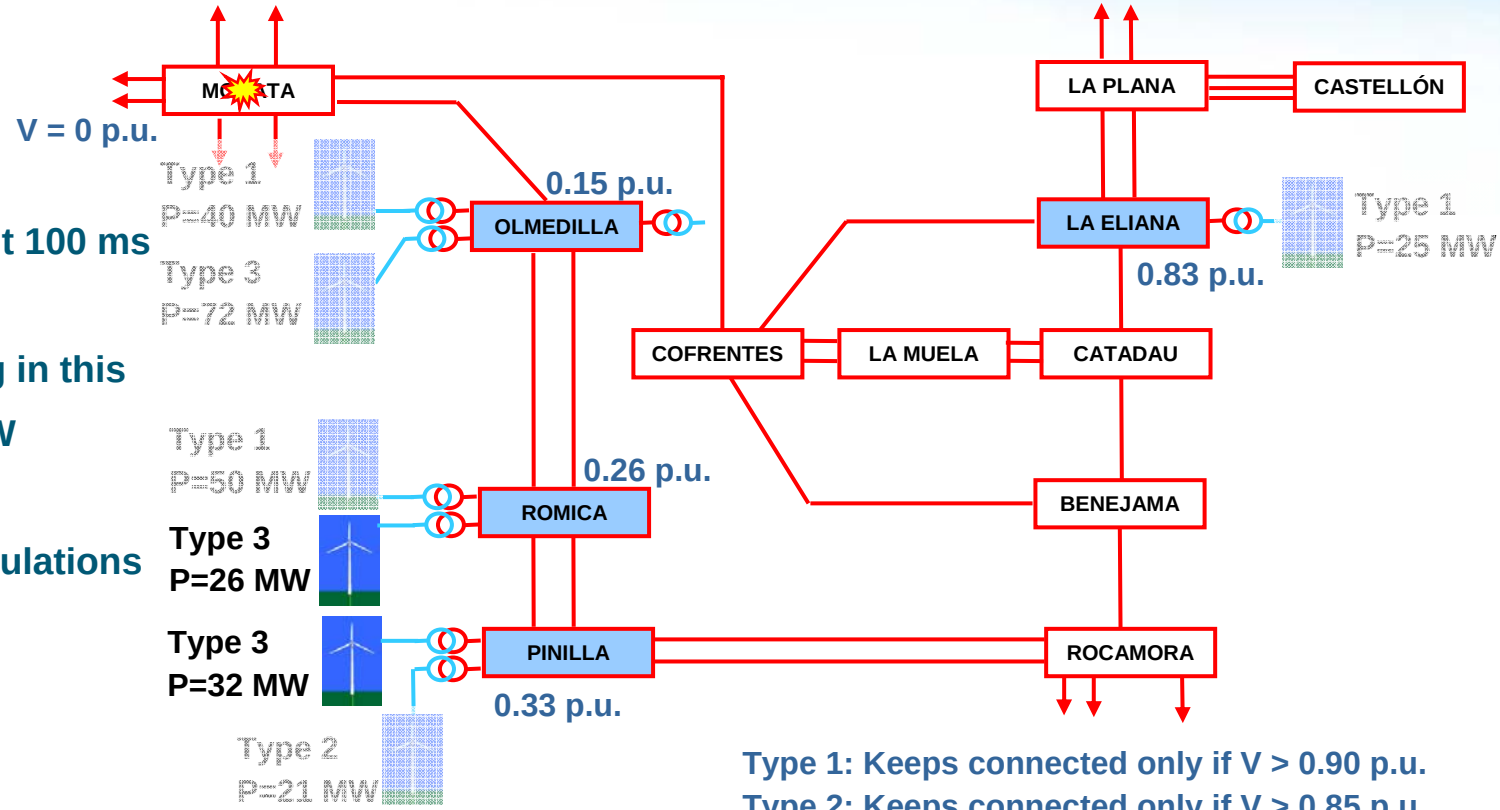
GEMAS: Wind Power Loss Simulation

Duration of the fault 100 ms

Generation tripping in this case P_{Loss}= 208 MW

Method allows calculations in real time

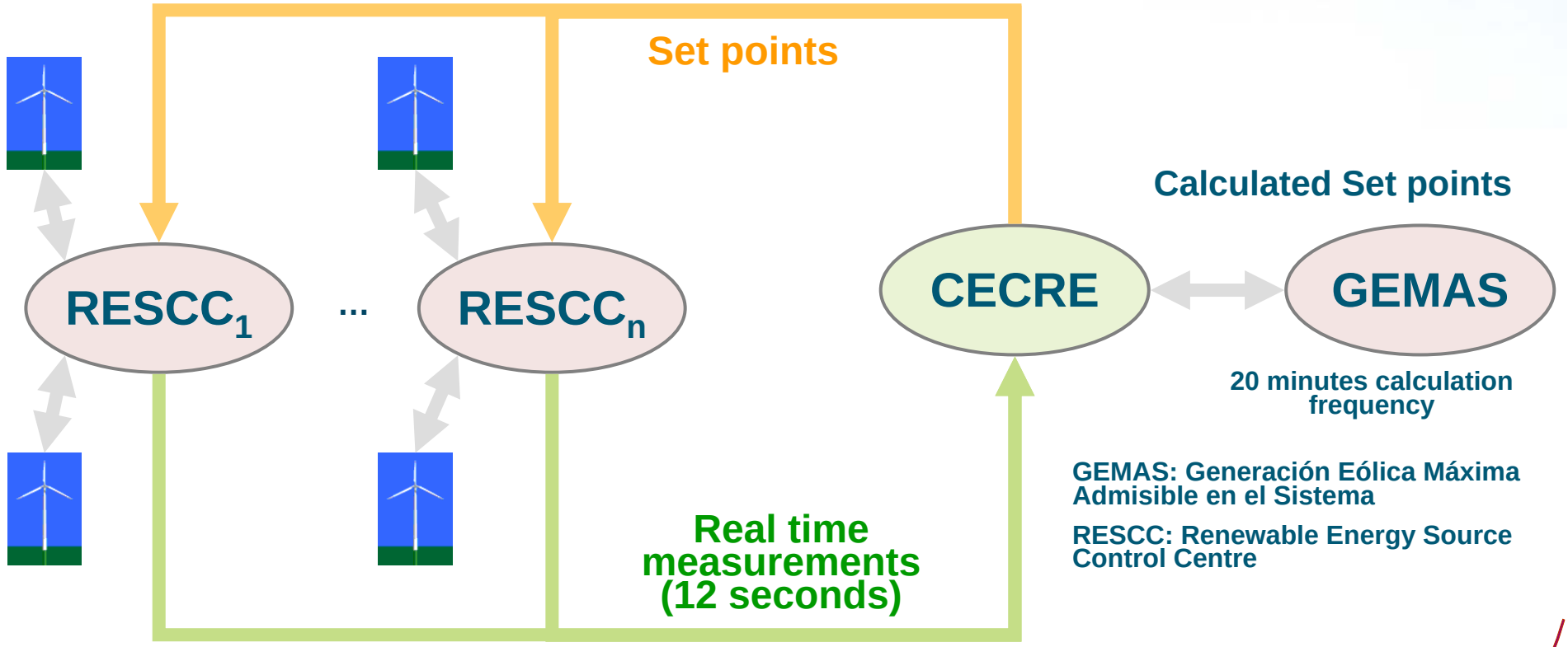


Type 1: Keeps connected only if V > 0.90 p.u.
Type 2: Keeps connected only if V > 0.85 p.u.
Type 3: Keeps connected only if V > 0.20 p.u.

Three-phase dead short circuits are simulated (switching studies with PSS/E) in 70 different substations.

