STANDARD

DNVGL-ST-0125 Edition March 2016

Grid code compliance

DNV GL AS

FOREWORD

DNV GL standards contain requirements, principles and acceptance criteria for objects, personnel, organisations and/or operations.

Any comments may be sent by e-mail to *rules@dnvgl.com*

CHANGES – CURRENT

General

This is a new document.

Contents

SECTION 1 GENERAL

1.1 Introduction

This standard provides a framework for proving grid code compliance by means of technical assessment, test, measurement, validation and simulation.

This standard should be used together with DNV GL's service specification for certification of grid code compliance DNVGL-SE-0124 /32/, which lays down procedural requirements for obtaining and maintaining third party evaluation resulting in confirmation stating proof of verification (GCC services). Such services are classified in different verification levels, the so called GCC-classes described in /32/. Final results of evaluation should be statements or certificates.

1.2 Objective

This standard

- serves as a basis for verification of generator capabilities concerning ancillary services and similar abilities to support the electrical system with technical services to improve security of supply and for which DNV GL is contracted to perform the verification
- defines assessment procedures and tests related to services as given in DNVGL SE-0124 /32/. It also helps finding an envelope for testing of different requirements
- promotes an internationally acceptable level with regard to security of supply by specifying clear assessment criteria for verification of grid code compliance based on the definition of minimum requirements by grid codes, national requirements, standards, recommended practices, guidelines, etc. as defined in [3.1.3] of DNVGL-SE-0124 /32/
- serves as a contractual reference document between suppliers and purchasers related to design, construction, installation, in-service inspection and especially related to national and regional grid connection approval procedures
- serves as a guideline for designers, suppliers, purchasers, regulators and both, system and plant operators
- specifies procedures and requirements for grid code compliance subject to DNV GL certification.

1.3 Scope and application

This standard is applicable to all types of units as well as for plants (plants are usually several electrically connected units, Figure 1-3), modules and facilities (several interconnected plants, Figure 1-1). Furthermore it is applicable to all parts, sub-components or part functionalities and any other electrical equipment related to it. The scope of individual assessment for verification or certification is described in [3.1.3] of DNVGL-SE-0124 /32/, and shall be defined for each individual case of assessment or verification.

See also the following two Guidance Notes for scope of assessment and structural integrity risk.

Guidance note 1:

The principle of assessment scope for certification according to /32/ is to limit the scope of this standard by the scope of the grid codes applied, depending on the GCC class chosen. The applicable scope of assessment for each certification is defined within the definition phase according to DNVGL SE-0124 /32/. More details upon assessment scope can be seen in [2.1] of this standard.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

Guidance note 2:

The structural integrity assessment for units and plants is outside of the scope of this standard. Nevertheless it is very important to evaluate the safe operation of the unit or plant especially during grid failure. This includes the evaluation of the relevant ranges of the safety system, protection and monitoring devices as well as the relevant ranges of the load assumptions.

This should be evaluated within the scope of a corresponding structural integrity assessment. This applies e.g. if rotating parts are involved in the unit and issues like over speed impose a risk to the unit's structural integrity, e.g. in the case of wind turbines. The evaluation is part of the design evaluation according to the respective standards and guidelines (e.g. GL IV-1 /15/, GL IV-2 /17/, IEC 61400-22 /14/ or DNVGL-SE-0074 /27/).

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

1.4 Glossary

Table 1-1 Terms and definitions

Term	*Definition*
active power	electrical active power, under periodic conditions, mean value, taken over one period T, of the instantaneous power p: $$P = \frac{1}{T}\int_{0}^{T} p(t) * dt$$ Remark 1: Under sinusoidal conditions, the active power is the real part of the complex power. Remark 2: The SI unit for active power is the watt. /16/.
asset	physical or logical object owned by or under the custodial duties of an organization, having either a perceived or actual value to the organization Remark 1 to entry: In the case of industrial automation and control systems the physical assets that have the largest directly measurable value may be the equipment under control./33/.
assessment	undertaking of an investigation in order to arrive at a judgment, based on evidence, of the suitability of a product /34/ Within this standard review is called assessment.
ancillary services	functional capabilities of electrical equipment serving the electrical system as required by the Relevant Network Operator (RNO) Within this standard ancillary services can be specified by GCC features, e.g. frequency control (in the App.A see D5 for details). The term 'ancillary services' refers to a range of functions which TSOs contract so that they can guarantee system security. These include black start capability (the ability to restart a grid following a blackout); frequency response (to maintain system frequency with automatic and very fast responses); fast reserve (which can provide additional energy when needed); the provision of reactive power and various other services as required in grid codes, all detailed in the App.A.
automatic voltage control	the capability to regulate a specific power system voltage, via adjustment of unit excitation within the limits of unit terminal voltage and VAR capability /40/ This can be performed by an automatic voltage regulator (AVR), a continuously acting automatic equipment controlling the terminal voltage of an asset, equipment, plant or unit by comparing the actual terminal voltage with a reference value and controlling by appropriate means the output of an excitation system, depending on the deviations.
black start capability	an ancillary service usually not required from wind turbines or PV inverters - is the capability of recovery of a module from a total shutdown through a dedicated auxiliary power source without any energy supply which is external to the plant, equipment or asset within this module
certificate	proof of evidence of compliance based on independent assessment issued by DNV GL's certification body renewables certification
certification	action by a certification body, providing written assurance that adequate confidence is provided that the asset in question is demonstrably in conformity with a specific standard or other normative document Certification is the final statement that all requirements of a standard or normative document have been satisfied or conformed to. (ISO 17000:2004): Third-party issue of a statement, based on a decision following review, that fulfilment of specified requirements has been demonstrated related to products, processes or systems. Review shall in this context mean a documented, comprehensive and systematic examination of a product, process or system to evaluate its compliance with the specified requirements. Specified requirements refer to a need or expectation that is stated in normative documents such as national or international standard or DNV GL Service Specification.
certification phase	see "phase"
certification procedure	also called certification scheme, i.e. a sequence of phases or modular steps to be completed prior to the issue of a certificate The description in [3] in DNVGL-SE-0124 /32/, gives the main certification procedure related to this standard.
certification report	see [3.3.2.1] in DNVGL-SE-0124 /32/, verification report with additional credibility due to assessment made strictly according to certification procedures by the accredited certification body DNV GL RC

