Grid Connection of Wind Farms

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Abstract. The aim of this paper is the assessment of the wind generation influence on the voltage quality. First of all, the dynamic behaviour of a complete network, composed by more than 1200 buses and which contains nuclear, hydroelectric, wind and thermal generation, has been simulated by PSS/E. Afterwards a simpler grid, which permits the control of the different parameters of the network in an easier way, is analysed.

The effect of the wind energy on the grid can be appropriately mitigated with a grid reinforcement. To achieve it, several studies have been carried out. The purpose of these studies are to select the best options to modify the existing network as adding substations, branches, transformers, as well as correctly calculate the influence of the wind generation on power quality.

Key words: wind energy, voltage fluctuations, wind farm connection.

Introduction

The influence of wind energy on the grid behaviour mainly depends on the wind power and the short circuit power at the point of connexion.

The interaction between wind farms and their impact on the voltage quality in the point of common coupling with the grid are topics of increasing concern. The maximum allowable wind power in any network usually requires the assessment of the influence of wind fluctuations.

This paper analyses the influence of some parameters of the electrical network on the dynamic behaviour. An electrical network has been simulated in PSS/E, applying a gust to the wind farms. The aims of the study are focussed on analysing the voltage fluctuations through different parameters from the network and its own configuration. The voltage fluctuations are measured according to the IEC 61400-21.

The dynamic analysis of a large system by means of PSS/E requires a great deal of time. Moreover, the wind turbine user model is specially time-consuming. By this reason, a secondary objective of this study is to reduce the simulation time by means of an equivalent network.

Dynamic conditions

The most unfavourable situation is that the gust reaches simultaneously all the wind farms of the system. The real case is not so critical, since each wind farm and each wind turbine of the farm receive a somehow different wind gust at a slightly different time.

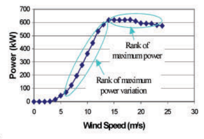


Figure a. Power curve of a wind turbine of 600 kW.

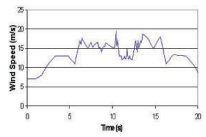


Figure b. Wind gust.

The voltage fluctuations became higher if the wind speed variation is suited in the rank of maximum power variation (see figure a).

The wind gust considered in this work (figure b) is based on wind speed real measurements , and it has been applied simultaneously to all the wind farms.

STUDY

Several dynamic simulations have been carried out in order to analyse the influence of wind generation on voltage fluctuations, first in a complete network of more than 1200 buses and afterwards in a reduced network. Therefore, this paper is divided into two differentiated parts:

A. Analysis with the complete network
B. Analysis with the equivalent network

A. Analysis with the complete network

The simulated network consists on models of conventional generation provided by PSS/E (hydro, thermal and nuclear power plants) and wind turbines, with squirrel cage and doubly fed induction generator.

It is composed of three zones represented by a bus.

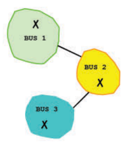


Figure. Network outline

Analysis with the complete network: Studies considered

Table. Cases analysed to obtain the voltage fluctuations and wind power evolution in the complete network

Study 1	It is the base case with 500 MW of wind power distributed along the network	
Study 2	It has been concentrated 100 MW of wind power in the Zone 3	The greatest voltage fluctuation increment is produced in the bus 3.
Study 3	230 MW of wind power have been distributed along the grid.	The three zones are affected in a similar way.
Study 4	The transmission network has been looped and the new wind power (≈500 MW) has been distributed over the grid again.	No increments in the voltage fluctuations are found relevant. The adding of looped systems on the grid is able to hold on the voltage fluctuations.

Analysis with the complete network: Results

Therefore, the allowable wind power for network bus depends on the network makeup. The effect of the wind energy on the grid can be strongly mitigated with an appropriate network reinforcement.

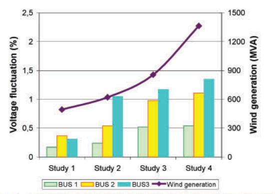


Figure 1. Voltage fluctuations and wind power evolution in the complete network.

B. Analysis with the equivalent network.

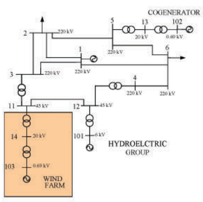


Figure. Equivalent network.

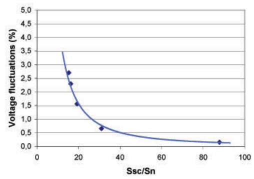
The influence of the grid parameters can be analysed by means of the simple network shown on the figure.

The BUS 1 is the "boundary bus" which connects to the external network.

A squirrel-cage induction wind farm have been connected to the BUS 11. Moreover, a 15 MW hydroelectric group, a 8 MW co-generation system and two 15 MW loads complete the network under test.

Wind power influence

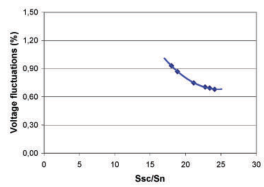
The nominal power installed in the wind farm is progressively increased. At the same time, the structure of the network is held on.



As it was expected, a rise in the wind farm production implies a large diminution on the rate Ssc/Sn in its point of connection. This means a bigger weakness of the grid and a growing of the voltage fluctuations. As it can be observed in the figure, in this case the relation Ssc/Sn should be higher than 20, according to the current Spanish legislation.

Short circuit power influence

On the one hand, the nominal wind power is fixed at 12 MW to analyse the short circuit power influence on the voltage fluctuations. On the other hand, the short circuit power varies considerably by means of the generator with infinite inertia (in a real network, these variations on the short circuit power would be obtained modifying the grid configuration).



The voltage fluctuations decrease as short circuit power increases. Then, the wind power to be installed without disturbing the power quality can be greater.

This objective can be achieved modifying adequately the network configuration.

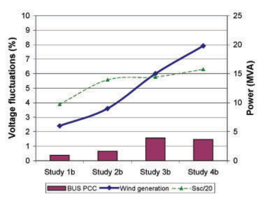
Voltage fluctuations, wind power and Ssc evolution

In this section Sn and Ssc varies at the same time in a similar way as the complete network.

Study 1b	It is the base case with 6 MW wind power distributed along the network.	
Study 2b	Wind and short circuit power has been increased	The voltage fluctuations are constrained, because the short circuit power is also risen
Study 3b	Additional 7 MW have been installed in the wind farm. Ssc in the bus PCC is held on	The voltage fluctuations are considerably increased
Study 4b	Wind and short circuit power have been increased	This confirms that if the grid is suitably reinforced, new wind power can be installed without jeopardising power quality

Voltage fluctuations, wind power and Ssc evolution: Results.

If the rise of nominal wind power were only noticed, greater voltage fluctuations would be expected in the Study 2b and in the Study 4b. Conversely, fluctuations don't increase as much as expected due to the increase of the short circuit power, which strengths the network and it makes the transmitted voltage fluctuations be smaller.



Conclusions

The behaviour of the two networks is comparable, the grid strengthening implies a rising of the short circuit power, which permits to ameliorate the grid stability. If the short circuit power is adequately risen, the voltage fluctuations are limited even if wind power increases.

Therefore, the allowable wind power for network bus depends on the network makeup. The effect of the wind energy on the grid can be strongly mitigated with an appropriate network reinforcement.

In this paper several studies have been carried out to demonstrate it. In each study a different network condition is considered. The network evolution has consisted on increasing the wind power installed, at the same time the network has been strengthened by adding substations, branches, transformers, etc.