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Grid Codes Requirements for Wind Farms

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Abstract— **Increasing wind power penetration levels to the power systems of many regions and countries has led to the elaboration of specific technical requirements for the connection of large wind farms, usually as a part of the grid codes issued by the Transmission System Operators (TSOs). These requirements typically refer to large wind farms, connected to the transmission system, rather than smaller stations connected to the distribution network. The new grid codes stipulate that wind farms should contribute to power system control frequency and also voltage), much as the conventional power stations, and focus on wind farm behavior in case of abnormal operating conditions of the network (such as in case of voltage dips due to network faults). Grid code requirements have been a major driver for the development of WT technology**

Index Terms—**Transmission System Operators (TSOs), Low Voltage Ride Through (LVRT), Fault Ride through (FRTDoubly-Fed Induction Generator (DFIG)**

I. Introduction

The article focuses on the technical regulations regarding the connection of large wind farms to the high voltage transmission system, whereas requirements concerning small units or dispersed generation connected to the distribution network are not presented. The latter ones usually refer to power quality, contribution to short-circuit level and protection system settings that are not key issues for large wind power stations connected to the transmission system. The main emphasis is placed on the requirements that have been introduced in the last years and concern active and reactive power regulation, voltage regulation and wind farm behavior during grid disturbances. The technical implementation of the above requirements is not part of the grid codes. Several solutions are provided by wind turbine manufacturers, in order to achieve grid code compliance. In the second part of the article, a brief presentation is made of available technologies for modern, commercial wind turbines, in terms of their electrical system configuration, as far as their response to grid disturbances and compliance to grid code requirements is concerned.

II. GRID CODE

A grid code is a technical specification which defines the parameters a facility connected to a public electric network has to meet to ensure safe, secure and economic proper functioning of the electric system. The facility can be an electricity generating plant, a consumer, or another network. The grid code is specified by an authority responsible for the system integrity and network operation. Its elaboration usually implicates network operators (distribution or transmission system operators), representatives of users and, to an extent varying between countries, the regulating body

Contents of a grid code vary depending on the transmission company's requirements. Typically, a grid code will The present paper extends the overview to several countries, providing a presentation and comparison of the most recent available editions of the following grid codes

I. The German code from E.ON Nets that applies to networks with voltage levels 380,220 and 110kV. Its requirements are often used as a reference for other codes.

II. The Great Britain code, where the requirements for wind farms are presented in combination with requirements for other power production units. It applies to networks with voltage levels 400, 275 και 132 kV (32 kV for Scotland).

III. The Irish code published by ESB National Grid (Section WPFS1, Wind Farm PowerStation Grid Code Provisions), applying to network voltage levels 400, 220 και 110 kV.

IV. The Nordic Grid code from Nortel that applies to all wind farms connecting to Nordic Grid (the interconnected system of Denmark, Sweden, Norway and Finland)

V. The code of Denmark, referring to wind turbines connected to grids with voltages below 100 kV. Some of Extra's requirements applying to wind turbines connected to networks with voltage levels above 100 kV are also presented

VI. The grid code of Belgium issued by the Belgian TSO, Elias, applying to networks with voltage levels 30 to 70 kV and 150 to 380 kV

VII. The grid codes of two Canadian TSOs, Hydro-Quebec, applying to networks withvoltages above 44 kV and Alberta Electric System Operator (AESO), that applies towind farms with rated capacity above 5 MW connected to network voltages 69 to 240 kV

VIII. USA rule for the interconnection of wind generators published by FERC in June 2005 that applies to wind farms with rated capacity above 20 MW

IX. Codes from other countries like Spain, Italy, Sweden andNew Zealand

3. COMMON GRID CODE REQUIREMENTS

The present Section includes the requirements encountered in the majority of grid codes concerning wind farm interconnection. These include fault ride-through, system voltage and frequency limits active power regulation and frequency control, as well as reactive power/power factor/voltage regulation.

3.1. Fault ride through requirements

The large increase in the installed wind capacity in transmission systems necessitates that wind generation remains in operation in the event of network disturbances. For this reason, grid codes issued during the last years invariably demand that wind farms (especially those connected to HV grids) must withstand voltage dips to a certain percentage of the nominal voltage (down to 0% in some cases) and for a specified duration. Such requirements are known as Fault Ride through (FRT) or Low Voltage Ride through (LVRT) and they are described by voltage vs. time characteristic, denoting the minimum required immunity of the wind PowerStation. The FRT requirements also include fast active and reactive power restoration to the prefaultvalues, after the system voltage returns to normal operation levels. Some codes impose increased reactive power generation by the wind turbines during the disturbance, in order to provide voltage support, a requirement that resembles the behavior of conventional synchronous generators in over-excited operation.

