Grid Code Compliance beyond simple LVRT

Tobias Gehlhaar, Germanischer Lloyd, Hamburg, Germany

Abstract— In the past years grid code compliance of wind farms was mainly investigated with a focus on the simple ability to run through grid faults. Having tested and certified the so called LVRT behaviour (low-voltage ride-through) is almost state of the art.
Most grid codes have further requirements, both, operational and such during grid fault conditions. Those other requirements did not play a big role as most focus was on LVRT; this is going to change now. Germany is now, after Spain and Greece, the third government putting grid code compliance to law and even making it a prerequisite for receiving any payment for feed-in of wind borne electrical current.

Index Terms
Certification, Fault Ride-Through, Grid Code Compliance, Low-Voltage Ride-Through (LVRT), Power Purchase Agreement, reactive power control, SDLWindV, wind farm control, zero-voltage ride-through.

I. INTRODUCTION

Power plants used to dominate requirements set by system operators in the past, resulting in rules and regulations called grid codes. They always had to be obeyed, fortunately there where a lot of exceptions concerning wind turbines in the past. Wind farm operators usually have specific grid codes named in the contract with the system operator for power purchase and electrical connection to the system. If big black-outs occur, the system operator might ask, whether wind farms where compliant with the grid code named in this contract. As very high costs occur after black-outs, somebody has to pay for, liability of the wind farm operator might be an important question, too. Nevertheless, many wind farms where running without the knowledge, whether they fulfill the grid code named in the contract or not.

As installed wind turbine capacities grow bigger, more and more system operators started asking questions and requiring evidence of compliance with grid codes. At the same time, system operators started to understand what advantages they c0uld use for the safety of their systems when using the abilities wind turbines have.

Wind turbine manufacturers started testing their turbines with low-voltage ride-through full scale tests in the field [12]. This mainly helped the turbine manufacturers to get a feeling for the ability of their turbine types; however, it does not really help wind farm operators proving compliance of wind farms with grid codes.

Some governments involved themselves in the issue, paying extra money if wind farms comply with the requirements, usually proven by a corresponding certificate.

In Spain, the government demands grid code compliance by certification since 2008 [2]. Luckily, this requirement is, at the same time, excluding wind farms from the need to show other abilities than LVRT. Wind farm operators in Spain are proving compliance with the Spanish grid code by showing the ability to ride through faults according to the corresponding requirement [3]. After 2011 the Spanish government will demand additional requirements from wind farms [4].

In Germany, a complete system of proving conformity with medium voltage grid code was established by the federal association of water and electricity (bdew) in 2008 [1] and followed by the government in 2009, adopting the same approach for high voltage, too [5]. This system is based on two kinds of certificates: The Type Certificate (“Einheitenzertifikat”) for each wind turbine type (e.g. model x of manufacturer y) and the Project Certificate (“Anlagenzertifikat”) for each wind farm (e.g. wind farm Bremen of wind farm owner Ackermann).

For the time being a bonus will be paid if wind farms in Germany can show compliance by a Project Certificate. After June 2010 wind farms to be erected in Germany have to comply by law. Furthermore the price for wind energy, as fixed in the law, will only be paid if wind farms comply.

Summing up the motivation for wind farm operators to show grid code compliance of their wind farms is based on the wish to get the bonus payment (today), the legal demand to do so and the fact that they will not get the legally fixed price for the current produced. On top of that, system operators could make use of there requirement and deny grid access for those wind farms not being compliant with the grid code applicable at the site. If this happens, wind farm owners could not even sell their wind energy on the stock exchange, as they do never get transmission capacities.

The German example shows, that system operators and governments are completely serious about their aim of forcing wind farms to help the power system to stay safe and stable and finally to become smart. Smart Grids are the

---

Tobias Gehlhaar is with Germanischer Lloyd Industrial Services GmbH, Competence Centre Renewables Certification, Steinhoeft 9, 20459 Hamburg, Germany. (e-mail: Tobias.Gehlhaar@GL-Group.com).

vision of the future, wind farms have to be smart, too. The grids can only become more intelligent, if all active modules react according to the same clever rules. Standardization and harmonization therefore is inevitable. This task has already been started concerning grid code harmonization on EU level at EWEA and on a world-wide level as well.

