Barriers (and Solutions...) to Very High Wind Penetration in Power Systems

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ID of the Problem(s)

A. Several countries and regions in Europe already have high wind penetration;

B. Wind generation is highly variable in time and space and it doesn't offer guarantee of power. High penetration may require added reserves (and costs...) for some power systems;

C. The concept of renewable energies maximum penetration limit is unacceptable (at least in EU...)

D. Transmission grids and operation strategies to cope with wind generation from a high to a very high level are being developed: there are solutions already identified or in use for the most common grid/system constraints.

Common Technical Barriers to High Wind Penetration

A. Limited Capacity of the Grid

B. Wind doesn't offer Security of Supply and impacts on Power Unit Scheduling

C. If a system already has a significant amount of RES, wind integration in large amounts may produce Energy Congestion / Surplus Management

Technical Power Barriers to High Wind Penetration

A) Transmission Grid Limited Capacity

1) Most classical "technical" barrier

- Although is really an economic one, not a technical…

- In Europe this issue is being addressed in different ways. The vast majority of countries nowadays include RES and particularly wind energy in their transmission grid development plans.

- For the distribution grid reinforcement costs, different countries have different solutions: from 100% utility support up to 100% payment by the wind developer.

2) Common to all new power plants, RES or not.

Technical Power Barriers to High Wind Penetration

B. Security of Supply. Unit Scheduling

1) Balancing Power

Wind is (totally) time dependent and gives no guarantee of firm power… there are added costs for wind integration for some power systems.

2) The excessive "Wind Power Variability"

wind forecasts are improving every day, being used by all major TSOs in Europe with acceptable deviations within time ranges useful for power system operation.

3) Wind Generation Technical Reliability

The main concern of every TSO with high penetration is the sudden disconnection of all or most of the wind generation as a response to a fast grid perturbation, normally referred as a "voltage dips".

Technical Power Barriers to High Wind Penetration

C. Operational Energy Congestion. Surplus Management

Different generation mixes face different challenges:

1) **In power systems where the energy mix is flexible in terms of regulation, there is almost no added reserve cost associated with the integration of wind in the system**
   - e.g. high penetration of hydro plants with storage capacity.

However…

2) **an issue that is commonly raised in these systems is the possibility of of surplus of renewable generation (e.g. wind + hydro) that raises the uncomfortable issue of either disconnecting wind generators or spilling water**
   - which would be turbinable in the absence of wind. The issue is (again) more economical than technical.

Tools and Methods to find Solutions

Solutions: The Future Power Systems with Large Wind Penetration

Smart dealing with Grid Capacity

GIS location of the wind resource ("as geographical wind dams") and grid connection demands from the wind farm developers, enable the DSO and TSO to define, if necessary:

1. ***When and where to extend the transmission*** *network to avoid large investments for low wind sites or small wind farms.*
2. *Grid planning should take into consideration the special characteristics of wind generation, i.e., its time and space variability and consider* ***grid reinforcement vs grid monitoring and wind power control****. Curtailment may prove to have high economic benefits and should be assessed.*
3. ***Combined probabilistic and deterministic approaches*** *are the most appropriate, with the wind modeled, if possible, with spatial correlation factors resulting from the wind resource GIS mapping.*