Table 1-1 Terms and definitions (Continued)

Term	*Definition*
closed distribution system operator	within EU area: (CDSO) is a natural or legal person operating, ensuring the maintenance of and, if necessary, developing a closed distribution network according to article 28 of directive 2009/72/CE /37/
combustion engine	is an engine which generates mechanical power by combustion of a fuel, here: unit with combustion engine (gen-set)
compliance monitoring	the process to verify that the (technical) capabilities of plants are maintained by the facility owner to be compliant with the specifications and requirements of the scope to be defined according to [3.3.3] of the DNVGL-SE-0124 /32/
compliance simulation	the process according to the coming EU commission regulation (see /37/ and /28/), in order to verify that power generating modules are compliant with the specifications and requirements of the network code /37/ and /28/, for example before starting their operation The verification shall include, inter alia, the review of documentation, the verification of the requested capabilities of the module by simulation studies and the revision after comparison against real measurements (model validation according to [2.7] here and according to [3.2.3] and [3.2.4], both in DNVGL-SE-0124 /32/
compliance testing	the process to verify that power generating modules are compliant with the specifications and requirements of the future EU commission regulation (see /37/ and /28/), for example before starting their operation The verification includes, inter alia, the review of documentation, the verification of the requested capabilities of the module by practical tests according to test plan (Sec.3 here and [3.2] in DNVGL-SE-0124 /32/).
component	main part of an asset, module, plant, unit or any other equipment
component certificate	see [3.3.2.3] in DNVGL-SE-0124 /32/
conformity statement	statement of compliance – for statement level (IEC: conformity statement) A conformity statement is issued to confirm that the verification process has concluded that the object complies with the specified requirements.
connection agreement	is a contract between the RNO (relevant network operator) and the power generating facility owner which includes the relevant site and technical specific requirements for the facility
connection point	the point at which the power plant is connected with the grid of the grid operator (generally the point at which the circuit breaker, meter and protection relays are installed) Within EU area: The interface at which the power generating module is connected to a transmission, distribution or closed distribution network according to Article 28 of Directive 2009/72/CE as identified in the Connection Agreement /37/
control function	some GCC-features according to Appendix are related to control of other GCC-features Such control functions are typically performed by plant control which can be separate equipment, integral part of units or even cascaded control equipment on plant, module, or even facility level. Part of control functions may be performed by system operators, e.g. in providing corresponding signals for set point or mode selection purposes
control area	a control area is defined as a power system, a part of a system or a combination of systems to which a common power generating control scheme is applied The electrical interconnections within each control area are very strong as compared to the ties with the neighboring areas /33/ the RNO is usually technically responsible for his control area.
cost-benefit analysis	a process by which the RNO weighs the expected costs of alternative actions aiming at the same objective against the expected benefits in order to determine the alternative with the highest net socio-economic benefit If applicable, the alternatives include network-based and market-based actions, e.g. using validated software models according to [3.2.4] in the DNVGL-SE-0124 /32/.
current	electrical current is - unless stated otherwise - the current referring to the root-mean-square value of the positive sequence of the phase current at fundamental frequency, see also /38/ and /39/
customer	DNV GL's contractual partner It may be the manufacturer, its supplier, an EPC company, the developer, the operator or any other contractor
distribution system operator	(DSO) - is a natural or legal person responsible for operating, ensuring the maintenance of and, if necessary, developing the distribution network in a given area and, where applicable, its interconnections with other networks and for ensuring the long-term ability of the network to meet reasonable demands for the distribution of electricity

Table 1-1 Terms and definitions (Continued)

Term	*Definition*
droop	is the ratio of the steady-state change of frequency (referred to nominal frequency) to the steady-state change in power output (referred to maximum capacity) concerning frequency response
duration	see voltage dip duration
electrical power system components	equipment interconnected in an electrical system able to generate / convert, collect and transform electrical power including associated measuring and protection system
electrical system	within this standard, electrical systems are distribution systems, transmission systems and other electrical grids intended to conduct, store, and control electrical energy in order to provide it to electrical loads owned by private, public or industrial end users as required by national laws (security of supply)
energisation operational notification	special project certificate of GCC class I for EU area called EON - is a notification issued within EU area by the RNO to a facility owner prior to switching on of its internal network An EON entitles the facility owner within EU area to energise its internal network by using the grid connection.
engineering procurement construction (EPC)	under an EPC contract, the contractor designs the asset, procures the necessary units etc. and builds the asset (usually a plant or module)
equipment	electrical equipment Software and hardware intended to convert energy to electrical power, to provide any GCC feature related to that or being required according to the scope. Electrical equipment can be structured in units and plants, as most of the equipment is of a distributed power generating type. Electrical equipment can be e.g. power cables, power transformers, reactive power compensation installations as well as protection and control systems as far as applicable. Electrical equipment is a system or component that forms part of an asset In other words electrical equipment is any power installation as defined in /40/ with assembled electrical equipment or electronic equipment or a combination of electric and electronic equipment in a given location and designed for coordinated operation and connected to an electricity supply system Remark 1: The use of the installation is not specified, but it is interacting with the electricity supply system, either directly for example by means of control, regulating and protection equipment, or indirectly for example by means of measurements leading to intervention by personnel. Remark 2: Instead of "power installation" sometimes the wording "electrical installation" may be used. /40/
equipment certificate	see [3.3.2.4] in DNVGL-SE-0124 /32/ Certificate for equipment, assets, units or functions.
evaluating party	an independent party comparing results with requirements
existing power generating module	a module which is not a new module
exhaustive requirements	GCC-features fully specified by the future EU commission regulation /37/, /28/, not having the need of being nationally specified, too Opposite: Non-exhaustive requirements, see /28/.

Table 1-1 Terms and definitions (Continued)

<table>
<tr><th>Term</th><th>Definition</th></tr>
<tr><td>facility</td><td>means a facility that converts primary energy into electrical energy and which consists of one or more modules connected to a network at one or more connection points; term mainly used in EU area. short form used in the text for “power generating facility”, see Figure 1-1, Figure 1-3 and Figure 1-4.

