# Advanced Requirements for Wind Power Plants

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## ABSTRACT

The difficulties of the wind power integration into the power grid have been overcome in several countries by requiring more services to the wind power. Those modern services are exposed. The international committees of wind turbine guidelines are focused in describing more services that wind power plants must offer in order to collaborate in the power system stability. The special services are explained as well.

It is the responsibility of the transmission system operator to demand special services to the wind power plants according to the TSO's knowledge of the network. To carry out these studies it is recommended to use models validated through field tests and the result of simulations done to the manufacturer's data models. To prove the fulfilment of the requirements described in the grid code will lead to a simpler power grid to control and more benefits for developers and manufacturers since more wind power could be installed in the power grid.

***Keywords:*** *wind energy, grid code compliance, on site tests, model validation*

## 1 INTRODUCTION

Nowadays wind turbines are generally required to offer ancillary services similar to those provided by conventional generators. One of the most important services wind turbines must offer is to stay connected to the grid in fault situations delivering the reactive current specified in the recent grid codes [1].

Under Voltage Ride-Through capability (UVRT) is required by TSO's for connecting wind farms in power systems as it is defined in the main grid codes. Wind farms must remain connected and actively contribute to system stability during a wide range of network fault scenarios. UVRT requirements differ according to the dynamic characteristics of the power system concerned [2].

Regarding the connection of wind power plants, it should be remembered that in each country, the grid conditions are different. In some places, the grid is not as strong as in others, e.g. Ireland (island) vs Germany (strong power system). In other places the wind potential is very important, such as UK. The TSO of different countries have set different technical restrictions for wind power integration. These restrictions are imposed for ensuring that wind turbines have regulating and dynamic properties that are essential for maintaining a reliable power supply and voltage quality in the short and long term [3].

In order to increase wind energy penetration into power networks achieving at the same time the continuity and security of the supply, some countries have developed specific grid codes for wind farms. In general, all of them focuses on power controllability, power quality and fault ride-through capability. In the Spanish case [4], wind turbines are required to offer grid support to the network in case of voltage dips. Power quality requirements are very well described in the IEC 61400-21 [5] where flicker emission, harmonic compatibility levels and voltage dip behavior are fully analyzed.

## 2 BRAZIL PICTURE

There are several advanced requirements required for wind power plants in Brazil. However, the requirements of the Brazilian TSO are not needed to be tested in the field. The tests that are being required currently by ONS are the following: Measurements according to IEC 61000-4-30 [6] before and after the wind power plant activity; Characterization of one wind turbine according to IEC 61000-4-30.

Thus, the following considerations could be widely discussed: Is it considered to test the wind turbine according to IEC 61400-21 for proving all the capabilities not only for flicker emission?; The *Submódulo 3.6* [7] describes many requirements but there is no need for proving the fulfillment. In addition to the campaign of power quality measurement if IEC 61400-21 applies, could be required to carry out a battery of tests for proving the fulfillment of all the capabilities described in the *Submódulo 3.6*?; Does all the wind power plants connected to the Brazilian power grid cope with (at least) the UVRT requirement in order to avoid dangerous blackouts?

## 3 ADVANCED REQUIREMENTS OF TSO

As explained above, there are some TSO demanding advanced services in order to preserve the system stability. High penetration of wind power is considered when wind power production covers more than 10% of the consumption [3]. Some of the most representative cases are: **Spain**, where it is mandatory to present the grid code compliance through simulations (using validated models) or field-tests. The validation of the power plant model is being required currently; **Germany**, where it is mandatory to test the wind turbine on site according to the German guideline (FGW TR3), to simulate the same tests carried out on site and to validate the simulation comparing both results according to the corresponding German guideline (FGW TR4); **South Africa**, the TSO is requiring a validated model of wind power plants and a demonstration of having active and reactive control depending on the voltage, frequency, etc.

In this point, the state of the art is presented by describing the requirements being asked now.

- **Fault ride through** (taking into account both voltage dips and overvoltages) There is still no TSO asking for on-site test for the overvoltage ride through but the on site test for proving the undervoltage ride through is widely agreed as needed. It is important to set the voltage level wind power plants must withstand (see Fig 1) and the contribution regarding reactive power during the fault according to the TSO requirements.

