

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

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**Abstract**—In this paper the existing technical barriers that prevent the accomplishment of a very high wind generation penetration in a power system are presented. Since several countries and regions in Europe are already experiencing such high wind penetration or, as a minimum, planning their grids and operation strategies to cope with wind penetration from a high to a very high level, the solutions already identified for the most common constraints are also identified.

**Index Terms**— high penetration, power system studies, wind energy, wind turbines.

## I. INTRODUCTION

The current challenge for the wind energy research area is motivated by the wind turbine manufacturer's success. It is a recognized fact that the high capacity installed in the latest years, mostly in European countries, but recently also in the U.S., is introducing a new set of technological challenges for both grid planners [1]-[2]-[3] and Transmission System Operators (TSOs). These recent concerns are a real TSO challenge: are the conventional power systems capable of coping with the wind power generation in large quantities, without requiring new system operation tools, increased performance of the wind turbines or even a change in the power system conventional mode of planning and operation strategy? This is a legitimate TSO concern as it is their responsibility to manage the system within safety boundaries and respond to official regulatory bodies for the occurrence of serious events or even "blackouts". The fact that large 100<sup>th</sup> megawatt wind parks start to be seen as "conventional power plants" and start to behave almost as any other generating unit is not only a positive issue, but also a clear sign of maturity of this technology.

This paper presents some current methodologies for overcoming the usual existing barriers to integrate wind power in the grid, thus enabling to embed a large amount of wind generation in the power system.

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## II. TECHNICAL BARRIERS TO HIGH WIND PENETRATION

### A. Transmission Limited Capacity

The first historical reason normally invoked to limit the amount of wind generation embedded in the grid is the limited grid capacity. That limitation of capacity usually refers only to the transmission capacity, once in most countries and power systems the developers of a new wind park are already asked to invest themselves on the distribution grid reinforcement and even pay the totality of the cost to build the interconnection lines to the already existing network. In European countries this limitation is being addressed in different ways, but the vast majority of countries are dealing with this classic barrier and nowadays include renewable energy in general and wind energy in particular in their transmission system development plans [4]-[5].

### B. Security of Supply. Power Unit Scheduling

#### 1) Balancing Power.

Being a time dependent and highly variable energy source, wind power gives no guarantee of firm power generation at all or, at the most, gives a very reduced one at a very short production forecasting time scale. It is a commonly accepted fact that there is a threshold, after which increasing the wind power penetration also increases the power reserve requirements of a system. This has been addressed in detail for some power systems or control areas, e.g. Nordpool [6] and the results are quite encouraging: the associated costs are much lower than expected up to a certain upper limit and are only representative for very high penetrations, the increase level strongly depending, as expected, on the system generation mix. For example, a hydro reservoir generation component will contribute to keep these costs smaller.

#### 2) Wind Power Time and Space Variability

It was back in the early 1990' that some scientists started to address the problematic issue of the excessive "wind variability" and, at that time, the almost impossible task of forecasting the wind production within time intervals useful for power system operation [7].

Another issue strongly related to the wind generation used to be the high frequency content of the power delivered to the system, mainly in the range of flicker emission (from 0.1 to 20 Hz). Those fluctuations could degrade the quality of the