A power generating facility

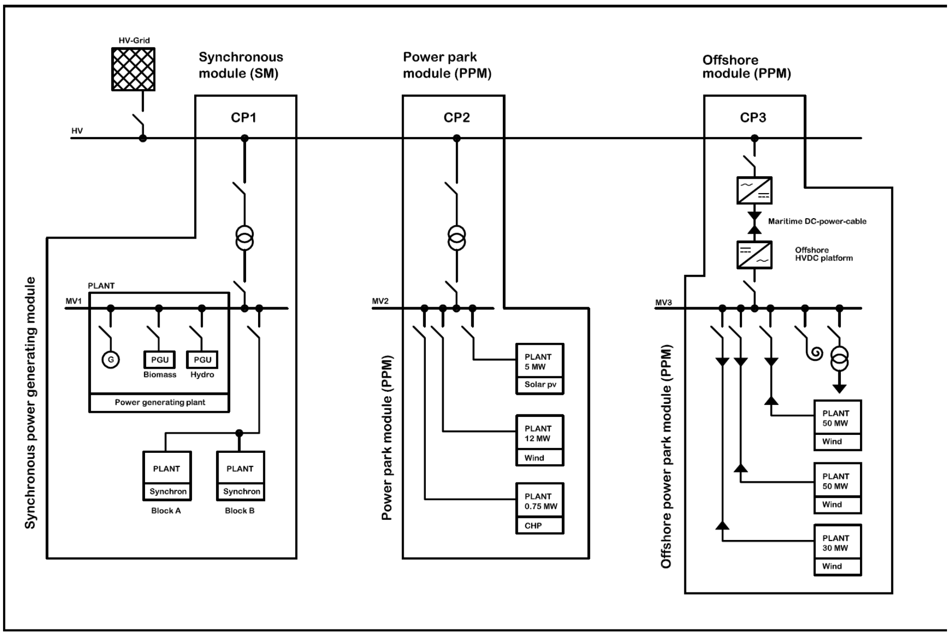


Figure 1-1 Modules and plants forming a facility</td></tr>
<tr><td>fault-ride-through</td><td>FRT (fault-ride-through) means surviving any fault possible in electrical systems including over-voltage ride-through and under-voltage ride-through</td></tr>
<tr><td>final operational notification</td><td>Special project certificate of GCC class I for EU area called FON - is a notification issued by the RNO to a facility owner confirming that the facility owner is entitled to operate the module or plant by using the grid connection because compliance with the technical design and operational criteria has been demonstrated as referred to in the future EU commission regulation /21/.</td></tr>
<tr><td>frequency</td><td>the frequency of the electrical power system that can be measured in all network areas of the synchronous system under the assumption of a coherent value for the system in the time frame of seconds (with minor differences between different measurement locations only); its nominal value is 50 Hz or 60 Hz</td></tr>
<tr><td>frequency response</td><td>See frequency control</td></tr>
<tr><td>frequency control</td><td>a typical ancillary service and more specifically the capability of a module, plant or unit to control speed by adjusting the active power output in order to maintain stable system frequency (also applicable as speed control for synchronous modules). Also possible is the control of the frequency by electronic measures like power frequency converters. IEC definition is called “frequency control mode”: control of the frequency of one or more connected a.c. networks by varying the transmitted power. /36/

Sometimes it is also called frequency response with the following similar definition. Within IEC terminology this term is called automatic generation control and is defined like this: the capability to regulate the power output of selectable units in response to total power plant output, tie-line power flow, and power system frequency /35/. However, within this document this is called frequency response</td></tr>
<tr><td>frequency response dead band</td><td>a typical GCC-feature used intentionally to make the frequency control not responsive. In contrast to (in) sensitivity, dead band has an artificial nature and basically is adjustable. Further detail definitions are given in the App.A of this standard</td></tr>
<tr><td>frequency response insensitivity</td><td>a typical GCC-feature being the inherent feature of the control system defined as the minimum magnitude of the frequency (input signal) which results in a change of output power (output signal). Further detail definitions are given in the App.A of this standard</td></tr>
</table>

Table 1-1 Terms and definitions (Continued)

Term	*Definition*
frequency sensitive mode	(FSM) is a typical GCC-feature. If a module is operating in the FSM mode which will result in active power output changing, in response to a change in system frequency, in a direction which assists in the recovery to target frequency, by operating so as to provide frequency response. Further detail definitions are given in the App.A of this standard
frequency withstand ability	the design and the ability of any equipment, unit or asset to tolerate changes in the system frequency in a given tolerance band without tripping or switching off in any other way and without being damaged due to wrong design
geographic target area	covering grid code compliance in a couple of countries might be a sales or marketing point of view for units or even plants. Such area is called geographic target area and could be defined by sales (trading area), by governments (countries), by technical GCC-features (50Hz countries), by RNO responsibility (control area), by grid code applicability (jurisdiction) etc.
GCC class	assessment level for grid code compliance. GCC class x is defined in order to classify the level of assessment performed. Assessment levels can limit the amount of requirements as described in DNVGL-SE-0124 /32/ in [3.1.3] in more detail. In short: — GCC class I is an assessment level accepted by the responsible network operator (RNO) in charge for a specific area. — GCC class II — is the assessment level given in the DNVGL-SE-0124 /32/ in [3.1.3] and the grid code applied (intersecting set of requirements). — without GCC class means the requirements are defined individually based on the GCC features. The GCC class is also distinguishing between the assessment level for types of units on the one hand (TCx), and for site specific plants (so called projects, PCx) on the other hand
GCC features	a well-defined functional performance of any electrical equipment under given operational conditions, usually intended to provide a technical function important for the security of supply or other important reasons. This can be any ancillary service capability under assessment. The scope of examination is given as the GCC class. Examples for GCC features are ancillary services like frequency control. In the outdated /Technical Note/ GCC features are called. GCC-Parameters /36/
GCC services	grid code compliance services provide evidence by objective means that electrical equipment fulfills specific grid code requirements, GCC features, ancillary services or corresponding capabilities as described in the service specification /32/ based on details within this standard in combination with requirements set e.g. by electrical system operators.
generation	generation of electricity is a process of producing electrical energy from other forms of energy Remark: The amount of electric energy produced, usually expressed in kilowatt-hours (kWh) or megawatt hours (MWh). /39/ For the use within this standard, see below definitions for unit (power generation unit) and plant (power generation plant), both intended for the generation of electricity (see Figure 1-2).
grid code	a document that sets out the procedures and requirements relating to the activities of connection, management, planning, development and maintenance of the national electrical transmission and distribution grid, as well as dispatching and metering etc.
grid code compliance	GCC (grid code compliance) means the tasks related to certification, assessment and verification of technical performance capabilities required in grid codes and similar documents. Similar documents could be laws dealing with power purchase agreements or conditions related to grid connection. Also testing, simulating and evaluating of any electrical impact on the electrical systems for distribution and transmission of electrical energy can be part of GCC.
grid operator	see system operator or network operator
high-voltage ride-through	now called over-voltage ride-through. During faults in the electrical system voltage can rise at the output terminals of a unit. According to the grid codes of various system operators a plant shall stay operational during specific over voltage (OVRT, formerly called “high voltage ride through, HVRT”).
house-load operation	in case of network failures resulting in disconnection of modules from the network and being tripped onto their auxiliary supplies, house-load operation ensures that facilities are able to continue to supply their in-house loads.