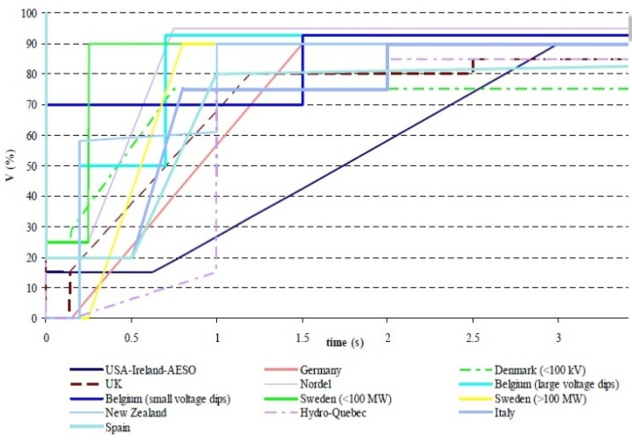


Figure 1. LVRT requirements of various grid codes.

Figure 1 presents in the same graph all LVRT requirements cited in the examined grid codes.

The requirements depend on the specific characteristics of each power system and the protection employed and they deviate significantly from each other

3.2 Requirements for reactive current supply during voltage dip some grid codes prescribe that wind farms should support the grid by generating reactivepower during a network fault, to support and faster restore the grid voltage. Eon requires wind farms to support grid voltage with

Specify the required behavior of a connected generator during system disturbances. These include voltage regulation, power factor limits and reactive power supply, response to a system fault (short-circuit), response to frequency changes on the grid, and requirement to "ride through" short interruptions of the connection additional reactive current during voltage dip, or increased reactive power consumption in the event of a voltage swell. The voltage control must take place within 20 ms after fault recognition by providing additional reactive current on the low voltage side of the wind turbine transformer amounting toat least 2 % of the
rated current for each percent of the voltage dip. A reactive power output ofat least 100 % of the rated current must be possible if necessary.
The above applies outside a±10% dead band around nominal voltage. According to the Spanish grid code, wind powerplants are required to stop drawing reactive power within 100 ms of a voltage drop and to be able to inject reactive power within 150 ms of grid recovery.

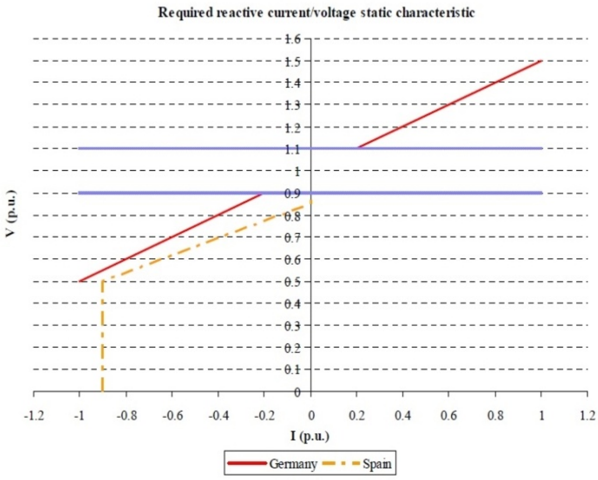


Figure 2:Reactive Current/Voltage Static Characteristics

4. ACTIVE POWER AND FREQUENCY CONTROL

These requirements refer to the ability of wind farms to regulate (usually, but not exclusively, reduce) their power output to a defined level (active power curtailment), either by disconnecting turbines or by pitch control action. In addition wind farms are required to provide frequency response that is to regulate their active output power according to the frequency deviations.

4.1 ACTIVE POWER CONTROL

Most grid codes demand active power curtailment upon request from the network operator, at a specified set-point. This is done either by disconnecting wind turbines or by controlling the pitch angle of the blades in order to limit the power extracted from the wind. Some grid codes also impose limitations on the rate of change of active power, with maximum and minimum ramp-up and ramp-down rates. These limitations aim to suppress large frequency fluctuations caused by extreme wind conditions and to avoid large voltage steps and in-rush currents during wind farm startup and shutdown.

4.2 FREQUENCY CONTROL

The frequency ranges required by the various grid. In the green frequency ranges, the wind turbines must remain connected and operate continuously at full power output. In the white ranges, they must remain connected at least for the minimum time specified, usually at a lower power output, in order to support the grid during frequency restoration. In many cases the active power reduction must be controlled proportionally with the frequency deviation from the nominal. In the extreme grey frequency ranges, wind turbines are allowed to disconnect from the grid. The active power requirements at different frequencies, if specified in the grid code.