A. *Requirements beyond LVRT*

Main requirements of system operators are usually taken from the following Table 1 [15],[9], being the maximum worst case when a grid code would require all of those items.

TABLE I

Possible grid code requirements (worst case list)

#	Topic	Example
1	Power control range of the wind turbine	Voltage control or Reactive power control
		Frequency control, power static, ramp rate
		Maximum start-up ramp rate
		Minimum run-back ramp rate
2	Behaviour of the wind turbine during grid failures	LVRT
		Current injection during LVRT, rise time, settling time
		Temporary Overvoltages
		Frequency gradient
3	Safety system protection and monitoring devices of the wind turbine	Over speed
		Chopper resistor
		Mechanical loads during LVRT on rotor blades and structure of a wind turbine
4	Power rating	Overmagnetization (U_{max}/f_{min})
5	Simulation Models	Validated rms-model for single turbines

B. *Changed requirements and combination trouble*

There are requirements to be met on mainly two levels. One level is the single wind turbine, which is usually not a single prototype, but a single specimen out of a serial production, resulting in many wind turbines with the same characteristics as being of the same turbine type. Grid Code Compliance (GCC) at this level is proven by having a valid Type Certificate (GCC). The second level is any wind farm, being built from turbines having met the first level of Type Certificate (GCC). These wind turbines are erected together with all the details forming a wind farm, connected via the wind farm transformer to the power system. As grid codes usually define there requirements at wind farm level, in this second level of requirement fulfillment finally the missing values can be verified. The Grid Code Compliance of a wind farm as such can be proven by a Project Certificate (GCC). Therefore, requirements split up in site specific and type specific. In addition wind turbine manufacturers used to split them up in LVRT and others.

Furthermore, we have different cases concerning the date a new grid code requirement comes into force. Some turbines are erected before that, some are running before that date, some can be upgraded and some cannot fulfill the new requirements. Looking at wind farms we have those consisting of only new types, those having both, old and new ones, those having also turbines without upgrading possibilities and a mixture of all cases. The ownership of those different parts in the wind farm might play a role, too, as well as in those cases with different wind farms at one grid connection point.

II. CRITICAL GRID CODE REQUIREMENTS

As grid code requirements are very different, depending not only on the country but also on the site (responsible system operator) and the voltage level for connection, only some examples can be given here. For a full overview on the relevant requirements, a more detailed analysis can be prepared by corresponding service providers, based on the special target markets in question. A regularly updated list of all grid codes from various countries and system operators known by Germanischer Lloyd can be seen on the internet [6].

Some more details will be given in the updated paper to be distributed at the day of the conference.

III. TESTING GRID CODE REQUIREMENTS

A. *Communication between wind turbine and PCC*

As most Grid Code Requirements are defined at the PCC (point of common coupling between system operators and wind farm owners grids) some values need to be transmitted to each single turbine. Especially in wind farms having mixed types of wind turbines might need individual setting possibilities concerning e.g. reactive power exchange for each single wind turbine. Such communication schemes need to be defined and agreed.

B. *Power Control Range*

During the test, active power will be reduced from full load to 20%. The time the turbine needs for this and the accuracy of the power reduction is to be found out. The system operator shall be able to set a limitation from the outside to a target value in order to e. g. protect its power lines from over loading. A couple of additional power control features can be required depending on other values like grid frequency. This is a different Grid Code Requirement, see the corresponding item below.

C. *Gradient of active power*

The turbine shall show its abilities to ramp up power with a given ramp rate. A stopped turbine is set to a 30% power increase in each minute. As this test lasts 10 Minutes it should be quickly done, but of course sufficient wind speed needs to be there, at minimum 50% of rated wind speed.

D. *Voltage or frequency bound power limitation*

Testing grid frequency changes is somehow tricky, as it would be quite dangerous to tell the turbine control different frequency values than the true ones. Therefore only two options exist. One is to tell the control that the normal frequency is neither 50 Hz nor 60 Hz, but something else, being the difference to be tested. Some Turbines are not able to set the grid frequency as a parameter in the turbine control. They need to use the second option: being tested with a grid simulator, being a frequency generator to be connected to the turbine control with the wind turbine switched off. Both options give the result, what the wind turbine behaves like when grid frequency changes.