Table 1-1 Terms and definitions (Continued)

Term	*Definition*
inertia	is a typical ancillary service not required in each case and more specifically related to the fact that a rotating rigid body such as an generator connected to a rotating mass maintains its state of uniform rotational motion. Its angular momentum is unchanged, unless an external torque is applied. In the context of this ancillary service, this definition refers to the technologies for which rotating masses, their speed and the system frequency are coupled. Further detail definitions are given in the App.A of this standard.
installation document	can be a special part of a certificate of GCC class I for EU area - a simple structured document (data / tick sheet) containing information about a type A module (Type A defined according to the future EU commission regulation /37/) and confirming compliance with the relevant requirements /37/. The blank installation document shall be available from the RNO for the type A facility owner or alternatively the site installer on the owner's behalf to fill in and submit to the RNO.
instruction	a command given orally, manually or by automatic remote control facilities, e. g. a set point, from a network operator to a facility owner in order to perform an action
inter–array cables system	MV cables that connect the nits one to each other and the plant strings to the MV switchgear installed in the substation. It is part of a module, and in most cases also part of a plant, but it could also be the lines between plants within one module or the common connection line of several plants with the single connection point of one module (see Figure 1-3).
interim operational notification (ION)	can be a special conditioned project certificate of GCC class I for EU area called ION - this is a notification issued by the RNO to a facility owner confirming that the facility owner is entitled to operate the module or plant by using the grid connection for a limited period of time and to undertake compliance tests to meet the technical design and operational criteria of the future EU commission regulation /37/
island operation	the independent operation of a whole or a part of the network that is isolated after its disconnection from the interconnected system, having at least one module supplying power to this network and controlling the frequency and voltage
limited frequency sensitive mode — over-frequency - LFSM-O — under-frequency - LFSM-U	a typical GCC-feature (LFSM-O) which means being in a module operating mode which will result in active power output reduction in response to a change in system frequency above a certain value, see [2.4.2]. Further detail definitions are given e.g. in D5 (in App.A). LFSM-U the same for under frequency, power output increase below a certain value of frequency
limited operational notification (LON)	can be a special part of a certificate of GCC class I for EU area - is a notification issued by the RNO to a facility owner which has previously reached FON status, but is temporarily subject to either a significant modification or loss of capability which has resulted in non-compliance to the future EU commission regulation /37/
low-voltage ride-through	now called under-voltage ride-through During faults in the electrical system voltage drops can occur at the output terminals of a unit. According to the grid codes of various system operators a plant shall stay operational during specific voltage drops (Under-voltage ride-through, formerly known as Low Voltage Ride Through, LVRT)
mandatory GCC services	when ordering a GCC service, it might be mandatory to perform some other GCC services, too, due to the case that they are correspondingly listed with "dependency on other steps in Table 3.3 in [3.4] in DNVGL-SE-0124 /32/
maximum capacity	a typical GCC-feature meaning the maximum continuous active power which a module can feed into the network as defined in the connection agreement or as agreed between the RNO and the facility owner It is also referred to below as P_{avail} and as P_{max}
minimum regulating level	a typical GCC-feature meaning the minimum active power as defined in the connection agreement or as agreed between the RNO and the facility owner, that the module can regulate down to and can provide active power control Further detail definitions are given in the App.A of this standard.
minimum stable operating level	is a typical GCC-feature meaning the minimum active power as defined in the connection agreement or as agreed between the RNO and the facility owner, at which the module can be operated for unlimited time. Further detail definitions are given in the App.A of this standard

Table 1-1 Terms and definitions (Continued)

Term	*Definition*
module	short form used in the text for "power generating module" Within EU area 3 types of modules are defined: "power park module", "synchronous module" and "offshore power park module". See Figure 1-1, Figure 1-2, Figure 1-3 and Figure 1-4. A module may contain one or more plants, lines and transformers, but only one single connection point (CP). With other words: for each CP there is one module only.
Network	electrical power grid or electrical system for collection, distribution or transmission of power
network code	other word for grid code
network operator	party responsible for safe and reliable operation of a part of the electric power system in a certain area and for connection to other parts of the electric power system /43/ The same as a system operator, grid operator, an entity that operates a network, these can be either a TSO, a DSO or CDSO. In case the respectively responsible network operator is referred to in the text the term "relevant network operator" is used (RNO) (i.e. the network operator in charge for the relevant equipment).
non-exhaustive requirements	such GCC-features specified by entso.e / acer not completely, but only to a certain extend The rest of specification is to be done by the national laws within EU, finally achieving exhaustive requirements, which are fully defined GCC-features.
over-voltage ride-through	during faults in the electrical system voltage can rise at the output terminals of a renewable generation unit According to the grid codes of various system operators a renewable generation plant shall stay operational during specific over voltage (UVRT, formerly called "high voltage ride through, HVRT").
overexcitation limiter	is a control device within the AVR which prevents the rotor of an directly network coupled separately excited synchronous rotating electrical machine within a unit from overload by limiting the excitation current This is not applicable to unit technologies with frequency converter between rotating electrical machine and the network
per unit	instead of percentage values, per unit does not use 100 as a reference but 1 (unit) It equals a value of percentage divided by 100.
phase	1) certification phases in the context of the DNVGL-SE-0124 /32/ are three different phases: definition phase, verification phase and certification phase, see [3] in DNVGL-SE-0124 /32/ 2) in electrical engineering, three-phase electric power systems have at least three conductors carrying alternating current voltages that are offset in time by one-third of the period. A three-phase system may be arranged in delta (Δ) or star (Y) (also denoted as wye in some areas) /34/ 3) in the context of periodic phenomena, such as a wave, phase angle is synonymous with phase /35/. Phase in sinusoidal functions or in waves has two different, but closely related meanings. One is the initial angle of a sinusoidal function at its origin and is sometimes called phase offset or phase difference. Another usage is the fraction of the wave cycle that has elapsed relative to the origin /36/
phase current	measured electrical current in 2 or 3 phases

Table 1-1 Terms and definitions (Continued)

<table>
<tr><th>Term</th><th>Definition</th></tr>
<tr><td>plant</td><td>short form used in the text for “power generating plant”, see Figure 1-2, Figure 1-3 and Figure 1-4.

