Integrating large quantities of wind in the electricity grid in Portugal

A view of the Transmission System Operator

REN – Rede Eléctrica Nacional, SA

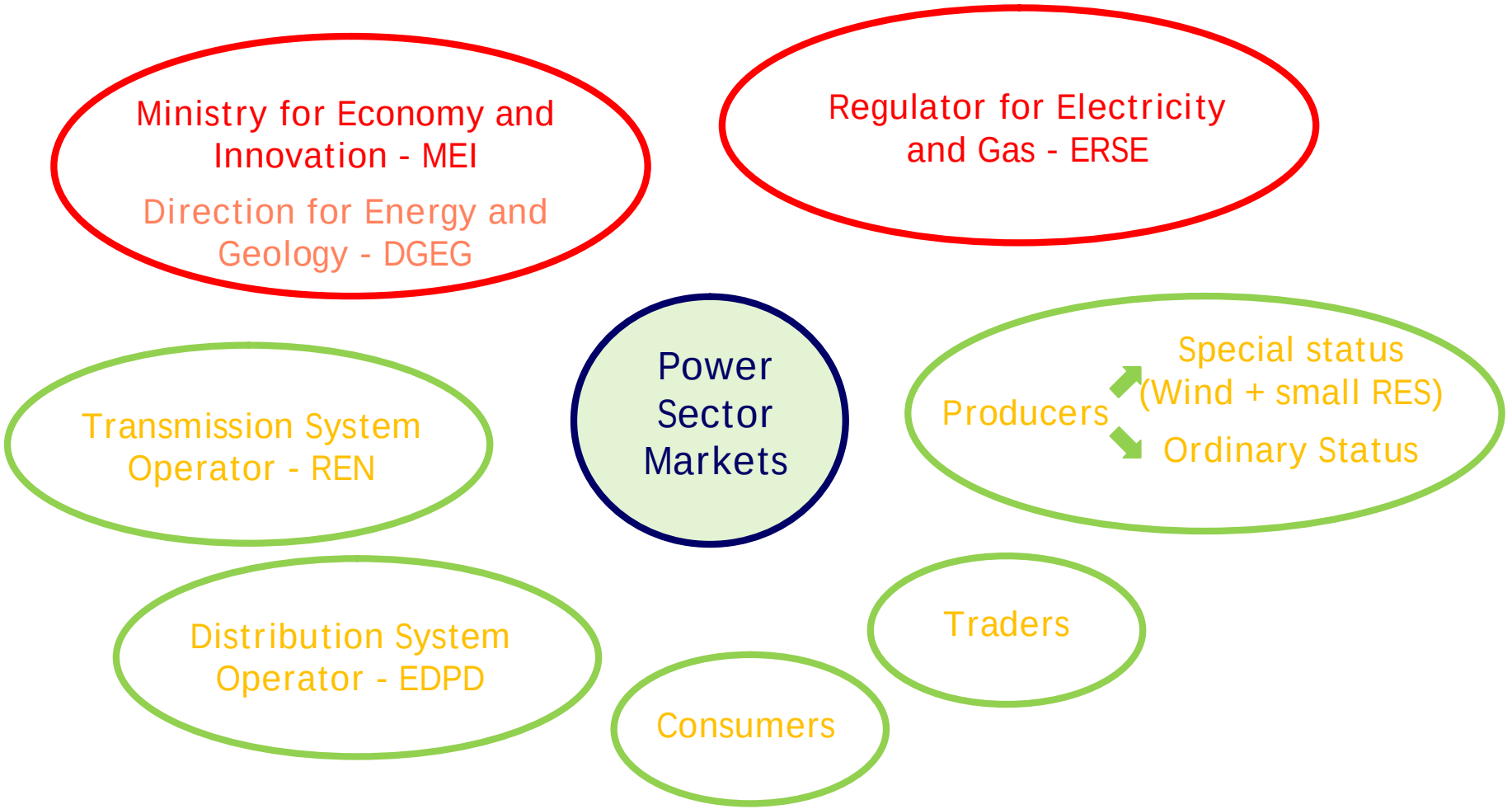
João da Silva Ricardo

joao.ricardo@ren.pt

Summary

- The power sector organisation and electric system
- The Portuguese goals for renewables
- Key challenges for TSO and DSO
- Coordination TSO-DSO and with neighbouring TSO
- The generation access rules
- The need for transmission grid extension and CAPEX
- Wind power and hydro in service & in action
- Key innovations in 2006 call for wind proposals
- Conclusions

The Power Sector organization (1/2)



≈ 20% of load on the market

The Power Sector organization (2/2)

Key responsibilities for new generation

Ministry + Directorate for Energy and Geology

- ü Policy making, including defining future national wind objectives
- ü Decisions on access of new generation
- ü Permits + licences (generation + grid)
- ü Value of feed-in tariffs for special status generation

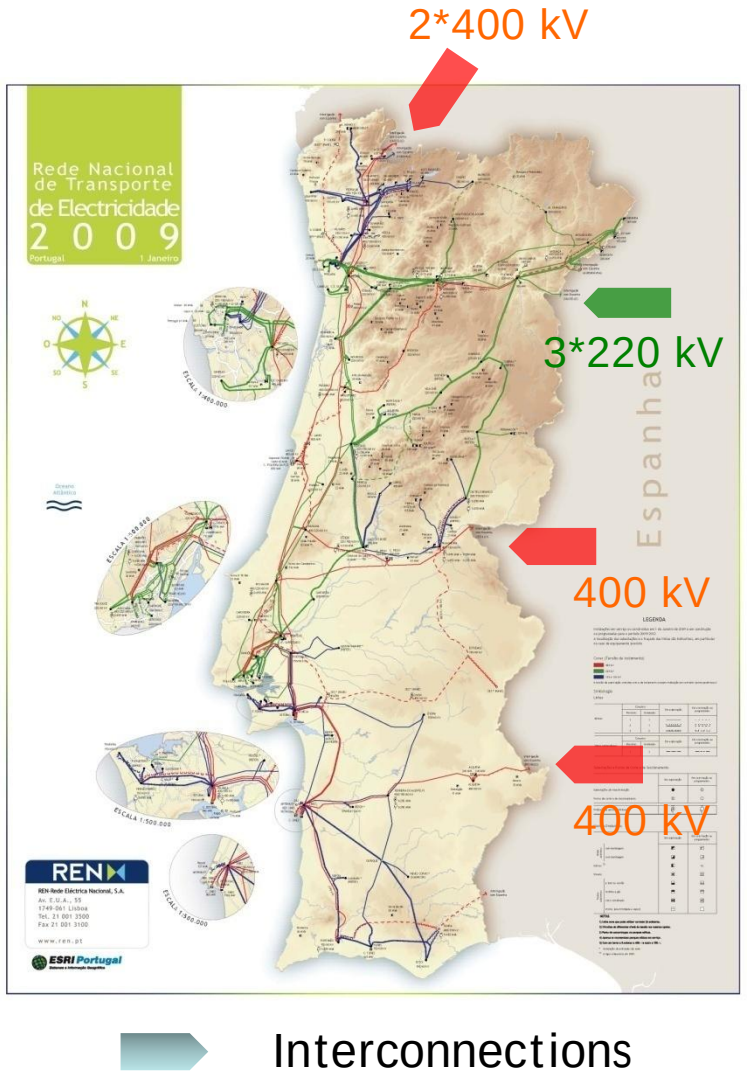
Transmission and Distribution Operators

- ü Adjust grid plans for objectives
- ü Build and reinforce the grids
- ü Define capacities of grid (public)
- ü Give (or NOT) OK for connections
- ü Define connection solutions
- ü Help wind producers in licensing + construction
- ü Real time system balance (dispatch)