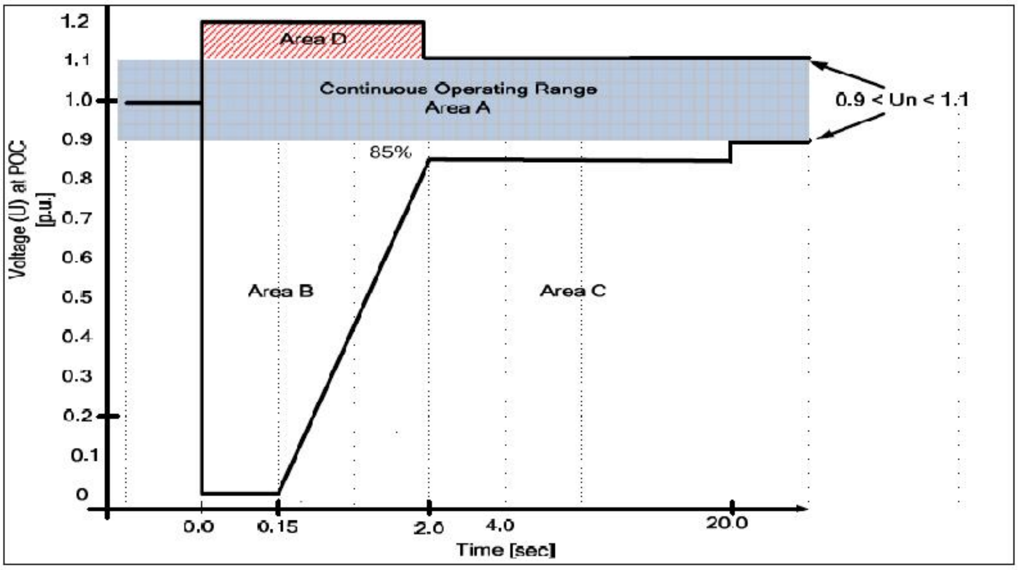


Fig. 1 Example of fault ride through capability for wind power plants [11]

- **Active power control**
  - **Setpoint**: the wind turbine (and later the wind power plant) should be able to follow the reference of the active power set by the TSO. Wind power plants must be able to limit their production to the value specified by the TSO in order to preserve the power system stability
  - **Frequency control**: the wind turbine / wind power plant should be able to control active power generation depending on the value of the frequency in order to balance small deviations between generation and demand
  - **Inertia response**: consists of providing a fast injection of active power when decreasing the frequency as the synchronous generator does
  - **Delta constraint**: the wind power plants must be capable of generating a little bit under the available power in order to keep a reserve of active power to increase when needed, see Fig. 2
  - **Ramp rate limitation**: the wind power plant must be capable of limiting of active power gradient to a certain amount of MW/min depending of the TSO needs, see Fig 2. Big changes of active power that can lead to changes in the frequency are avoided, see Fig. 2

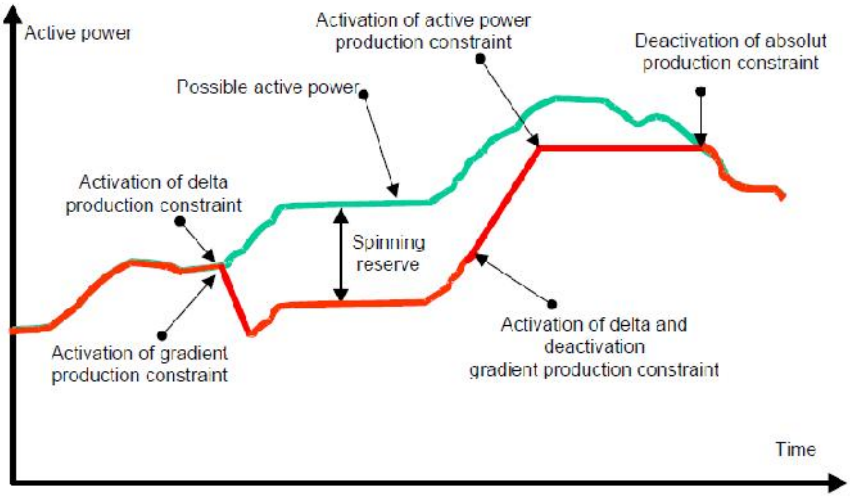


Fig 2 –Required active power control capabilities [7], [8]