A module may contain one or more plants, transformers lines and other equipment but only one single connection point CP.

A plant may contain one or more units.

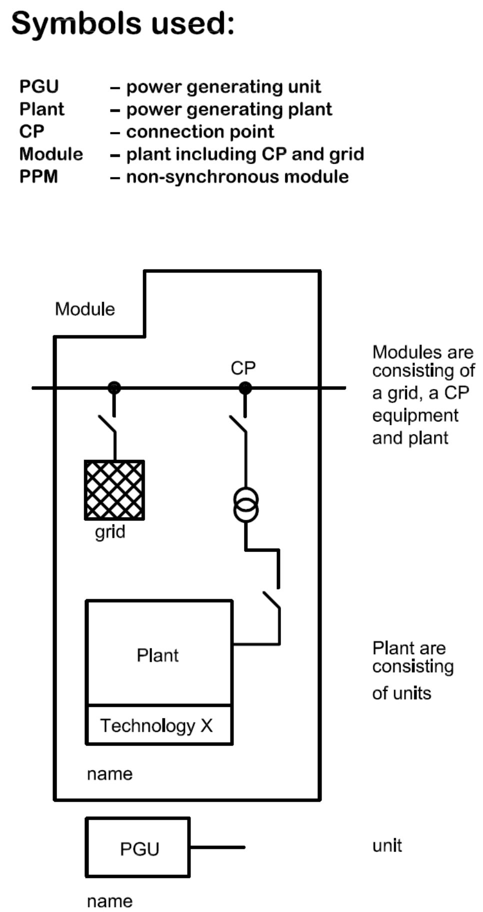


Figure 1-2 Symbols for CP, units, plants and modules</td></tr>
<tr><td>plant control</td><td>means both, control function of specific GCC features as well as the physical place where the corresponding control functions are performed, e. g. a power plant controller according to /44/</td></tr>
<tr><td>power factor</td><td>is the ratio of active power to apparent power

if displacement power factor is mentioned, this is the displacement component of the power factor; ratio of the active power of the fundamental wave to the apparent power of the fundamental wave /40/.</td></tr>
<tr><td>power generating facility</td><td>see facility, short form used within the text</td></tr>
<tr><td>powergenerating facility owner</td><td>a natural or legal entity owning a facility according to wording within EU

Short form below is facility owner. This is commonly known as plant owner or plant owner, power house owner, wind farm owner etc. This is not necessarily the operator, which could be a different party working on behalf of the facility owner. The difference between plant owner and facility owner might also be further equipment other than units and plants being also connected in the same facility (see Figure 1-1).</td></tr>
<tr><td>power generating module</td><td>term used within EU area. Short form in the text is module

See the definition of module.</td></tr>
</table>

Table 1-1 Terms and definitions (Continued)

Term	*Definition*
power generating module document	can be a special certificate within EU area called PGMD This is a document issued by the facility owner to be provided to the RNO for a type B or C module (A,B,C: the future EU commission regulation /37/ and /28/. The PGMD is intended to contain information confirming that the module has demonstrated compliance with the technical criteria as referred to in the future EU commission regulation /37/ and that necessary data and statements including a statement of compliance have been provided
Power generating plant	see plant
Power generating unit (PGU)	see unit
power installation	see equipment
power park module (PPM)	PPM is a special module within EU area with plants built from such units, which are connected to the plant network non-synchronously or through power electronics.
	see also "module"
power plant	see plant, short form for "power generating plant"
power system stabilizer	(PSS) - is an additional functionality of the AVR of a module, plant or unit with the purpose of damping power oscillations
P-Q-capability diagram	describes the reactive power capability of a module, plant or unit in context of varying active power at the connection point Further detail definitions are given in the App.A of this standard
project certificate	certificate as described in [3.3.2.6] in the DNVGL-SE-0124 /32/, it is a Certificate for facilities, modules or plants.
pump-storage	a hydro unit in which water can be raised by means of pumps and stored to be used later for generation
reactive power	reactive power Q in a single phase system is defined for steady-state and periodic signals as $Q = U_1 * I_1 * \sin\varphi_1$ where U1 and I1 are the r.m.s. values of the fundamental frequency components of the voltage and the current respectively, and φ1 is the phase angle between them. The reactive power in poly-phase system is the algebraic sum of the per-phase reactive powers: $Q = U_{L1} * I_{L1} * \sin\varphi_{L1} + U_{L2} * I_{L2} * \sin\varphi_{L2} + ...$ where L1 and L2 are the first and second phase of the system. /41/
relevant network operator (RNO)	electrical system operator in charge for the connection point or according to the connection agreement or PPA (power purchase agreement), this is the operator of the network to which a module, plant or unit is or will be connected – often responsible for a given control area
scope, defining assessment	the assessment scope of a GCC service can be different in each case but shall be defined in strict accordance to the DNVGL-SE-0124, SE /32/. It will be defined by the GCC class in each case. Details can be seen in [3.1.3] in DNVGL-SE-0124 /32/ (scope). Before any assessment can be performed, the scope of assessment will be defined for each customer on a case by case basis, based on the assignment procedure given in [3.1.3] in DNVGL-SE-0124 /32/. During assessment the scope and GCC class will be applied as agreed before
set point	is a target value for any parameter typically related to GCC-features and used in control schemes
significant power generating module	a special type certificate for EU area describing a module which is deemed significant on the basis of its impact on the cross-border system performance via influence on the control area's security of supply, which is identified according to the criteria set forth in the network code /21/ and falls within one of the categories provided in its Article 5 number 2
slope	slope is calculated by finding the ratio of the "vertical change" to the "horizontal change" between (any) two distinct points on a line As example for GCC one of the GCC-features within the ancillary service voltage control can be named. The slope in this case is defined as the ratio of the change in voltage, based on nominal voltage, to a change in reactive power fed in from zero to maximum reactive power, based on maximum reactive power
statement of compliance	See [3.3.2.2] in DNVGL-SE-0124 /32/