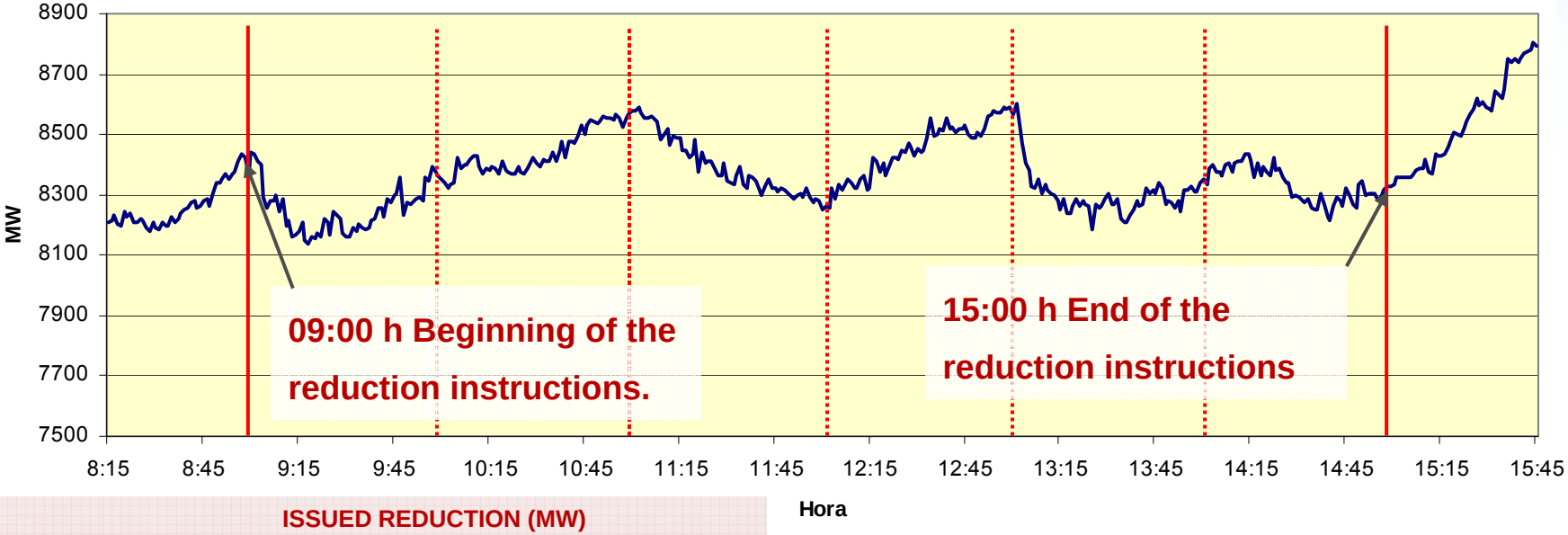
Admissible generation disconnection is calculated in order to prevent overloads in the tie lines with France or inadmissible voltage drops in the system.

GEMAS: Wind Generation Set-point Calculation



- Presently only done for wind generation, but these methodology can also be applied for all renewable energy sources.
- Allows substitution of conservative limitations based on worst case scenarios for real time production control.

Wind power reduction due to risk of generation trip 27/03/2008



CC.AA.	ISSUED REDUCTION (MW)					
	9-10 h	10-11 h	11-12 h	12-13 h	13-14 h	14-15 h
Galicia	48	62	74	19	91	19
Asturias	6	35	23	11	14	5
P.Vasco	0	0	0	3	0	0
Navarra	8	0	0	0	0	0
La Rioja	0	5	2	1	0	0
C. León	94	207	224	81	228	67
C. Mancha	88	142	148	49	231	73
TOTAL	243	451	471	164	565	165

- The reduction was instructed due to the risk of losing the interconnection with France if certain faults occurred, which would cause a sudden wind generation loss even if the fault was correctly isolated by the protection equipment.
- Set-points were recalculated each hour to adapt to changing conditions in the wind generation.

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Conclusions (I)

- **Wind energy in Spain have reached high penetration levels and these levels will continue to rise for several years.**
- **Control and supervision of special regime generation needed since it is already a large portion of the Spanish generation mix.**
- **RESCC and the CECRE improve the integration of special regime generation in the System Operation making these technologies compatible with security of supply.**
- **Better and safer integration means that more renewable energy may be installed at the same risk level.**
- **CECRE and GEMAS complement complex off-line transient studies with faster and easier static studies making real time simulations possible maximizing generation while keeping the system safe.**
- **Integration of wind energy will be easier as they adapt to the new "grid code", but as RES continue to grow other limitations might arise in the future for further integration.**

Conclusions (II)

- Other factors would increase the possibility of wind integration: capacity of the French interconnection, more pump storage capacity
- Future challenges: balance feasibility, continuous voltage control, participation in ancillary services (primary, secondary and tertiary reserve, unbalance management), impact of significant solar energy…
- In the future, additional tools will need to help the SO with these challenges:
  - Optimal probabilistic reschedules in the congestion management process (start-ups, shutdowns, use of pump units) to absorb volatility and forecast errors
  - Optimal voltage control orders from the CECRE

Recommendations

- Study and develop a suitable regulation (payments, connection requirements, curtailment conditions etc.) with the horizon and global target in mind, manufacturers and promoters
- Install the best available technology (avoid later repowering)
- Perform wind penetration studies considering static evacuation capacity, transcient stability, maximum wind concentration
- Learn from countries with similar conditions
- Bilateral communication for real time visualization and allow fast curtailment capacity, maximises wind integration: CECRE

Thank you for your attention