The Portuguese electric system (1/2)

Key technical features: ***Grid*** (Dec 31st 2008)

- Current peak demand: *9110 MW*
- Average load growth: *4,3 %* *(last 15 years)*
- Transmission grid – lines and substations
  - 400 kV: *1589 km* *Substations: 53*
  - 220 kV: *3257 km*
  - 150 kV: *2667 km*
  - Transmission grid power transformers
  - Autotransformers: *9921 MVA*
  - Transformers to 60 kV - distribution and renewable generation *16273 MVA*

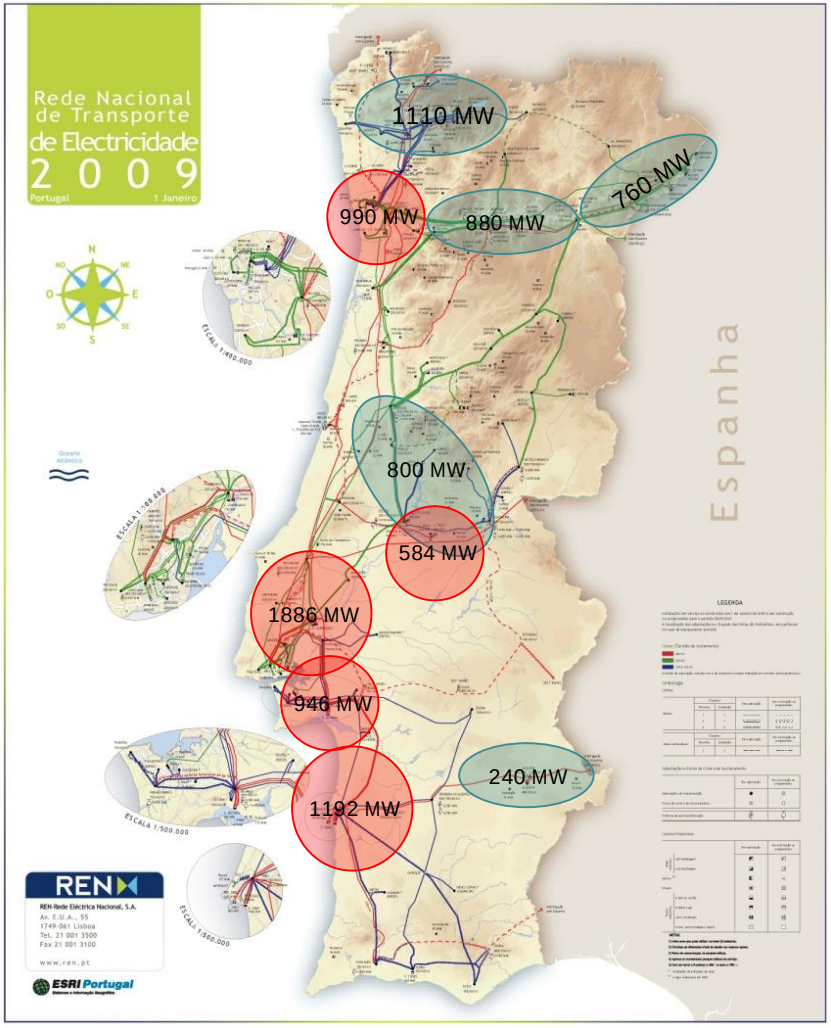


The Portuguese electric system (2/2)

Key technical features (cont)

Portuguese Generation System (Dec 31st 2008)

- Large Hydro *4578MW*
  - 3598 MW from which
  - 980 MW with pumping capacity
- Other renewable (Special status): *4518 MW*
  - *Wind - 2624 MW*
  - *Co-generation - 1463 MW*
  - *Small hydro - 379 MW*
  - *Photovoltaic - 50 MW*
  - *Waves - 2 MW (experimental)*
- Natural Gas *2166 MW*
- Coal *1776 MW*
- Fuel Oil *1712 MW*
- Gas-Oil *165 MW (fast start turbines)*
- Total in service - 14916 MW (Dec 31st 2008)



The Portuguese goals for renewables (1/2)

§ The global renewable energy (RE's) goals set for Portugal *keep growing*

Current 20-20-20 EU objectives for 2020 have led to the new target around

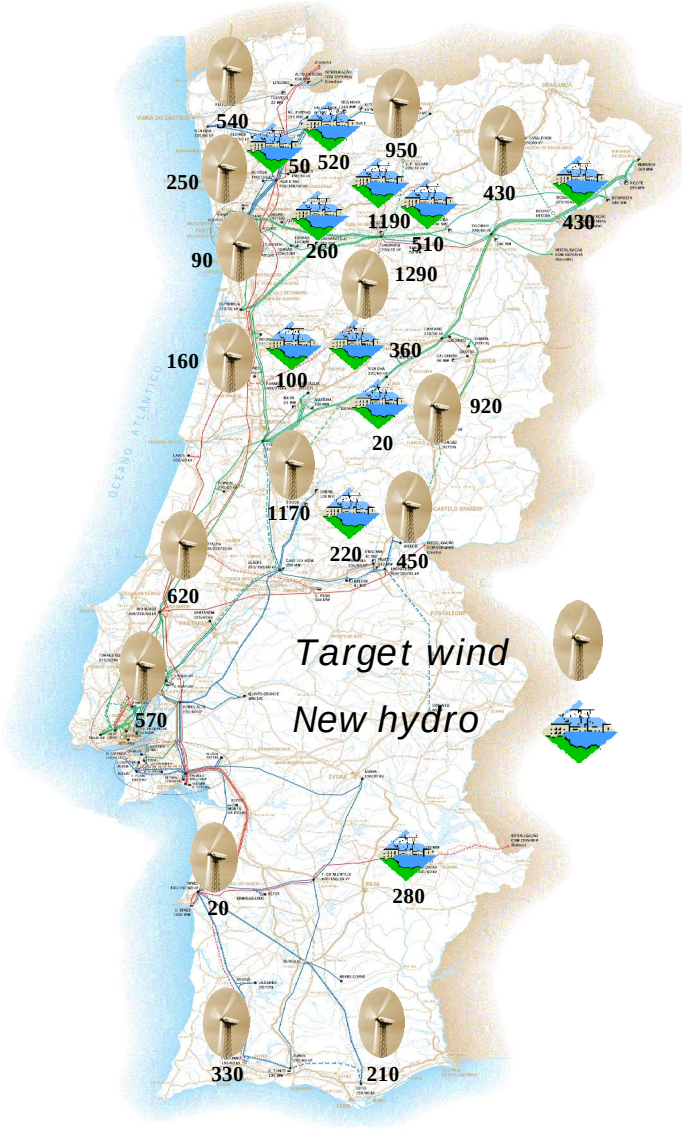
8 GW of wind

§ For a future 14 GW peak load system this means

1 - Increasing current 4,5 GW of large hydro with new capacity with pumping capacity

SO MUCH WIND NEEDS MORE PUMPING HYDRO!