E. *Reactive power exchange*

The maximum possibilities of a wind turbine concerning reactive power settings have to be recorded. Leading and lagging power factors and their maximum values depending on wind speed or active power shall be measured at the wind turbine and could be measured or calculated at the PCC. The need of reactive power exchange settings might be defined at PCC and distributed to the single wind turbines (see A). Reactive power exchange is sometimes required depending on other values like system voltage. This is counted as a different requirement (see F).

F. *Voltage control*

By changing reactive power exchange settings, the system operator is able to change the local voltage at defined wind farms very fast. This feature of a wind turbine shall be tested. For wind farms communication might be important again (see A).

G. *Power Quality*

In some countries grids are polluted with harmonic voltages and currents and other effects like flicker and switching operations, reducing the quality of the electrical energy provided being caused by electronic devices etc. mainly in the distribution grids. Such system operators tend to require a calculation for the wind farm, based on measurements per wind turbine type according to IEC 61400-21 or similar.

H. *Behaviour during grid failures*

There are two more requirements than LVRT (Low-Voltage Ride-Through) concerning grid failures. One requirement is grid disconnection due to voltage variations for longer periods than LVRT or based on a combination of reduced voltage and reactive power intake. The other requirement is short circuit current ratio to be within given limits. LVRT requirements itself have some more sophisticated part requirements which came up recently in Germany. The required current during the failure is not only depending on the residual voltage during the voltage dip, but also depending on the setting of k. This factor shall enable the system operator to adapt the current increase during voltage drops individually for each site. Standard valu

More tests will be given in the fully updated paper to be distributed during the conference.

IV. REFERENCES

Grid codes:

[1] Technical Guideline "Generating Plants Connected to the Medium-Voltage Network, guideline for operating plant's connection to and parallel operation with the medium-voltage network" *bdew (Bundesverband deutsche Elektrizitäts- und Wasserwirtschaft), June 2008.*

[2] Royal decree 661 "10556 REAL DECRETO 661/2007, de 25 de mayo, por el que se regula la actividad de producción de energía eléctrica en régimen especial," *Article 12, No 1b, page 22851 of BOE issue 126, Spain, dated May 26, 2007.*

[3] P.O.12.3., Madrid, Spain

[4] P.O.12.2, Madrid, Spain

[5] SDLWindV "Verordnung zu Systemdienstleistungen durch Windenergieanlagen (Systemdienstleistungsverordnung) – SDLWindV", *Bundesgesetzblatt Jahrgang 2009 Teil I Nr. 39 ausgegeben zu Bonn am 10. Juli 2009.*

[6] International Grid Code Comparison (IGCC-list) online available at http://www.gl-group.com/pdf/IGCC_list.pdf

Technical Reports:

[9] EWEA "Structural harmonized grid code template", work group result of EWEAS grid code group

[10] S. L. Talleen. (1996, Apr.). The Intranet Architecture: Managing information in the new paradigm. Amdahl Corp., Sunnyvale, CA. [Online]. Available: http://www.amdahl.com/doc/products/bsg/intra/infra/html

Papers from Conference Proceedings (Published):

[12] T. Bublat, T. Gehlhaar, "Comparison of high technical demands on grid connected wind turbines defined in international Grid Codes", in Proc. 2008 EWEC Conf.

[13] J. Moeller, "Over 1000 voltage dip tests," in *Proc. 1991 DEWEK Conf.*, pp. 315-320.

[14] F. Martin, I. Purellku, T. Gehlhaar, „Modelling of and Simulation with Grid Code validated Wind Turbine Models," in Proc. 2009 EWEC Conf.

Standards:

[15] GL Technical Note 065"Grid Code Compliance of Wind Turbines according to Grid Codes – Certification Procedure", Rev.6,.2009.

V. BIOGRAPHIES

Tobias Gehlhaar was born in Heidelberg in Germany in 1968. He studied electrical energy engineering at the Technical University Darmstadt and Ilmenau.

His employment experience included the Brasilian Company Cebra, the German ISLE, Wind Turbine Manufacturer Nordex, Status-Pro and Germanischer Lloyd Renewables.

Gehlhaar received the degree of Diplomingenieur from the Technical University of Ilmenau. He is head of the group electrical engineering and active in the fields of lightning protection and electrical engineering of wind turbines as well as for Grid Code Compliance with the focus on Certification.