Table 1-1 Terms and definitions (Continued)

Term	*Definition*
steady-state stability	if the network or a module previously in the steady-state reverts to this state again following a sufficiently minor disturbance, it has steady-state stability
step	there are two or three steps within one certification phase Within the DNVGL-SE-0124 /32/ steps are represented by a lower case character with bracket, following the number of the corresponding certification phase. E. g. step 1.a) is in phase 1 (definition phase).
synchronous compensation operation	an ancillary service function is the operation of any equipment without providing much active power, just to regulate voltage dynamically by production or absorption of reactive power

synchronous module (SM)	a special kind of module defined within EU area as an indivisible set of installations which can generate electrical energy such that the frequency of the generated voltage, the generator speed and the frequency of network voltage are in a constant ratio and thus in synchronism /35/
	See Figure 1-4
	This can be e. g.
	— a single unit with synchronous rotating electrical machine directly connected to the grid ("synchronous unit"), generating power within a facility directly connected to a transmission, distribution or closed distribution network, or
	— an ensemble of synchronous units generating power within a facility directly connected to a transmission, distribution or closed distribution network
	    — with a common connection point, or
	    — that cannot be operated independently from each other (e. g. units generating in a combined-cycle gas turbine facility), or
	— a single synchronous storage device operating in electricity generation mode directly connected to a transmission, distribution or closed distribution network, or
	— an ensemble of synchronous storage devices operating in electricity generation mode directly connected to a transmission, distribution or closed distribution network with a common connection point.

synchronous power generating module	see synchronous module (SM) above
synthetic inertia	is a facility provided by a power park module, plant, unit or HVDC system to replicate the effect of inertia of a synchronous module to a prescribed level of performance according to definitions within EU area
system operator	party responsible for safe and reliable operation of a part of the electric power system in a certain area and for connection to other parts of the electric power system /43/ The same as a network operator, also: grid operator. "System operator or owner": the entity responsible for making technical connection agreements with customers who are seeking connection of load or generation to a distribution or transmission system /42/.
test duration	see voltage dip duration and definitions in [3.3.4.2]
type certificate	certificate issued by a certifying body according to [3.3.2.5] in DNVGL-SE-0124 /32/. The type certificate will allow the customer to manufacture certified units during the period of validity of the certificate
under-excitation limiter	a control device within the AVR, the purpose of which is to prevent the directly network connected synchronous rotating electrical machine from losing synchronism due to lack of excitation This is not applicable to unit technologies with frequency converter between rotating electrical machine and the network.
under-voltage ride-through	during faults in the electrical system voltage drops can occur at the output terminals of a unit According to the grid codes of various system operators a plant shall stay operational during specific voltage drops (Under-voltage ride-through, UVRT, formerly known as "Low Voltage Ride Through, LVRT").

Table 1-1 Terms and definitions (Continued)

<table>
<tr><th>Term</th><th>Definition</th></tr>
<tr><td>unit</td><td>

units are defined as single generating installations converting renewable energy into electricity (e.g. single wind turbines, inverters with connected photovoltaic cells (PV) etc.).

The short form “unit” for “power generating unit” (PGU) is used in the text, for clarification see Figure 1-1, Figure 1-2 as well as Figure 1-3 and Figure 1-4 below. Several units are forming a plant, several plants form different kind of modules:

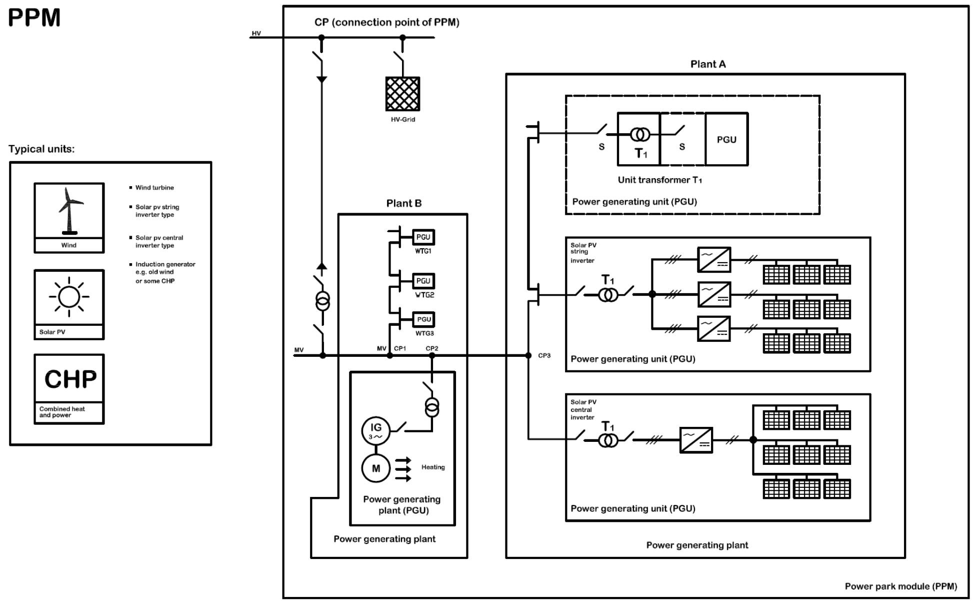


Figure 1-3 Units are forming plants and modules, here: power park module

A unit may contain a transformer, one or more converters, rotating electrical machines or photovoltaic cells when forming a special module called PPM in the EU area.

Units are defined as single generating installations (e.g. single wind turbines, inverters with connected photovoltaic cells (PV) etc.) converting renewable energy into electricity.

The short form “unit” for “power generating unit” (PGU) is used in the text, for clarification see Figure 1-1, Figure 1-2 as well as Figure 1-3 above and Figure 1-4 below.