2- Securing high level of interconnection capacity (target: from current 1,3 to 3 GW)



More hydro complements more wind !

§ More hydro creates more flexibility – Hydro is a valuable asset for high wind penetration

Also, some degree of more long term transfers are possible (weekly, monthly) – in larger existing reservoirs

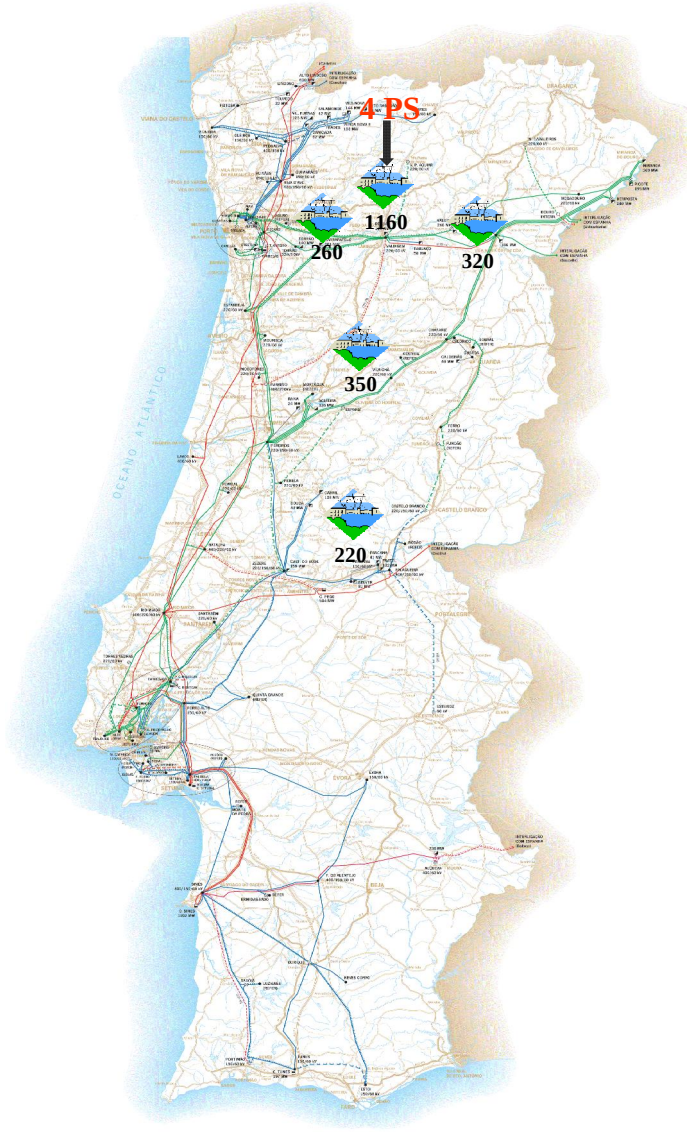
More capacity to follow shorter term wind variations (minutes, hours), easing stresses on thermal generation

Possibility of fast launch to help after tripping of wind or other generator types

The Portuguese goals for renewables (2/2)

- In 2007 the Ministry of Environment launched a National Plan for Hydro (NPH)
  - 8 new hydro power stations (PS) almost all of them reversible
  - New 1,1 GW of gen. capacity from which 0,9 GW with pumping capacity
- NPH 8 PS's where divided into groups and calls for proposals to build + own + operate were submitted to the market
- All winning proposals multiplied by at least 2 the foreseen installed power

The NPH, together with other new hydro projects, will secure ***new 3,5 GW*** *of hydro generating + pumping capacity*



Key challenges for the TSO and DSO

From late 90's REN has been creating a new paradigm to cope with growing targets in renewable disperse generation, *in close cooperation with the Ministry responsible for energy and the Distribution System Operator (DSO)*

1 Need of coordinated approaches of Ministry, TSO and DSO to

Review and update transmission grid planning decisions

Manage generation MW permit process – Max limits at each substation defined and public

2 Need to analyse and manage the future stability and security of the system

Reactive control (inc post fault)

Fault ride through capability

Coping with gener. intermittence

3 Need for steep increase in construction and upgrading of lines and substations

Faster environmental and legal permitting processes

Increase in project design + realisation outsourcing

Coordination with Distribution Operator (EDP, SA)

- Debate and agree on Distribution and Transmission grids developments
- Debate on technical rules with influence on Transmission Grid
- Review codes and standards on a coherent way
  - Dynamic specifications for frequency
  - Short circuit / Voltage dip generator adequacy – Fault ride through capability

It is key to create conditions to avoid massive and uncoordinated outages of generation:

REMEMBER THE EUROPEAN INCIDENT ON NOV 4th 2006

- Follow up on generation permit agreement decisions
- Common dialogue with investors, when necessary, for access decisions or investment realisation

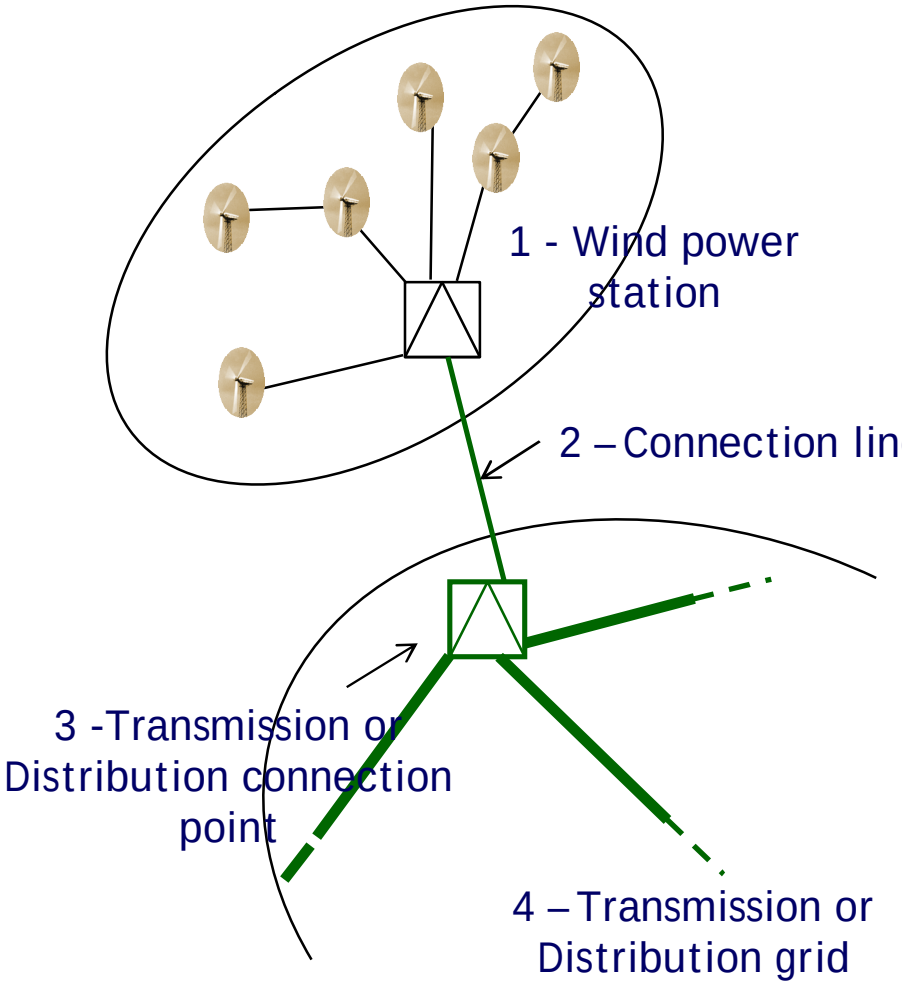
Coordination with neighbour TSO (REE, Spain)