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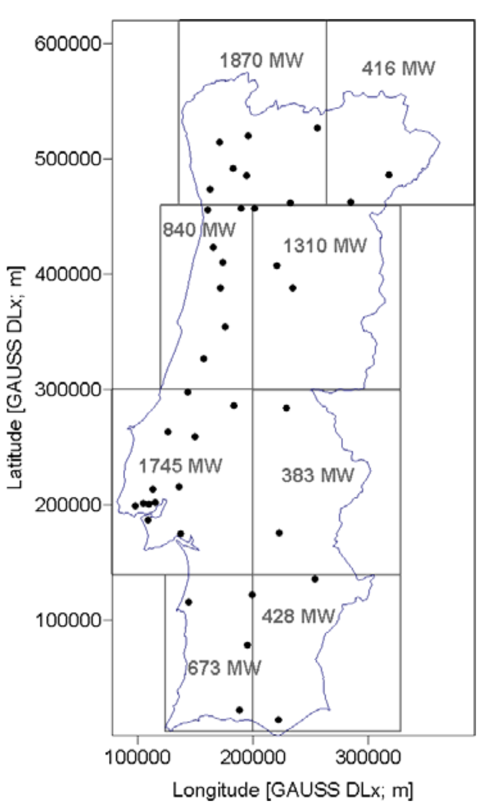
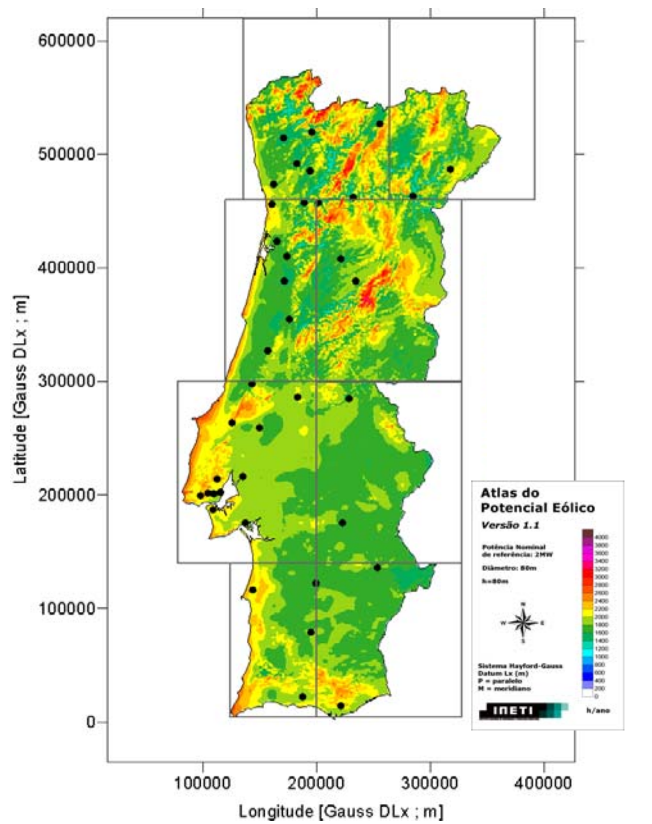
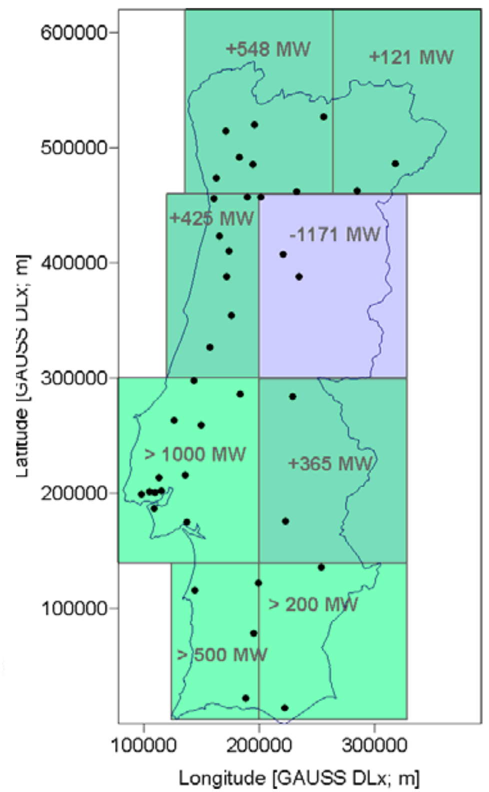
Solutions: The Future Power Systems with Large Wind Penetration



a) Grid capacity in 2013 (~7000 MW)