Several units are forming a plant, several plants form different kind of modules:

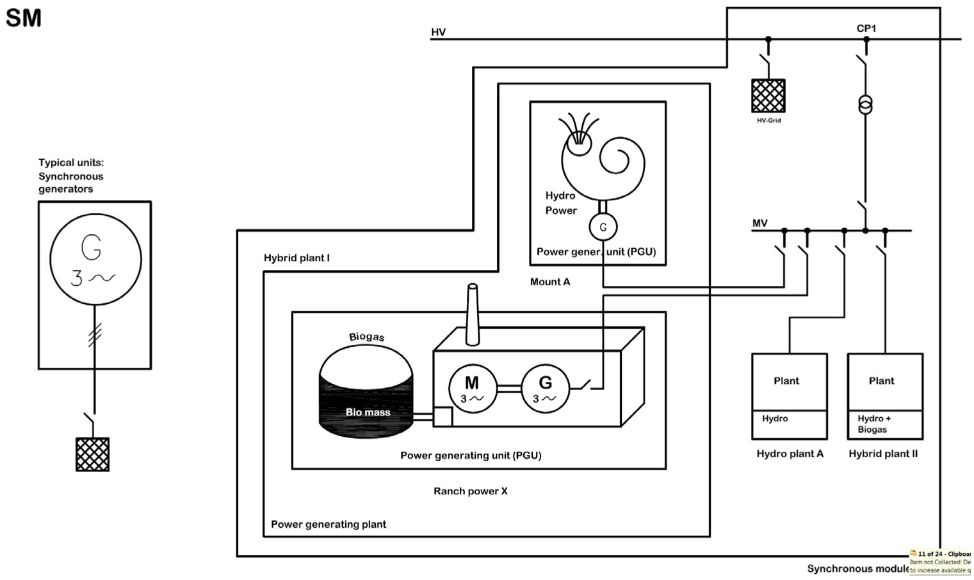


Figure 1-4 Typical units forming synchronous modules (SM)

</td></tr>
</table>

Table 1-1 Terms and definitions (Continued)

Term	*Definition*
unit (continued)	Units in synchronous modules contain synchronous generators, turbines or combustion engines. Details on the different kinds of modules see "module"
U-Q/P_{max}-profile	is a GCC-feature in the form of a figure (profile) representing the reactive power capability of a module, plant or unit in context of varying voltage at the connection point Further detail definitions are given in the App.A of this standard
verification	(ISO 9000:2005): confirmation, through the provision of objective evidence, that specified requirements have been fulfilled The term "verified" is used to designate the corresponding status. Verification can comprise activities such as: — performing an independent review/assessment to confirm the reported results of a design analysis; — witnessing activities such as manufacturing, testing, installation and commissioning to confirm compliance with specified procedures; — reviewing documents to assess compliance with specified requirements; — testing/inspecting components or products to determine the compliance to applicable specifications or technical standards.
verification level	see GCC class.
verification report	see certification report, for details see [3.3.2.1] in DNVGL-SE-0124 /32/. A certification report may be issued by DNV GL – Energy as a statement to confirm the outcome of a verification process. A certification report may be issued at any stage of the verification process; it can be the final deliverable if the specified requirements to conformity statement are not fulfilled.
voltage	see EN 50160
voltage control	1) is a typical ancillary service requirement, usually implemented by automatic voltage regulator (AVR) 2) is the continuously acting automatic equipment controlling the terminal voltage of an asset, equipment, module, plant or unit by comparing the actual terminal voltage with a reference value and controlling by appropriate means the output of an excitation system (or by other measures), depending on the deviations. Further detail definitions are given in the App.A of this standard
voltage dip duration	for verification of unit's ability to ride through faults, corresponding testing is described in [3.2.5] [3.3.4]. The tests are voltage dips, negative dips in the case of UVRT and positive dips in the case of OVRT. Test duration is the voltage dip duration planned for verification and means the time of the dip starting with the voltage drop to the test voltage level and ending with the voltage recovery back to the initial voltage. Detail definition is given by using the switching commands of switch S_2 in Figure 3-3 or by descriptions in [3.3.4.2].
voltage recovery	After a voltage dip has passed, the voltage reaches normal values again. This is regarded as voltage recovery.
wind power plant	see plant
wind turbine	unit which converts the kinetic energy in the wind speed into electrical energy. Whenever, in this standard the term is used to describe the wind turbine in general, it describes the rotor-nacelle-assembly including all mechanical and electrical components and the support structures, as this is the unit

Table 1-2 Acronyms and abbreviations

Acronym	*In full*
A	ampere, see „current", /38/ and /39/
AC	alternating current
ACER	Agency for the Cooperation of Energy Regulators, see www.acer.europa.eu
AVC	Automatic voltage control
AVR	automatic voltage regulator
BIL	basic insulation level

Table 1-2 Acronyms and abbreviations (Continued)

Acronym	*In full*
CBA	cost benefit analysis
CDSO	closed distribution system operator
CHP	cogeneration or combined heat and power (CHP) is the use of a heat engine or power station to generate electricity and useful heat at the same time.
CP	connection point
D	1) Dynamic performance, abbreviation used in the appendix for grouping GCC-features, see Table A-1: Introduction to GCC-feature listing 2) Harmonic voltage Distortion
DC	direct current
DER	distributed energy resources
DSO	distribution system operator
EC	equipment certificate
EMT, emt	electromagnetic transient
EPC	engineering procurement construction
f	frequency, Hz, see definition above under „frequency"
FON	final operation note
FRT	fault-ride-through
FSM	frequency sensitive mode
G	general grid code specifications, abbreviation used in the appendix for grouping GCC-features, see Table 13: Introduction to GCC-feature listing
GCC	grid code compliance
HVRT	OVRT, formerly called "high-voltage ride-through"
Hz	1/s
I	electrical current in A, definition above under the term „current"
Int	communication and control interface, abbreviation used in the appendix for grouping GCC-features, see Table A-1: Introduction to GCC-feature listing
ION	interim operational notification
IEC	International Electrotechnical Commission
ITT	invitation to tender
LFSM-O	limited frequency sensitive mode – over-frequency
LFSM-U	limited frequency sensitive mode – under-frequency
lt	long term flicker
LON	limited operational notification
LVRT	UVRT, formerly known as "low-voltage ride-through"
M	model related information data, abbreviation used in the appendix for grouping GCC-features, see Table A-1: Introduction to GCC-feature listing
ms	milli-seconds
MV	medium voltage level, usually between 1 and 60 kV
OLTC	on load tap changer
P	1) See Table A-1: Introduction to GCC-feature listing 2) Flicker value 3) Active power
PC	project certificate
PCC	point of common coupling
PGMD	powergenerating module
PGU	power generating unit
P_{max}	maximum capacity
Pn	offshore wind power plant nominal installed power
PPA	power purchase agreement, connection agreement
PPM	power park module, special kind of module of plants with non-synchronous units (see Figure 1-3)
PSS	power system stabilizer

