Title: Benefits of control centres in the operation of Electric Systems with high penetration of wind energy: Real experience

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Abstract:

There are over 6.000 MW of installed wind power In the Spanish Electrical System. This amount of installed power, compared with a load peak around 38.000 MW, has a big impact on system operation.

The System Operator must communicate with generator operators to respond to various criteria. The more significant parameters include:

- Production control
- Reactive power compensation
- Production forecasts

Within the last months, several short-circuits have caused significant wind generation interruptions, ranging up to 600 MW in one single short-circuit. For security reasons, studies have been performed to calculate production limitation, especially during low demand situations.

For these reasons, *Red Electrica* proposes the creation of control centres that can handle this type of energy installation, integrating other renewable energies as well.

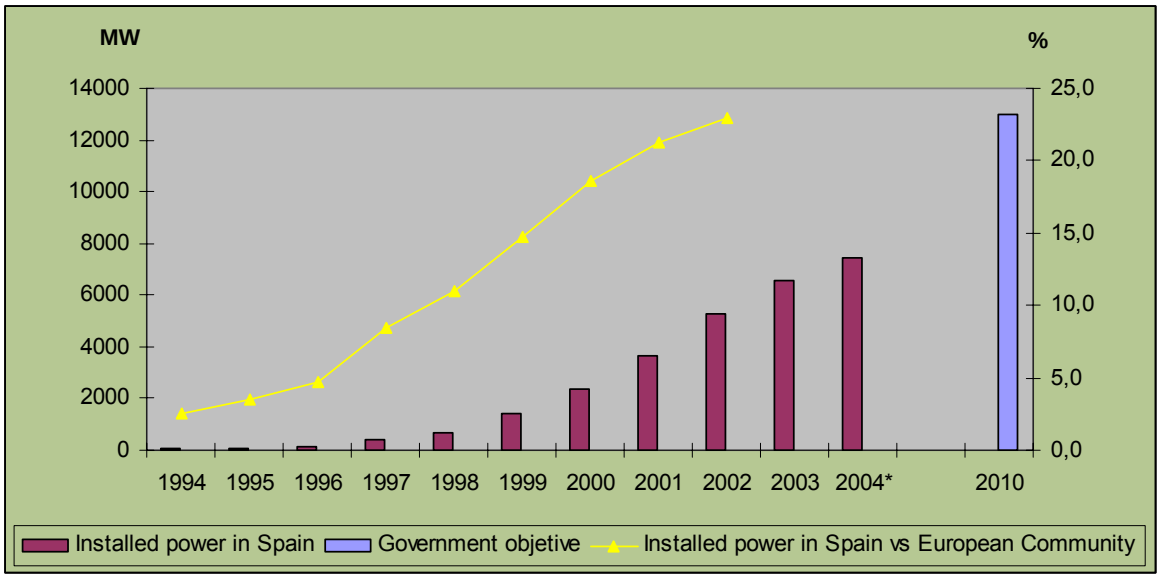
In July 2003 *IBERDROLA Energías Renovables* has inaugurated a new Control Centre for Operation of Renewables in Toledo. By 30 October 2004, sixty-one wind farms with approximately 1800 MW of installed capacity are remotely operated from this Centre. The objectives of the Centre are:

- Centralization of Operations, optimising resources through a significant reduction of local staff.
- Detection of failures and activation of maintenance squads, increasing the availability of wind farms
- Performance of energy control functions
  - operate at reduced power levels during periods with decreased transmission capacity or operate to reduce the power levels in response to technical restrictions
  - cooperate in voltage and reactive power controls
  - communicate with the System Operator Control Centre

This report presents the benefits of control centres demonstrating actual cases of production control during periods of very low demand. Production control was achieved for security reasons the 25th of December of 2003 and the 1st of January of 2004. The report also describes how Control Centres can be utilized to solve other difficulties.

1. Introduction

Until recently, installed wind power was anecdotic, and its influence on the system insignificant. Over the last few years however, the installation of wind power generation connected to the Spanish electric power system has grown very fast. This growth has proved even more rapid than the average growth within the European Community, as illustrated in figure 1.