(b) Onshore sustainable wind resource 5900 MW (aprox.) + >1000 MW offshore



(c) Deficit/superavit by region

Local distribution of wind resource vs. TN capacity

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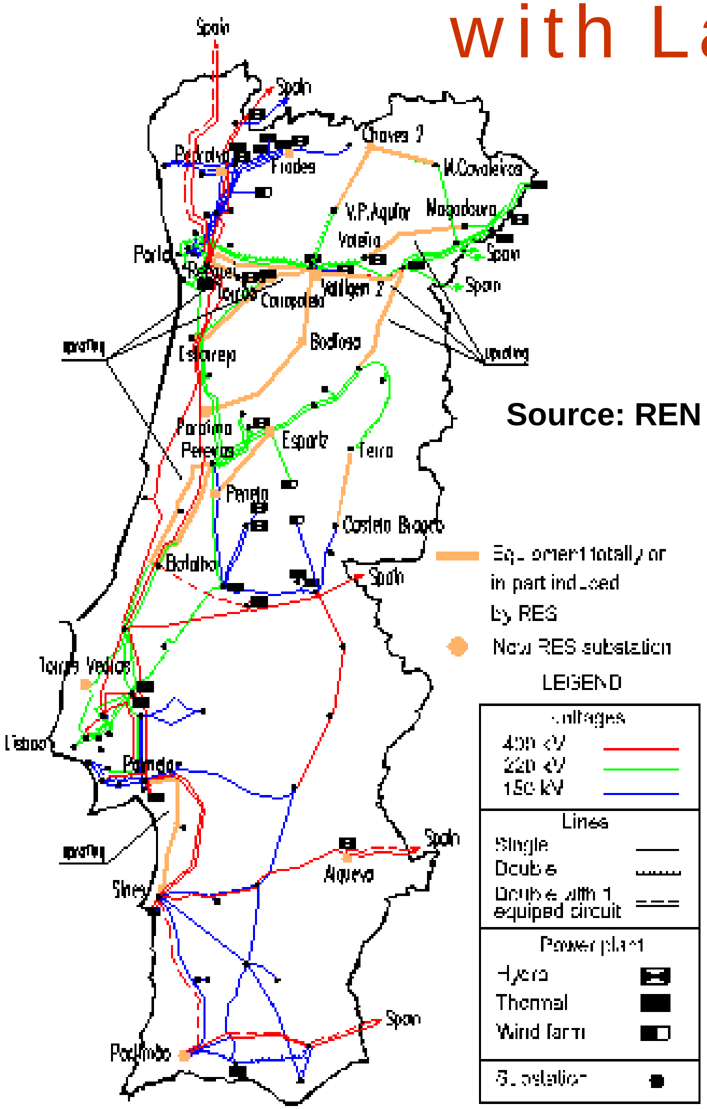
Solutions: The Future Power Systems with Large Wind Penetration



Source: REN

Find RES and load synergies and characterize the existing externalities,

The grid development plan to assess the wind power integration should also characterize the correlation with other RES (mainly hydro) to incorporate externalities and enable to accommodate the maximum RES penetration

Orange lines: RES induced (wind and large hydro)

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Solutions: The Future Power Systems with Large Wind Penetration

Integrated Smart Design and Operation of Power Systems

The IEA Wind IA started a new international cooperation project (Task 25) entitled "Design and Operation of Power Systems with Large Amounts of Wind Power", in the beginning of 2006. In this study, wind impacts on the system were mainly related to their time/range of scale and are globally identified as follows.

1) Regulation and load following [1 to 30 min.]

How the uncertainty introduced by wind power affects the allocation and use of reserves in the system.

2) Efficiency and unit commitment [hours to days]

Impact of wind power time variability and forecasting errors on unit commitment.

3) Adequacy of power [several years]

Avoided investment in conventional units due to existing wind capacity. Total secure supply available during peak load situations.

4) Transmission adequacy and efficiency [hours to years]

Depends on the location of wind farms relative to the load consumption, on the correlation between wind production and load and wind smoothing effect.

[IEA Task 25 – Large Wind Penetration]

Solutions: The Future Power Systems with Large Wind Penetration

Storage of Renewable Energy

- **The concept of wind energy storage - and other highly variable time-dependent renewable primary sources - is already in use.**
- **When hydro pumping storage is available, the methodologies able to identify the best combined wind/hydro pumping storage strategies should be used.**
- **Wind generation and energy price forecasts enable to optimise the daily operation strategy can be determined.**

[IEA Task 24 – Wind/Hydro].