The grid codes of the following countries demand that wind farms have the ability of activepower curtailment:

• Germany, with a ramp rate 10% of grid connection capacity per minute.
• Ireland, with a ramp rates 1-30 MW per minute.
• Nordic Grid Code, with a ramp rate 10% of rated power per minute.
• Denmark, with a ramp rate 10-100% of rated power per minute.

According to the German code when frequency exceeds the value 50.2 Hz wind farms must reduce their active power with a gradient of 40% of the available power of the wind turbines per Hz. The British code requires that wind farms have a frequency control device capable of supplying primary and secondary frequency control, as well as over-frequency control. It isremarkable that it also prescribes tests, which validate that wind farms indeed have thecapability of the demanded frequency response. The Irish code demands a frequency responsesystem, which will control active power according to a prescribed response curve. According tothe Hydro-Quebec grid code, wind farms with rated power greater than 10 MW must have afrequency control system that helps reduce large (>0.5 Hz) and short term (<10 s) frequencydeviations in the power system. As a general remark, it is clear that most grid codes requirewind farms (especially those of high capacity) to provide frequency response, i.e. to

Contributeto the regulation of system frequency. It should be emphasized that the active power ramp ratesmust comply with the respective rates applicable to conventional power units.

Reactive power control is important for wind farms, because not all wind turbine technologieshave the same capabilities, while wind farms are often installed in remote areas and thereforereactive power has to be transported over long distances resulting in power losses. Recent grid codes demand from wind farms to provide reactive output regulation, often in response to power system voltage variations, much as the conventional power plants. The reactive power control requirements are related to the characteristics of each network, since the influence of their active power injection to the voltage level is dependent on the network short-circuit capacity and impedance. Some codes prescribe that the TSO may define a set-point value for voltage or power factor or reactive power at the wind farm's connection point.

The reactive power variation capability according to the British and the Irish codes where:

(inMVAr) to: 0.95 leading power factor at rated MW output
(inMVAr) to: 0.95 lagging power factor at rated MW output
(inMVAr) to: -5% of rated MW output
(inMVAr) to: +5% of rated MW output
(inMVAr) to: -12% of rated MW output

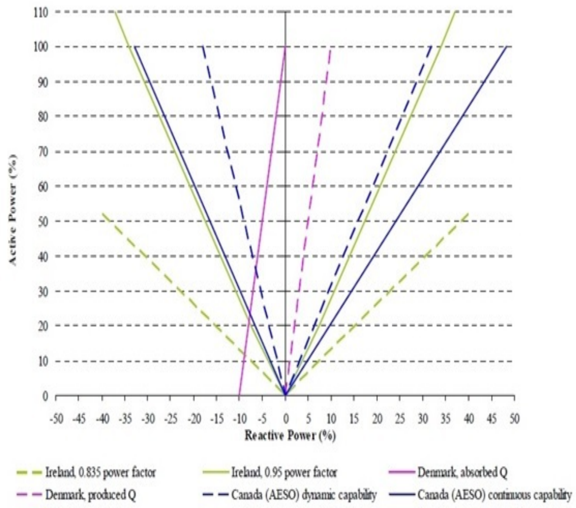
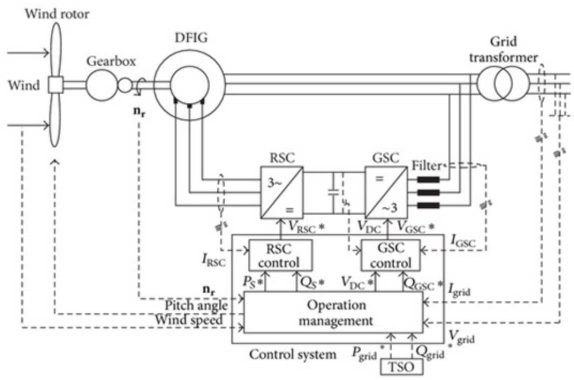


Figure 3: Reactive Power Control Analysis

6. WIND TURBINE TECHNOLOGIES AND GRID REQUIREMENTS

In this Section a brief review is presented of wind turbine technology aspects, associated with grid code compliance. Wind turbines are generally divided in two main technological categories:



Fig, 4 Wind Turbine Technology

Constant speed wind turbines, which are equipped with squirrel cage induction generators

Directly connected to the grid. The rotational speed of the rotor is practically fixed, since them

Operate at a slip around 1%. Since the induction machine absorbs reactive power from the grid, connection of compensating capacitor banks at the wind turbine (or wind farm) terminals is necessary. Their aerodynamic control is based on stall, active stall or pitch control. Variation of this scheme utilizes a wound rotor induction generator and electronically controlled external resistors to the rotor terminals, permitting a very variation of speed (typically up to 10% above synchronous).