* up to 20th July

Figure 1. Evolution of wind power generation connected to the Spanish electric power system and comparison with growth in European Community

In figure 2 wind-installed power at the end of years 2002 and 2003 is presented for the most representative countries in Europe. Wind installed power in Germany, Spain and Denmark is undoubtedly higher than the remaining European countries.

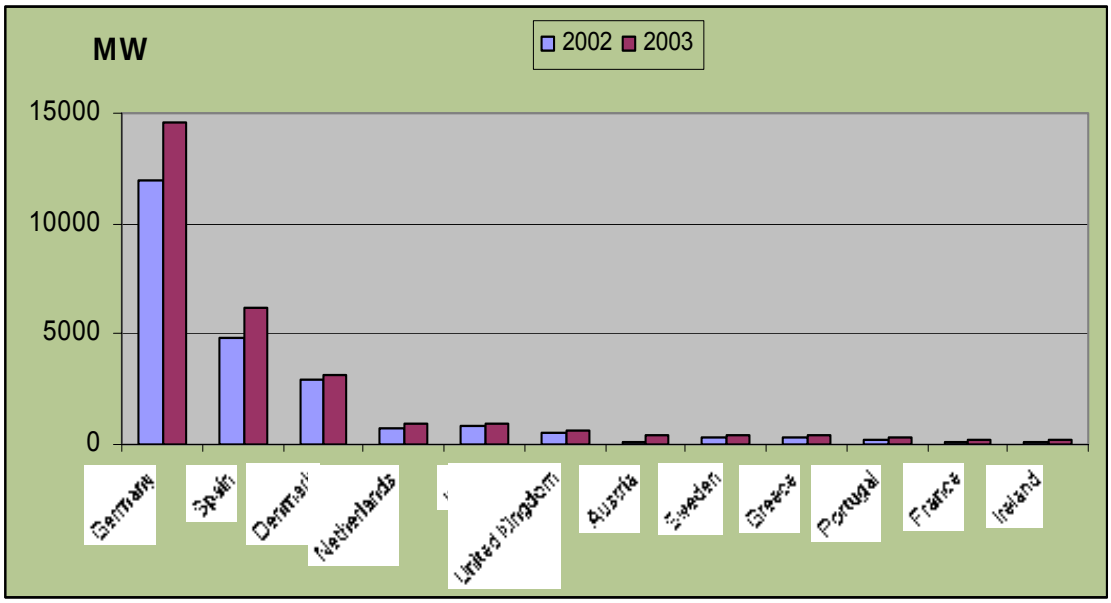


Figure 2. Wind installed power at the end of years 2002 and 2003 in the bigger producers of Europe

By relating wind-installed power with other figures, we can demonstrate that the importance of wind generation in Spain is not less than in other countries like Germany or Denmark (figure 3). When we compare wind-installed power with population (indirect way of comparing in-

stalled power with the size of the electric system), Spain appears to have a size comparable to Germany. If we compare wind installed power with import exchange capability, Spain fares well above other countries. This means that the transient support that Spain can receive from other countries is small compared with the wind-installed power.