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Solutions: The Future Power Systems with Large Wind Penetration

The Inevitable Challenge Towards Change

- **European TSOs <u>still do not share</u> fundamental <u>information for the operation of their power systems</u>**
  - *and have not implemented the available warning tools to help each other during events as the one that took place on the 4th November 2006.*
- **Taking into consideration the increasing <u>difficulties</u> felt by most, if not all, TSOs <u>to have environmental approval</u> for the construction of new transmission lines it <u>becomes "mandatory" to improve the existing network efficiency and utilization;</u>**
  - *by using online monitoring (temperature, wind, loads, etc), by introducing new components as FACTS, or by upgrading degraded components as conductors, protections and transformers, are urgent measures for TSOs.*

Solutions: Innovative Concepts of the Wind Power Plants already in use

Innovative Characteristics of the Wind Power Plants

- **Management of wind parks by clusters ("local wind power dispatch centers");**
- **Additional reactive power control: tg fi variable within [-0.2, +0.2];**
- **Curtailment of wind production for forecasted no-load periods;**
- **Solutions for "Wind/RES energy storage": specially as hydropower;**
- **Participation in the primary frequency control (e.g. 5% of P);**
- **LVRTF - *Ride through fault* capability**

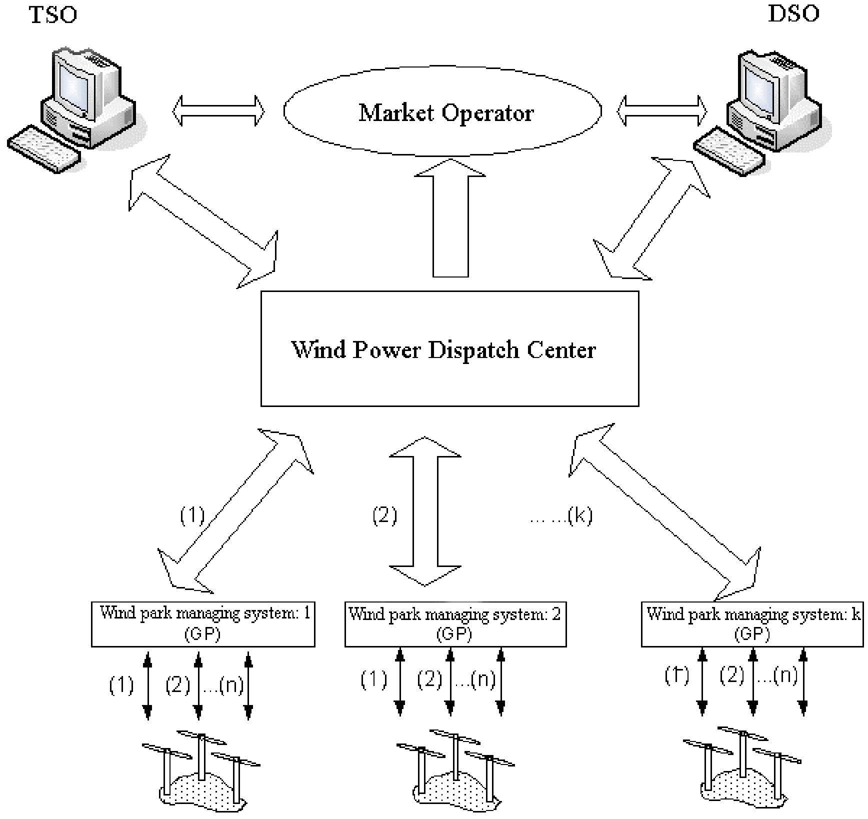
Solutions: Innovative Concepts of the Wind Power Plants already in use

New strategies and equipments

Installation of Wind Generation Dispatch Centres, acting as

"Generation Aggregation Agents"

the forecasted wind power dispatch centres will enable to monitor and adapt the wind production injection to the network operating conditions without compromising security operational levels.