6.2 Variable speed wind turbines

Variable speed wind turbines, the rotor speed of which varies significantly, according to the prevailing wind conditions. Two major types are available: The first is utilizes a Doubly-Fed Induction Generator (DFIG) and a rotor converter cascade of reduced rating, while the second employs a synchronous or induction generator, the stator of which is interfaced to the grid via a full-power converter. The aerodynamic control of variable speed machines is based onblade pitch control (although stall operation is in principle possible, but not preferred in practice). In case of DFIGs the generator's stator is directly connected to the grid while the rotor is connected through a cascade of two voltage source converters (rectifier-inverter, connected back-to-back. Wind turbines with full converter use either a synchronous or an asynchronous generator, whose stator is connected to the grid via an AC/DC/AC converter cascade. In this case, the converter handles the total generator power to the grid and therefore no size economies are possible.

As described in the previous Sections, the latest grid codes require that wind farms must remaining operation during severe grid disturbances, ensure fast restoration of active power to the pre-faultlevels, as soon as the fault is cleared, and in certain cases produce reactive current in order to support grid voltage during disturbances. Depending on their type and technology, wind turbinescan fulfills these requirements to different degreesin the event of a voltage dip, the generator torque reduces considerably (roughly by the square of its terminal voltage) resulting in the acceleration of the rotor, which may result in rotor instability, unless the voltage is restored factor the accelerating mechanical torque is rapidly reduced. Further, operation of the machine at increased slip values results in increased reactive power absorption, particularly after fault clearance and partial restoration of the system voltage. This effectively prevents fast voltage recovery and may affect other neighboring generators, whose terminal voltage remains depressed.

Since the dynamic behavior of the induction generator itself cannot be improved, measures that can be taken in order to enhance the fault ride-through capabilities of constant speed wind turbines are the following:

I. Improvement in the response of the wind turbine aerodynamic control system, in order to perform fast limitation of the accelerating mechanical torque, to prevent rotor over speed.
II. Physical limitations of the blades and the pitch regulation mechanism impose a limit on the effectiveness of such an approach.

Supply of reactive power through static compensation devices at the wind turbine or wind farm terminals, such as SVCs or STATCOMs. This device would provide high amounts of reactive power during faults, to effectively support the terminal voltage and therefore limit the magnitude of the voltage dip experienced by the wind turbines. Nevertheless, FACTS are complicated and costly devices, while there is an obvious limitation to the voltage correction they can achieve, particularly in the event of nearby system faults.

8. CONCLUSIONS

In this paper, the grid code technical requirements were presented for the connection of wind farms to the power systems, basically at the HV level. A comparative overview and analysis of the main requirements was conducted, comprising several national and regional codes from many countries where high wind penetration levels have been achieved or are expected in the future. The objective of these requirements is to provide wind farms with the control and regulation capabilities encountered in conventional power plants and are necessary for the safe, reliable and economic operation of the power system. Current wind turbine technology, particularly its development over the last years, has been heavily influenced by these requirements. Modern wind turbines are indeed capable of meeting all requirements set, with the exception of the constant speed machines, which are practically not marketed anymore for large scale applications.

IX. REFERENCES

[1] Grid Code - High and extra high voltage. E.ON Netz GmbH, Bayreuth, Germany, 1st April2006..
[2] The Grid Code, Issue 3, Revision 24. NATIONAL GRID ELECTRICITY TRANSMISSION
[3] The Private and Public Economics of Renewable Electricity GenerationSeverinBorensteinRevised December 2011 ,pp. 07–08
[4] Analysis of the renewableenergy sources' evolution up to 2020
Mario Ragwitz, Joachim Schleich, Fraunhofer ISI Claus Huber, Gustav Resch,(Germany) April 2005, pp. 93–101.
[5DushanBoroyevich, Chair Fred C. Lee ,Fei (Fred) Wang ,July 22nd, 2010Blacksburg, Virginia, pp. 33–98.
[6] TIDAL ENERGY by A. M. Gorlov, Northeastern University, Boston Massachusetts, USA.
[7S. Mathew, *Wind Energy, Fundamentals, Resource Analysis and Economics*. Berlin, Germany: Springer-Verlag, 2006.
[8] Ocean renewable energy:2015-2050,An analysis of ocean energy in Australia July 2012,by Sam Behrens, David Griffin, Jenny Hayward, Mark Hemer.