The generation access rules (1/2)

1. *The TSO - REN takes into consideration the national goals for RE's*, the wind and hydro resource location and developer's connection applications *when making the 'Grid Development Plan'*
2. REN calculates *grid generation reception capacities* for all substations according to grid plan. These values are public
3. *Investors present to the Ministry of Economy and Innovation (MEI) their applications* for new generation projects, including location
4. For each substation, *should there be excess capacity demand in comparison with grid capacity, a 'prorata' reduction* criteria is applied to define final MW which are attributed and reserved to each developer. TSO or DSO give MIE their OK (or opposition)
5. Also, in 2005 the Government launched a *call for tenders for two blocks of wind power* (1000 MW and 500 MW) all the different local capacities respecting grid capacities

A new grid planning +coordinated RE's MW permiting paradigm

The generation access rules (2/2)



Who builds/pays/operates what

1. Wind generation power station inner grid and main substation

   Constructed, paid by and remaining property of the developer

2. Connection line

   The same but once built, property will pass to TSO or DSO

3. Connection bay

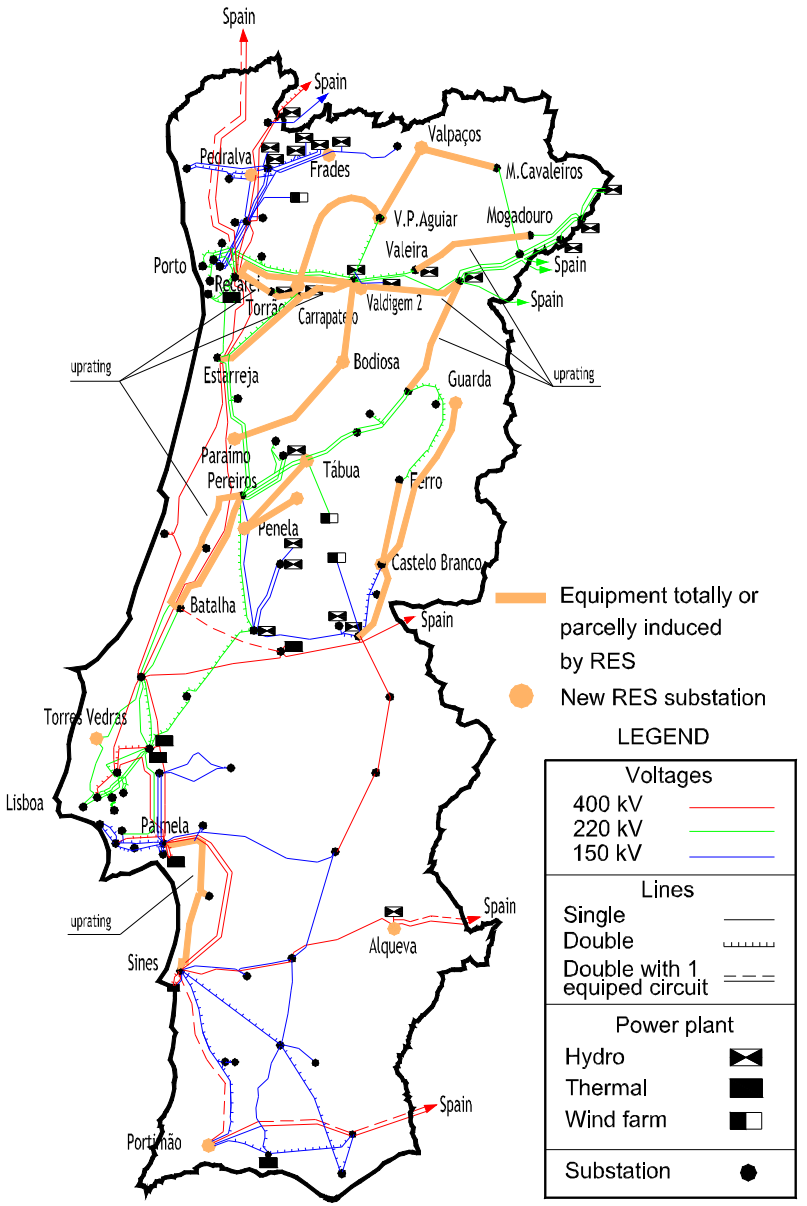
   Constructed by TSO or DSO and paid by developer

4. Transmission or Distribution internal reinforcements

   In charge of TSO or DSO costs socialized through tariffs

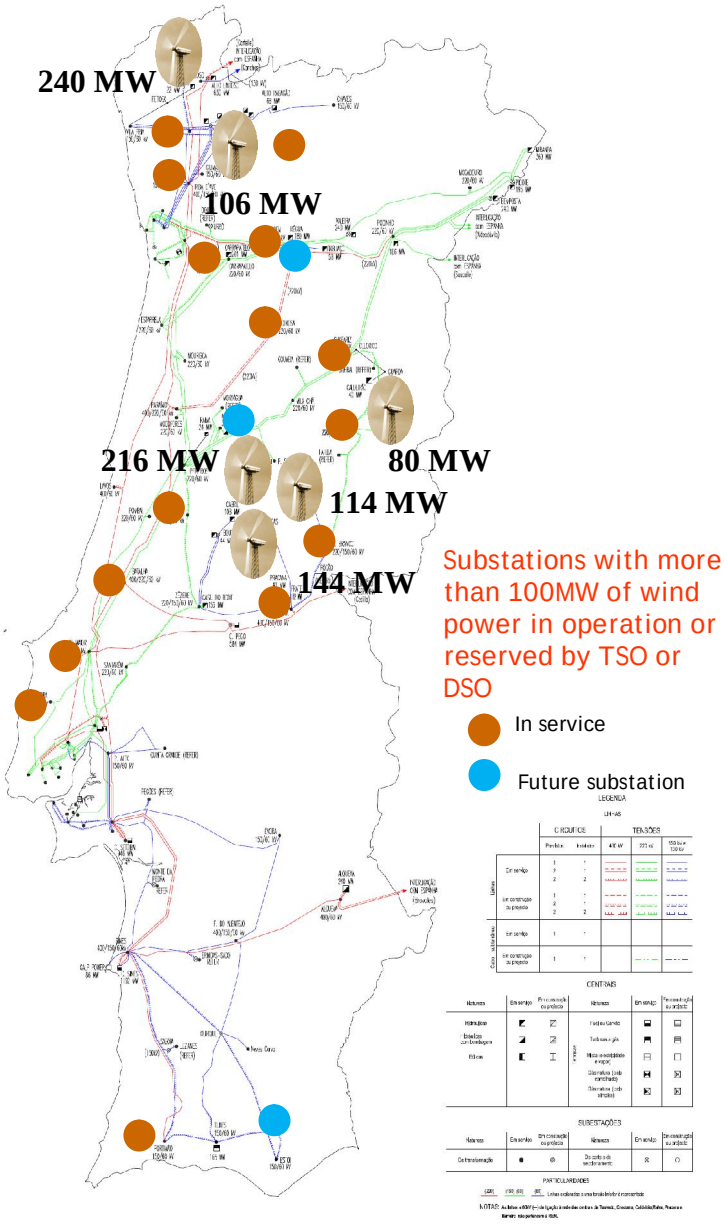
The need for Transmission Grid extension (1/2)