Source: INESC-Porto

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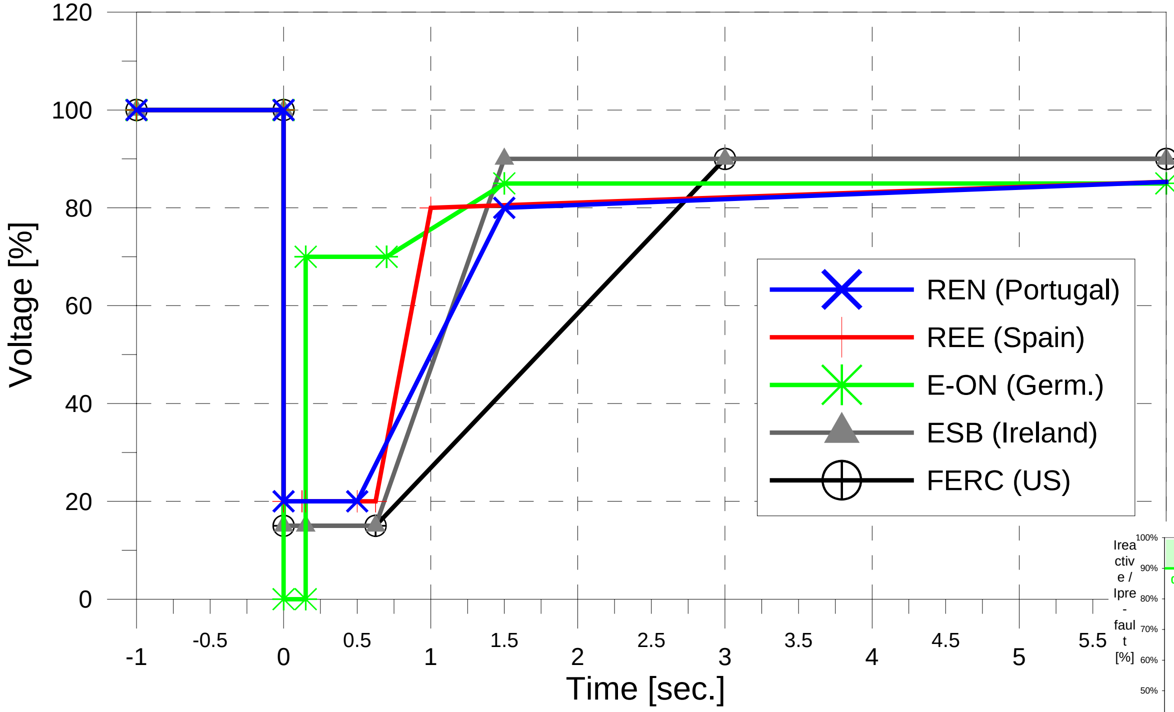
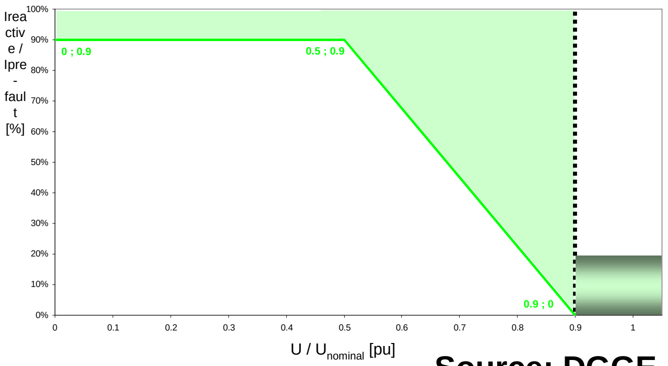
Solutions: Innovative Concepts of the Wind Power Plants already in use