- **Reactive power control**
  - **Setpoint**: the wind turbine (and later the wind power plant) should be able to follow the reference of the reactive power set by the TSO. Wind power plants must be able to limit their injection/consumption of reactive power to the value specified by the TSO in order to preserve the power system stability
  - **Voltage control**: the wind turbine (and later the wind power plant) should be able to control reactive power generation/consumption depending on the value of the voltage in order to maintain the value of the voltage in the point of common coupling.
  - **Power factor**: The wind power plant must be capable of modifying its power factor according to the needs of the TSO. Usually, the required is to be able to modify the power factor between 0.95 capacitive and 0.95 inductive.
  - **Ramp rate limitation**: the wind power plant must be capable of limiting the injection of reactive power to a certain amount of MVAr/min depending of the TSO needs. Big changes of reactive power that can lead to changes in the voltage are avoided.

## 4 FIELD TESTS AND MODEL VALIDATION

Many grid codes from the Distribution or Transmission System Operators (DSO and TSO) are requesting a validated wind turbine model before the connection agreement. Because there is no international standard for the wind turbine models and their validation, every manufacturer has developed their own simulation model and validation procedure.

The future guideline IEC 61400-27 [8] will be a useful tool for TSO validating models and so integrating wind power plants into their grid simulations. According to [9], "the purpose of IEC 61400-27 is to define standard, public dynamic simulation models for wind turbines and wind power plants, which are intended for use in large power system and grid stability analyses, and should be applicable for dynamic simulations of power system events such as short circuits (low voltage ride through), loss of generation or loads, and typical switching events (e.g. line switching)"

Requirements about model validation will be mandatory in the future in many countries since it is an essential tool for carrying out complex simulations of the power system with many renewable energy sources.

It is worth to mention that e2Q has been pioneer in this field being accredited for validating models according the standards of Spain, in process for the accreditation of TR4 for the German market and performing several studies in South Africa.

## 5 CONCLUSION

The importance of wind power production has been shown from some years ago to nowadays but its penetration in power systems has risked the grid stability in certain cases. One of the key issues regarding wind power disadvantages is the behavior in the event of voltage dips. When voltage dip situation occurred, several MW of wind power production could be lost. Grid codes dictate guidelines for wind power plants to comply in order to enhance power system stability.

In order to guarantee the stability of the system, the TSO and the DSO must ask for strong proofs from wind power plants of the requirement fulfillment. This must be achieved through on site tests and validated models.

The requirement of proving the demanded services must not be seen negatively. It will help all parties involved, the **TSO** providing higher system stability, **developers** since a more stable system will admit more MVA of wind energy and therefore the possibility to develop new projects will increase and **manufacturers** increasing the demand for their products with competitive advantages

No demand of these requirements to the Wind Energy will lead to an increase in the complexity of the control system, an increase in the need of reserves in the system, to get higher periods with constraints in the wind power production, etc. In summary, to get a more unstable system.

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**BIOGRAPHIES**

**Miguel Asensio** – MSc Industrial Engineering from the Polytechnic University of Madrid and MBA by the Institute for Executive Development in Madrid, has spent his entire career in the energy sector, while since 1995 focusing on renewable energies. Since then he has held several senior positions in companies, currently combining the post of Deputy Director in energy to Quality (E2Q) and Director of Business Development at Barlovento Recursos Naturales

**Carlos Álvarez** – Born in Spain in 1979, got his PhD on 2011 working about DFIG wind turbines and voltage dips in the Carlos III University of Madrid, Spain, in the electrical department. On 2012, he joined Energy to Quality, electrical division of Barlovento Recursos Naturales, as Technical Manager. His main interest is grid integration studies.

He has published several papers about voltage dips and optimal location of reactive power in power grids and one book titled "Reactive Power Management of Power Networks with Wind Generation"

PhD Alvarez is member of several groups, e.g. the maintenance group of the IEC 61400-21, of the working group IEC 61400-27 or the TPWIND WG3 – Grid Integration

**Daniel Faro** – was born in Recife, on October 24th, 1977. Graduated on Mechanical Engineering in the Federal University of Pernambuco, Recife (2001). Master Degree in Energetic and Nuclear Technologies in UFPE (2005) with emphasis on the design of wind turbines for the Brazilian Conditions.

He has signed the recent publications: integrated system for monitoring and analyze meteorological stations, definition of validation criteria for wind data from time-space wind surface patterns, use of GIS in terrain exploitation for wind power plant development. Nowadays coordinates R&D projects on wind resource assessment and Improvement of a wind turbine project for the Brazilian wind conditions