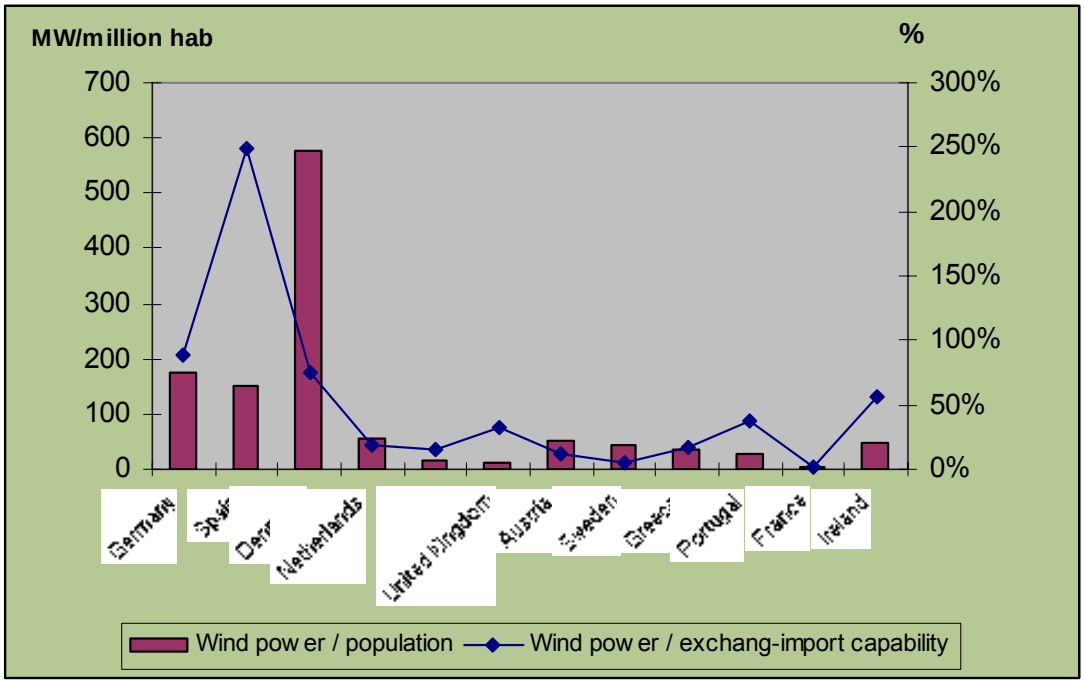


Figure 3. Relation of wind power installed vs. population and vs. exchange capability

The average size of wind farms in Spain is presented in figure 4. These values are distorted because farms with installed power less than 50 MW have a more attractive investment return rate. For this reason, larger farms are divided in some cases. Nonetheless, my comparing figures 1 and 4, we can see the sizeable number of farms installed (and planned) vis-a-vis the consequent difficulty of the System Operator to communicate with all the producers.

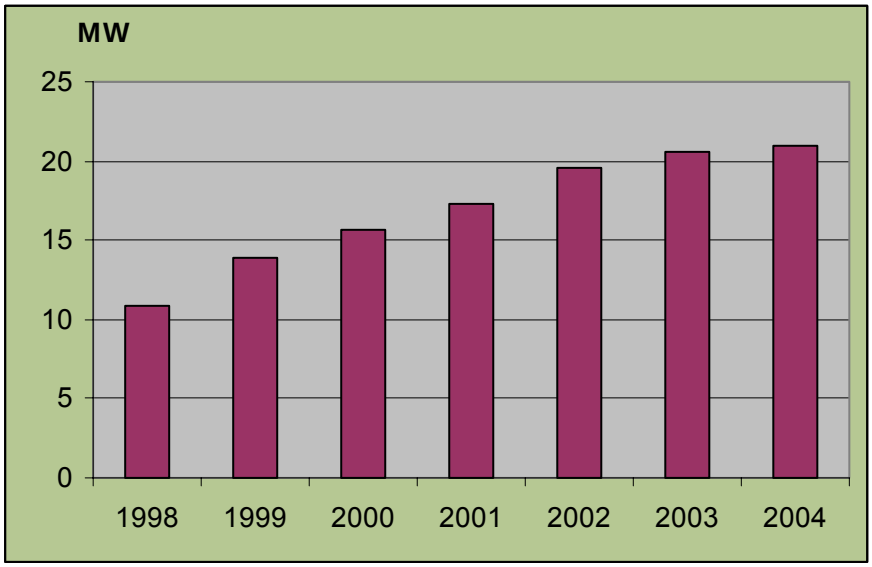


Figure 4. Average size of wind farms in Spain

2. Coordination between the System Operator and the producers in Spain. Operation procedures

The relation between the System Operator and the producers is regulated in *the Operation Procedures*, published in the official regulation. Nowadays, some of these Operation Procedures apply to all producers, while others apply only to those producers who participate in the Market. Some do not apply to special regime producers such as those relating to renewable plants and co-generation plants. Over time, more and more Operation Procedures are applying to special regime for two reasons:

- As there is economical incentive to participate in the market, some special regime producers are participating in the market, and more are expected to do so in the near future.
- New Operation Procedures cannot ignore the big influence of these producers in the correct operation of the system, and will include them in the scope of application.