LVRTF capability + added reactive



LV Ride Through Fault Capability from several Grid Codes

Reactive power contribution



Source: DGGE

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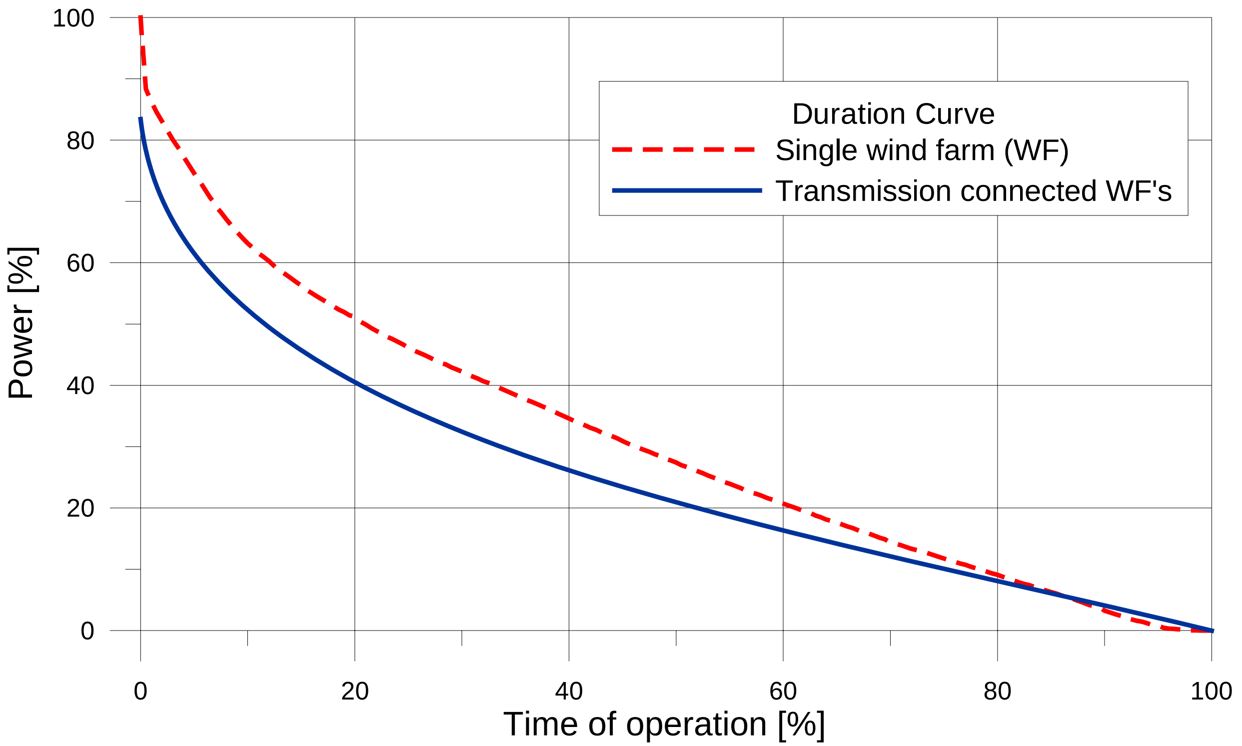
Solutions: Innovative Concepts of the Wind Power Plants already in use

Wind Power Control and Curtailment



The replacement of conventional generation by hundreds of wind generation units spread over the transmission and distribution system requires the development of new concepts for monitoring, controlling and managing these generation resources.

Innovative Concepts of the Wind Power Plants (already in use)