- The Planning decisions for RE's include some new lines and substations, and anticipates the scheduling of others previously planned
- The map shows the key items *in orange*, including mainly the following items:
  - Uprating or upgrading of existing lines
  - Upgrading of a few existing substations
  - Some new lines and substations
  - Construction of new bays in substations
  - Boost in reactive compensation capacity
- Reasons to reinforce the grid 1 - It is necessary to collect wind in inner areas 2–More transmission capacity from these areas to load areas (litoral) and to Spain is needed



The need for Transmission Grid extension (2/2)

- From 2000 on, for the transmission grid (TG)
  - *New substations (SB's)*
  - *New lines and*
  - *Uprating of existent lines and SB's*
- 6 large wind projects (900 MW) already in operation in 220 or 150 kV
- In the next 3-4 years, other 1400 MW will also be connected to the grid
- 70% of the current 3050 MW of wind are connected to the distribution networks BUT
- *Most of the additional RE's large generation will – mainly almost all the large hydro – will connect to the 400 kV level*



CAPEX and breakdown for wind and large hydro

- In the overall period 2009 – 2014, the investment *directly attributable to wind and large hydro, ie*

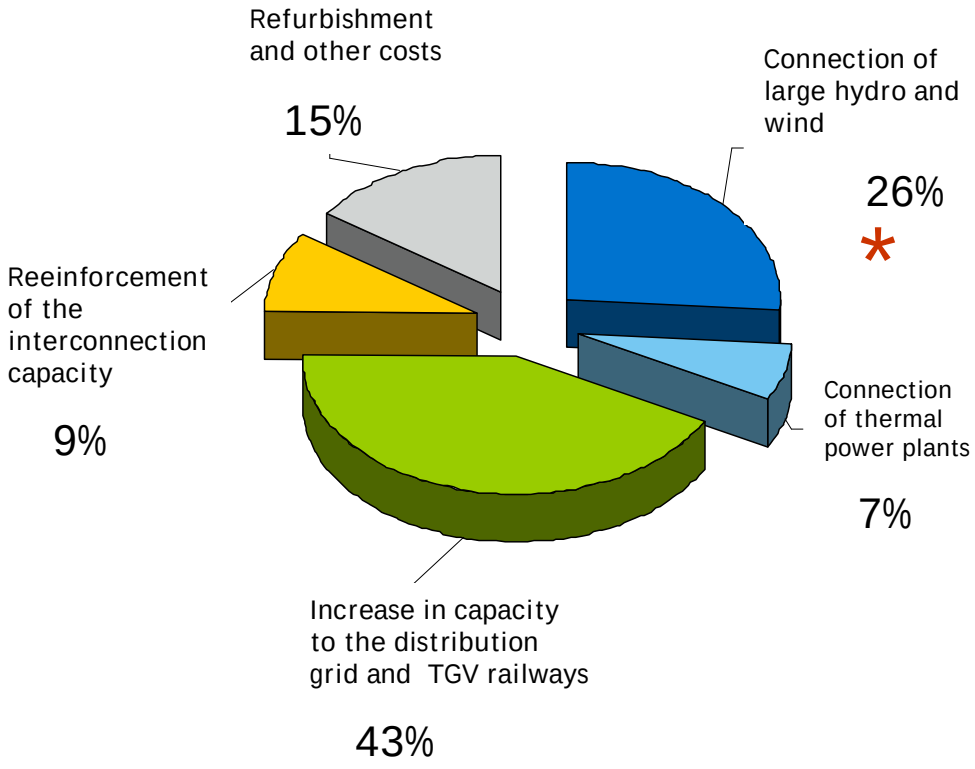
  (sum of *cost % of contribution for wind+hydro objectives of each investment item*)

  *will amount to 400 M€ (* see pie) for new 4.5 GW of wind and new 2 GW of large hydro*

- These numbers *do not consider* the investment of the wind park and its main substation nor the direct line to the grid connection point, which are all built and paid for by the developers

Breakdown of 2009 – 2014

REN CAPEX ~1600 million €
(6 years)