Several important aspects for the correct behavior of the electric power system are regulated in these procedures. Among the most important that concern the production units, are the following:

- Production plants / maintenance plans
- Production units unavailability
- Technical restrictions (to solve security problems)
- Primary, secondary and tertiary regulation
- Voltage control

The correct coordination, in many of these cases requires effective communication between the System Operator and the producer during a 24-hour per day basis. This is achieved through generation dispatching offices (generation control centers) that have resources available 24 hours a day and retain the authority and the means to operate each of the production units they handle. This would be impossible for the System Operator, a separated communication with all producing units, to handle effectively.

In the case of renewable plants, the average size is smaller than ordinary regimen plants, and thus the number of agents could increase, making the need for a generation dispatching office very urgent. There is also another difficulty: the possibility of different producers connected to the same network bus. In this case any petition issued by the System Operator, at bus level, has to be divided by a bus coordinator (or by the generation dispatching office) between the different producers.

3. Centre of Operation for Renewable Energies (CORE)

Historically, IBERDROLA has been one of the pioneer companies in the Spanish hydro and wind sectors. In 2001, with the new Iberdrola Strategic Plan, renewable energies became one of the essential bases of its business strategy. At the end of September 2004, the total renewable installed capacity was 2,777 MW distributed in:

- A total wind-installed capacity of 2,502 MW, in approximately 80 wind farms

and

- 275 MW in 124 small hydro plants

Renewable Energies represent 10% of Iberdrola's Group generation capacity and approximately 7% of its production in 2004. The target-installed capacity is 4,500 MW by 2008.

"Iberdrola Energías Renovables" has a new Control Centre for Operation of Renewable plants since July 2003. It is a 24-hour operated Control Centre. It receives all the real-time data of the wind turbines, substations and transmission lines.

With the creation of this Centre, IBERDROLA Energías Renovables has achieved the key aims that were originally planned to improve its business potential:

- Centralize the Operation, optimising resources with a significant reduction in local staff.
- Reduction of costs due to unavailability of wind turbines:
    - The supervisory system allows the immediate detection of non-functioning wind turbines and incidents or faults in substation and lines, and they can be remotely operated to run again if it is possible
    - Furthermore, the detailed information of relevant signals and alarms of each machine are retained allowing the operators of the Centre to perform remote diagnoses of the causes of fault. With this information, they activate local maintenance squads to troubleshoot failures. As a result, we can reduce repair times and increase the availability of the wind farms.

The *Centre of Operation of Renewable Energies* ***(CORE)*** project commenced with the design specifications in December 2002. From January to July the design was developed and commissioned for the first five wind farms. Significantly, today sixty-one wind farms have been connected to the Centre with around 1800 MW.

By the end of 2004, around ninety wind farms and six small hydroelectric power plants will be operated from the Centre.

One of the most important goals, in addition to improving availability, is the capability to perform energy control functions. It is essential to meet the new requirements of the grid operation as a response to high penetration rate of wind energy. The implemented functions allow for the following:

- To operate at reduced power levels during periods with reduced transmission capacity or to lower the power level to solve technical restrictions
    - Regulation of active power for each wind turbine
    - Transmission of set point from control centre
    - Regulation of active power for wind farm
- Cooperate in voltage and reactive power control by mean of:
    - Power factor regulation (cos φ) in wind turbine
    - Regulation of power factor in wind farm, also with compensating elements in substation
- Send the production forecast to the market or to the distribution company

- Communicate with the System Operator Control Centre or with other energy management centers

The **CORE** has a powerful and user-friendly operation interface. It allows the operators to manage large amounts of information, and to make decisions easily and quickly. The man-machine interface presents the real-time data of wind turbine, electric substation and transmission line:

- Up to nearly 300 signals and alarms of every wind turbine can be acquired from the communication with the WTG control system
- All the measurements from the meteorological tower
- All the measurements and alarms of the electrical systems

In addition, there are some special tools to save and manage the historical data. After one year of operation, the CORE has accumulated a valuable data base of the WTG´s activity.

Some of the most relevant characteristics of the system are:

- Multimedia alarm management
- Flexible and centralized configuration
- Object oriented technology
- TCP/IP communications
- Communication protocol by exception
- Capacity for application development and integration

5. Case History

Due to the sensitivity of wind power plants to disturbances, a loss of up to 600 MW of wind production has occurred in the Spanish Electrical System. Figure 5 presents the total wind production in the Spanish Peninsular Electrical System during the 18th of January of 2004. The curve shows the wind production in peninsular Spain, with some sudden trips of production coincident with correctly cleared short-circuits in the transmission network. In this case, the interrupted production does not exceed 500 MW, but should the short-circuit occur in a day with more wind, or wind installed power increases, the amount of production disconnected will also increase.