New strategies and equipments

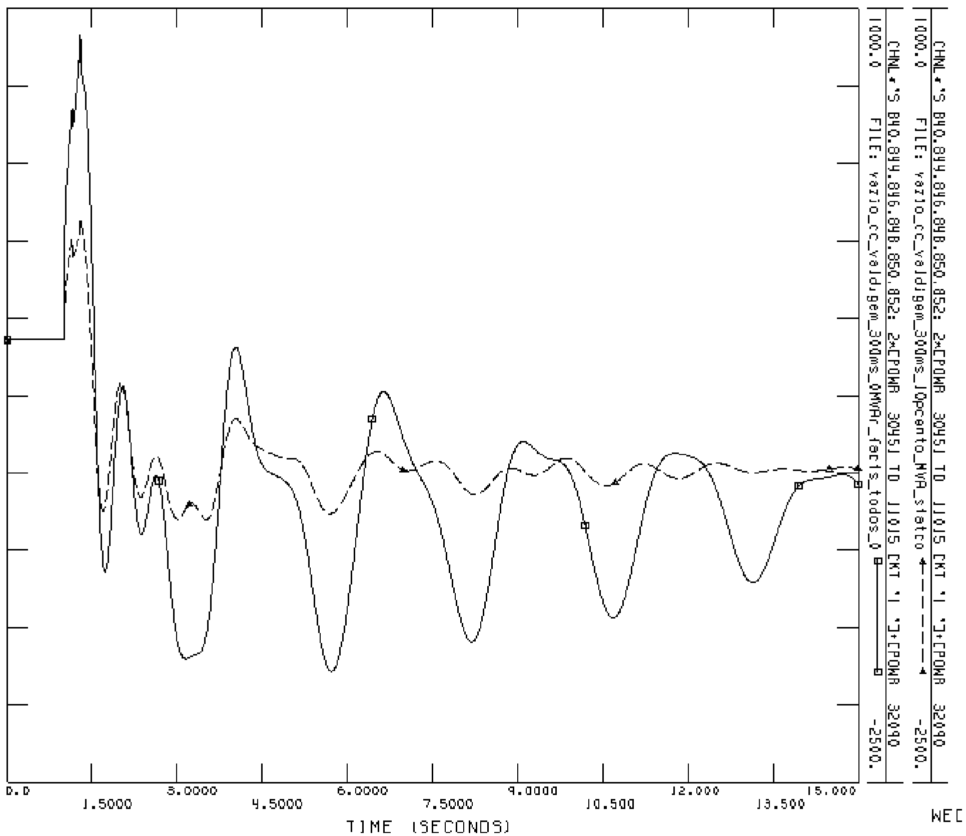
FACTS

It is also possible to install FACTS in strategic buses of the network:

i) to mitigate the impact of short circuits;

ii) help to prevent the disconnection of large amounts of wind power for under voltage protection relays actuation (much cheaper than equip all WT's to have LVRTF) ;

iii) strongly contributes to the damping of the oscillations.



Source: INESC-Porto

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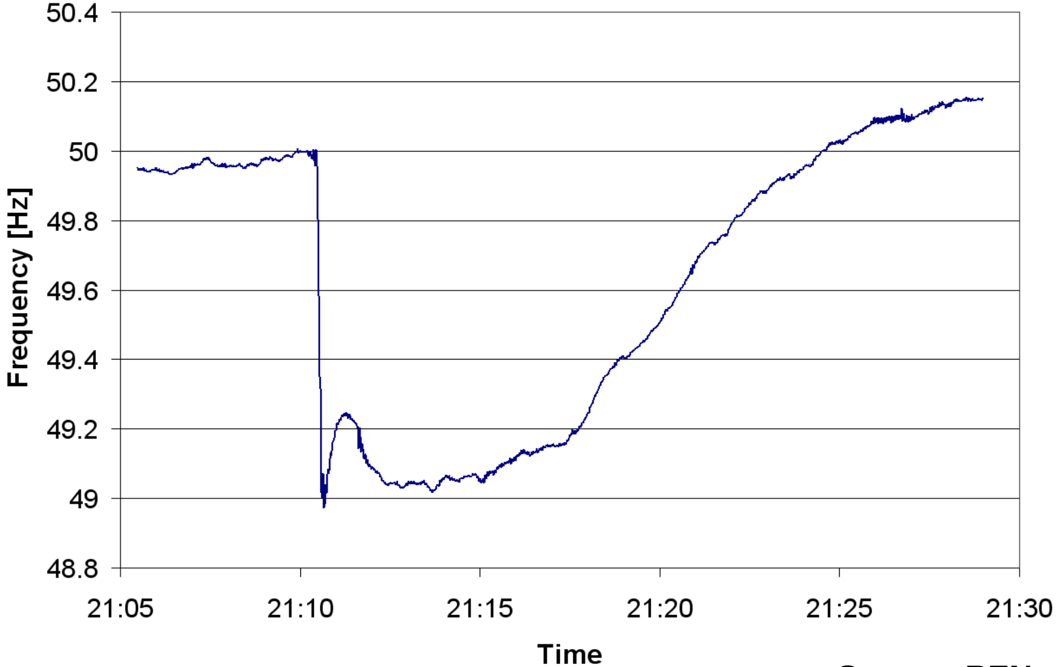
Solutions: Innovative Concepts of the Wind Power Plants (already in use)

Innovative Characteristics of the Wind Systems

Participation in the primary frequency control (experimental) by (DSO controlled) power curve regulation (frequency dip, 4th Nov.);



Source: REN

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Synthesis (1/2)

- The wind industry has experienced a remarkable increase in performance in what concerns the power system interface.

- The studies needed in order to assess high wind penetration are still being accomplished in many countries, however it is already clear that the wind industry has moved in the right direction with the integration of functionalities as LVRTF, remote condition monitoring and added generation control.

Synthesis (2/2)

- The close cooperation of TSOs, DNO's and the wind industry indicates it is possible to have wind penetration at large scale, this based on the results of some pioneering countries.
- The common barriers that prevented the large wind penetration are nowadays turning into questions as,
  - "what part of the wind capacity needs to have LVRTF capability ?"; and
  - "when, where and under what circumstances do the wind power stations need to be deloaded ?" in order to provide primary frequency control".

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