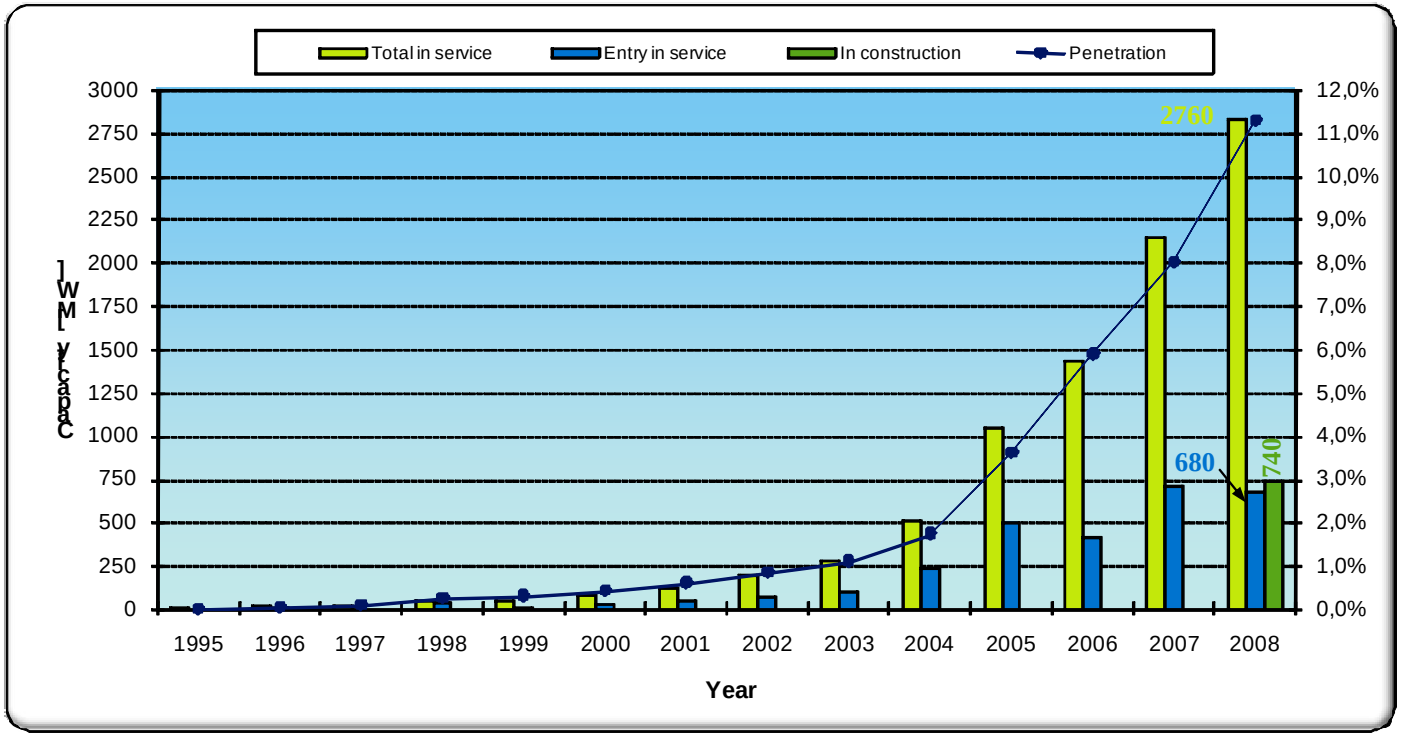
REN construction management response

- In the past - Most of the line or substation projects made 'in house'
- Later: Legal increase in environmental administrative procedures – outsourcing of studies – 'in house' formal procedures with Authorities
- Early 2000' – became clear need to important increase in investments due to RE's national objectives
- Need to adapt further in recent years – Total investment from 150 to above 250 M€ per year – *Further increase of outsourcing*
  - Call for and help the creation of new construction service providers
  - Enlarge outsourcing – All projects and environmental studies outsourced
  - Even complete processes of environmental studies plus administrative plus procedures plus construction are now organised and outsourced

Wind power in service and foreseen

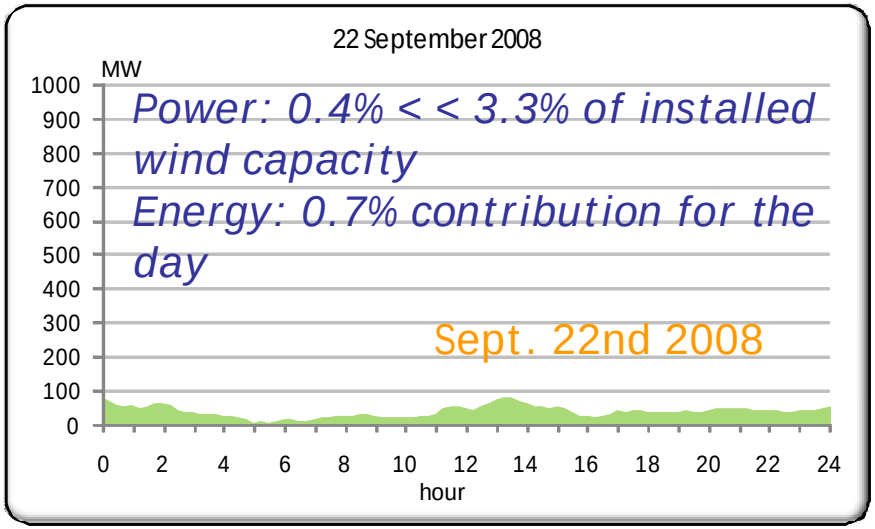
§ As of Dec. 31st 2008, 2760 MW of wind were in operation in Portugal and generation was 5 TWh, 11% of total injected energy into the grid during 2008. Something as 13% is expected for 2009

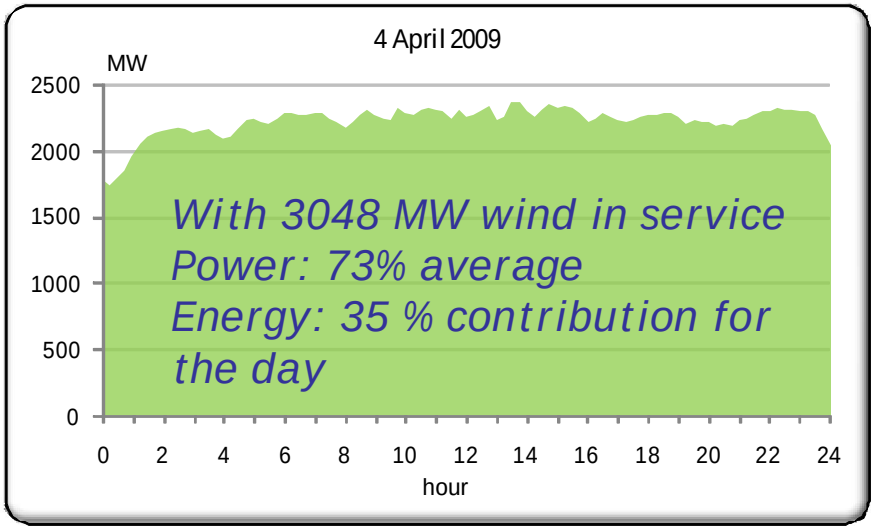
§ The steep growth of wind will keep going for the next years