Figure 5.- Spanish wind production during short-circuits (MW)

In order to evaluate the influence of these trips in the system security, the amount of connected ordinary regime plants is very important because they help contain the disturbance and recover the system parameters after the disturbance. For this reason, the same amount of wind production loss would be more severe in low demand condition than in peak demand condition.

Being aware of this drawback, Red Eléctrica de España (Spanish SO and main Transmission utility) has evaluated the maximum wind power penetration that is compatible with system security according to transient stability simulations in different situations. This evaluation was required to reduce wind generation production according to the results of the studies from the first of January of 2004. The different responses of wind generators in four distribution zones in Spain, to a request for limiting the production is shown in figure 6. These graphs display the aggregated production of the distribution zones. The first of the four graphs shows the production of a zone that has a control centre, with a very good response. Conversely, the request to limit the production has not been correctly followed in the other zones.

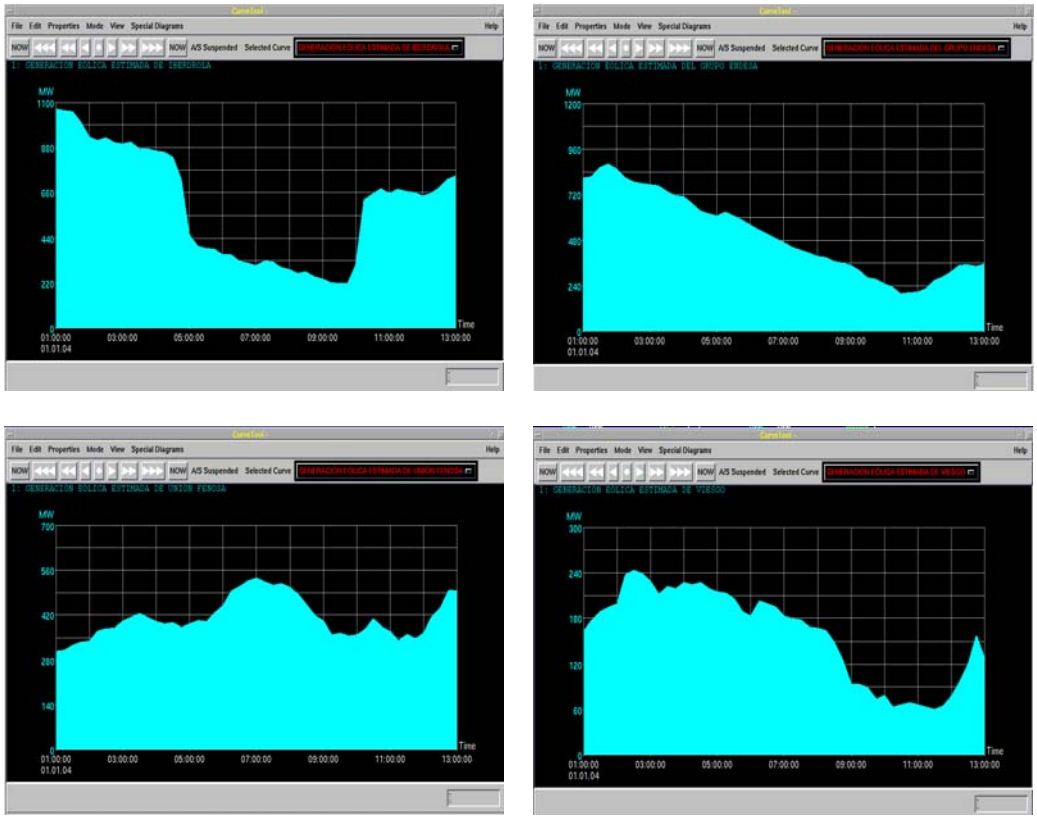


Figure 6.- Wind production in four different distribution zones

These case studies confirm the importance of connecting all wind generation plants to a control centre to effectively inter-act with the System Operator.