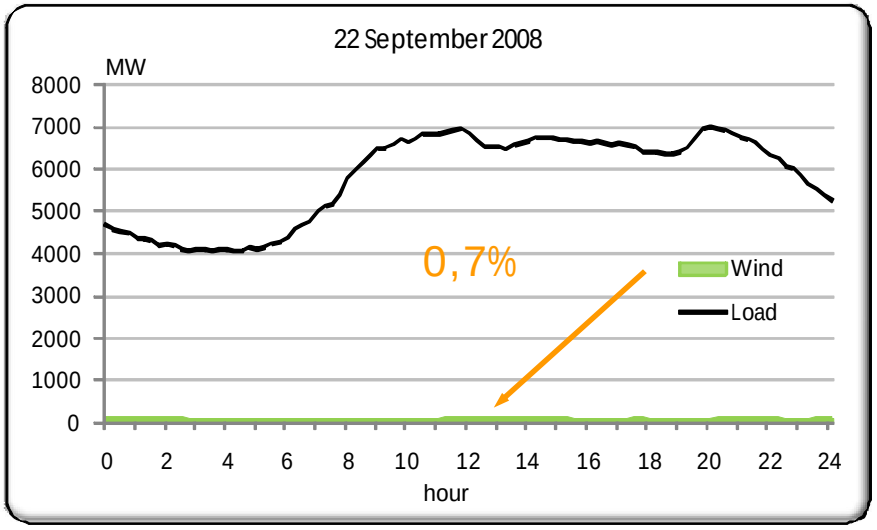


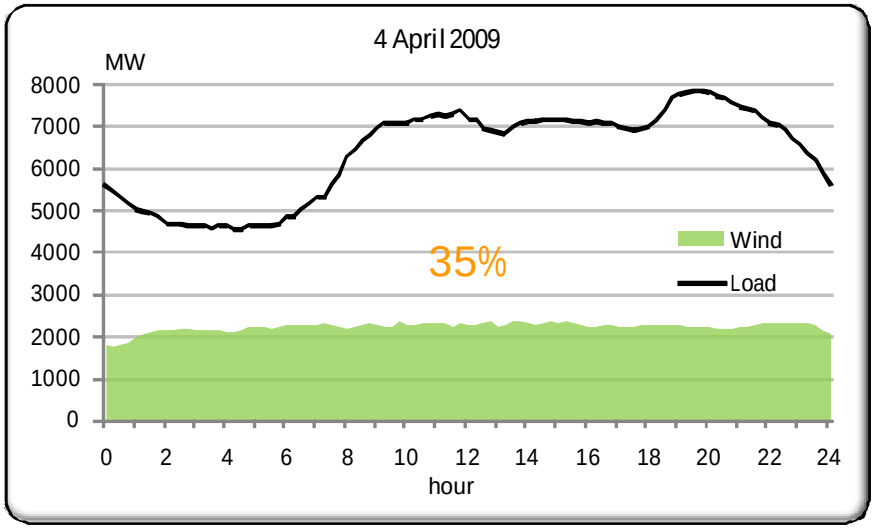
Wind power in action – extreme days 2008/09

April 4th 2009



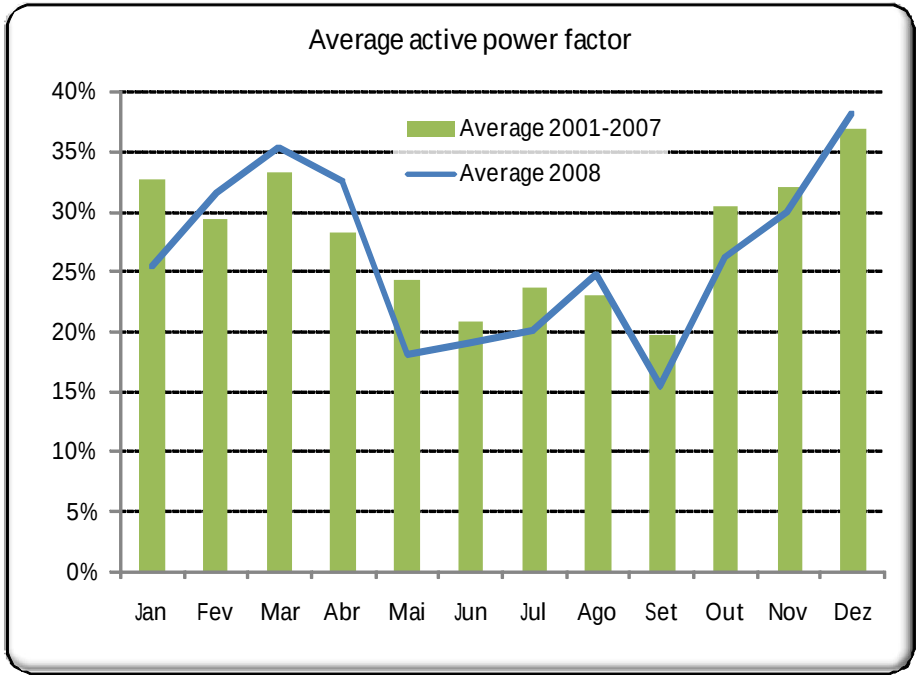


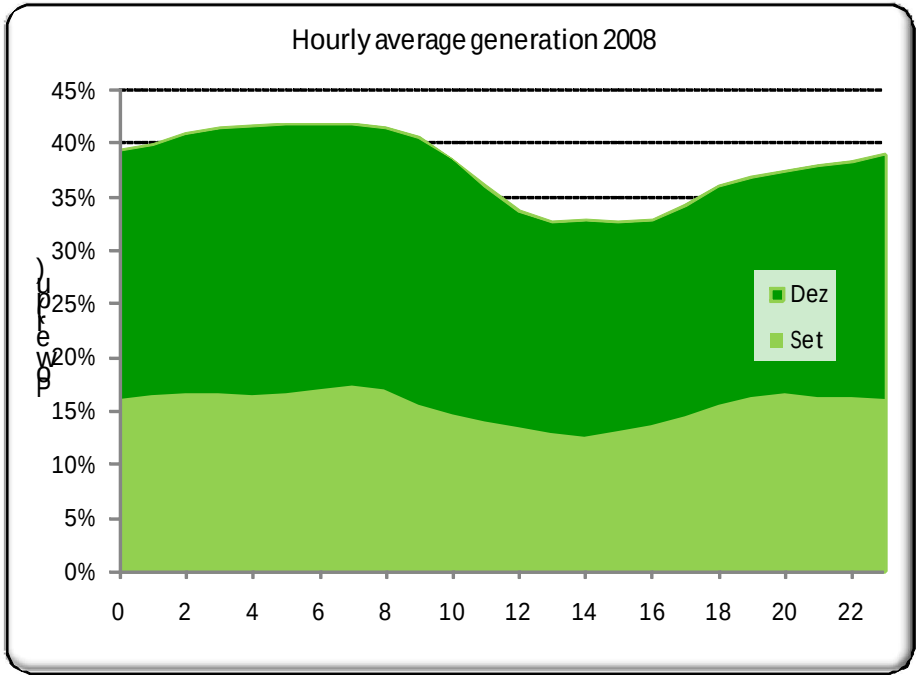




Wind power in action – monthly variability

- Dec 2008 – average power factor above 35%
- Active power factor varies along the months of the year
- Wind generation is somewhat lower during the day
- Total year variability of wind energy much lower than the one of hydro





Hydro power in service

- Existing large hydro

  4.4 GW → 1580 MW reservoir
  1860 MW run of river
  980 MW pumping

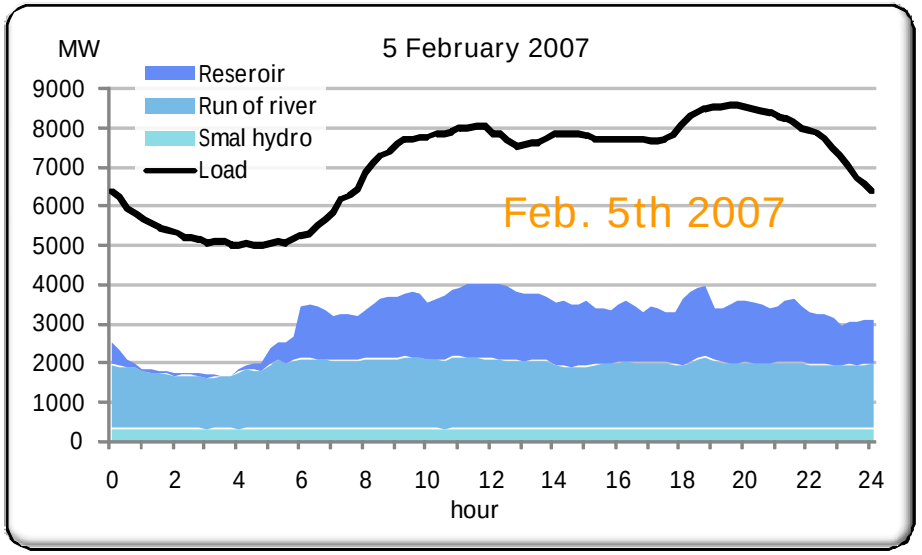
- Plus existing 537MW of small hydro
- Average year productivity ~11 TWh

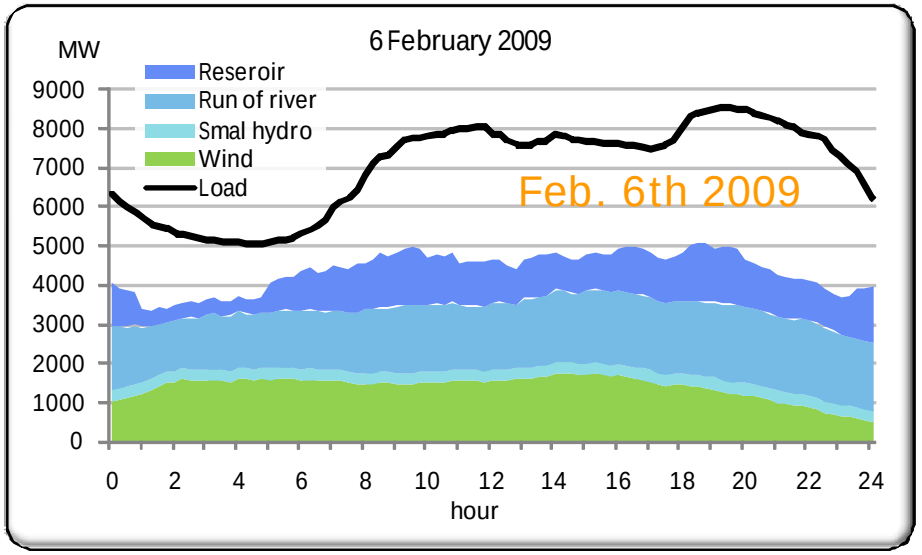
  ~21% of total current consumption

- Important year variability ratio dry/wet year ~ 1 to 3
- The largest production in one day 2008-09 - Feb 6th 2009

  Hydro -> 49% of load

  Hydro + wind -> 62% of load





Key innovations in 2006 call for proposals (1/2)

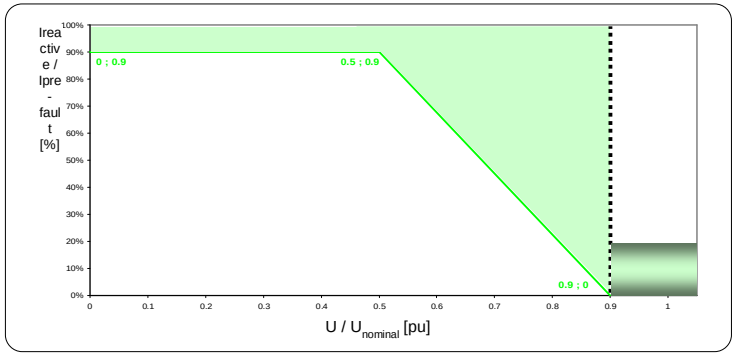
Innovative characteristics of the new wind power stations

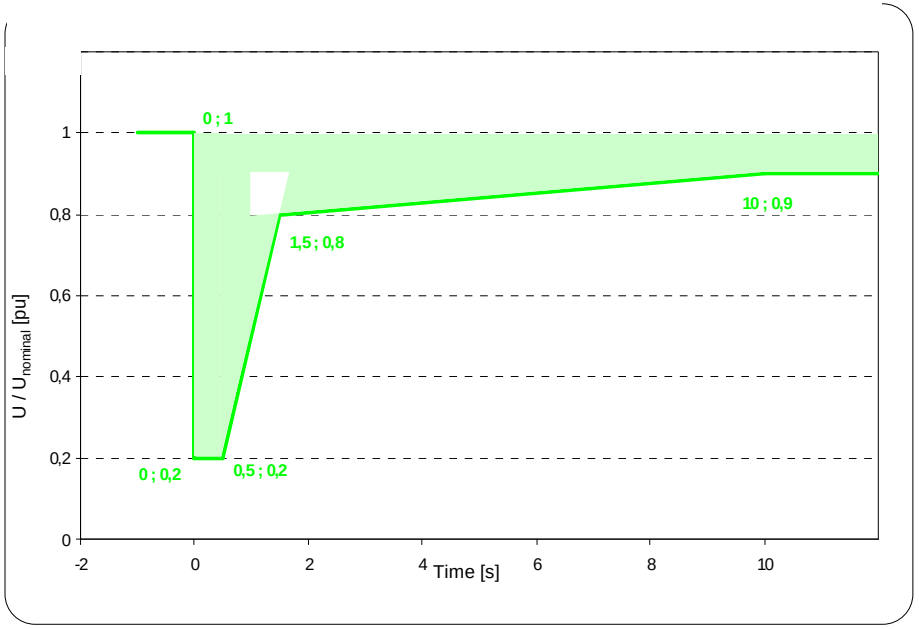
1. Management of wind power stations by clusters ("local wind power dispatch centers")
2. Steady state reactive power control: tg fi within [-0.2, +0.2]
3. Wind curtailment (no-load periods; 50h/year, max)
4. Solutions for "wind/RE's energy storage"; specially with hydro power stations
5. Participation in the primary frequency control

   wind turbine operation at 95% of P_{opt} in previously requested periods (by TSO)
6. *RTFC - Ride Through Fault Capability* as a "minimum requirement" for system security
7. Installation of *Wind Generation Dispatch Centres* with wind forecast (also in REN's national control dispatch centre)

Key innovations in 2006 call for proposals (2/2)

- *The need for TSO's and DSO's (60% of wind!) to safeguard system security following post-fault or voltage dips* lead to the specification of FRTC for wind generators in any high wind penetration scenario
- Joint Iberian dynamic studies of REN and REE justified this need
- *Wind generator manufacturers* had already understood that lack of resistance was becoming a barrier to high wind penetration and *have been developing excellent FRTC performance of new generators*
- Post fault reactive behaviour is also key for grid security





Conclusions

- High penetration of wind and hydro generation – IT IS POSSIBLE - Main challenge for TSO and DSO
- New approaches needed and implemented: results OK so far
- A wise level of central management is important
- Cooperation and coordination between TSO and DSO's and also with neighbour TSO's and RE's associations are also necessary
- Specification of new technical requirements for secure and flexible future system operation is key
- Revision of codes and rules must be done at an early stage of the process
- Internal changes inside TSO and DSO at planning, construction and system operation

MULȚUMESC

Thank you

for your attention

João Ricardo

REN, Rede Eléctrica Nacional, SA
Portuguese TSO

joao.ricardo@ren.pt