Table 1-2 Acronyms and abbreviations (Continued)

Acronym	*In full*
pu	also p.u. per unit, similar like % but normalized to 1 (unit)
PV	Photovoltaic, a technology for transforming sunlight directly into electricity
$Q_{overex\ max}$	maximum (over-excited) reactive power injected by the plant at the PCC (capacitive operation of the plant)
$Q_{underex\ max}$	maximum (under-excited) reactive power absorbed by the plant at the PCC (inductive operation of the plant)
R	1) Frequency voltage and power rating (steady state performance), abbreviation used in the appendix for grouping GCC-features, see Table A-1: Introduction to GCC-feature listing 2) Electrical resistance
RES	renewable energy resources which can be used to power equipment for generation
RMS, rms	root mean square
RNO	relevant network operator
S	1) site specific data, abbreviation used in the appendix for grouping GCC-features, see Table A-1: Introduction to GCC-feature listing 2) Abbreviation for electrical apparent power
s	second
SE	service specification
SM	synchronous module
SIL	switching impulse level
t	time
TC	type certificate
THD	Total harmonic distortion
TOV	temporary over voltage
TSO	transmission system operator, here: electrical systems
TXT, txt	Abbreviation for representing the need of a textual description for this GCC-feature and for its value setting. Used in the appendix, if GCC-feature definition is not fully generic, it is not sufficient to give a value as success criteria, additional description or text is needed
UVRT	under-voltage ride-through (formerly known as LVRT)
U	test voltage levels, see Figure 3-4
V	volt, unit for electrical voltage, see EN 50160
Var	reactive power unit representation, consisting of volt and ampere
WECC	The Western Electricity Coordinating Council (WECC) is a non-profit corporation that exists to assure a reliable Bulk Electric System in the geographic area known as the Western Interconnection. WECC has been approved by the Federal Energy Regulatory Commission (FERC) as the Regional Entity for the Western Interconnection. The North American Electric Reliability Corporation (NERC) delegated some of its authority to create, monitor, and enforce reliability standards to WECC through a Delegation Agreement. https://www.wecc.biz/Pages/home.aspx
WTG, WT	wind turbine generator, meaning the same as wind turbine
X	Electrical reactance
Z	1) Electrical impedance, including resistance and reactance 2) Additional Definitions to be specified as described in [A.4]

Table 1-3 Greek characters

φ	phase shift angle between voltage and current
α, β, γ	subscripts used for voltage dip level definition

Table 1-4 Subscripts

α	drop requirement for UVRT meaning drop to medium remaining voltage level in the test
β	drop requirement for UVRT meaning drop to highest remaining voltage level in the test
γ	drop requirement for UVRT meaning drop to lowest remaining voltage level in the test
available	a maximum currently available value (at a given time of a variable measure) being not reduced by any means usually compared to a value being reduced by any factor or function (throttling or curtailment)
OVRT	value for over-voltage ride-through
i	referring to the current value
inrush	Initial higher value due to electro-physical behaviour
k	Short-circuit value
LL	Line to line value (delta)
min	minimum value
N, n	nominal value
negative	negative sequence representation of the value
P_{avail}, P_{max}	maximum capacity, maximum available power
positive	Positive sequence representation of the value
P_n, P_N	nominal power
$Q_{overex\ max}$	maximum (over-excited) reactive power injected by the module, plant or unit at the PCC (capacitive operation of the plant)
$Q_{underex\ max}$	maximum inductive (under-excited) reactive power absorbed by the module, plant or unit at the PCC (inductive operation of the plant)
r	rating value
rem	remaining value, e.g. after a voltage drop during voltage dipping, see Figure 3-5
rise-max	maximum rise time
max	maximum value
remaining	value which can be achieved in reality, when dipping to a specified nominal value (e.g. U_{γ}), the difference is due to control results of reactive power, tolerances etc.
recover	value marking the end of the recovery time
RMS	root mean square value
settling max	maximum value after settling of the value took place in time
st	short time flicker value
t_1	Shortest test time, see Figure 3-4
t_2	Longest test time, see Figure 3-4
u	referring to the voltage value

Table 1-5 Verbal forms

Term	*Definitions*
shall	verbal form used to indicate requirements strictly to be followed in order to conform to the document
should	verbal form used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required
may	verbal form used to indicate a course of action permissible within the limits of the document

1.5 References

The technical requirements and acceptance criteria for GCC as given in this standard refer to services specified in the Service Specification DNVGL-SE-0124 /32/ (and to the grid codes as specified individually). This means that each requirement given within this standard shall only be applied if the service ordered by the applicant calls for such as detailed in the Service Specification DNVGL-SE-0124 /32/.

Grid Code listing can be seen at http://www.dnvgl.com/GridCodeListing.pdf continuously updated by DNV GL.

Other references used throughout this standard are listed below.

If standards are referenced in the text of this document, the currently valid edition is to be used at the time of question. So the below stated editions are examples only. In case newer editions exist, these shall be used.

Table 1-6 References

/1/	IEC 61400-1: 2005 Wind turbines – Part 1: Design requirements, third edition, August 2005
/2/	FGW TG8 Technical Guidelines for Power generating Units, Part 8: Certification of the electrical characteristics of power generating units and systems in the medium-, high- and highest-voltage grids, Rev. 7 or newer, Fördergesellschaft Windenergie und andere Erneuerbare Energien (FGW e.V.), Germany
/3/	FGW TG3 Technical Guideline for Wind Turbines-Part 3: Establish electrical characteristics of power generating units connected to the medium-, high- and extra high voltage level (Technische Richtlinien für Windenergieanlagen – Teil 3 Bestimmung der Elektrischen Eigenschaften von Erzeugungseinheiten am Mittel-, Hoch- und Höchstspannungsnetz), Rev. 23 or newer, Fördergesellschaft Windenergie und andere Erneuerbare Energien (FGW e.V.), Germany
/4/	TN 066 Technical Note (TN 066), Certification of grid code compliance (GCC) Test procedure for low voltage ride through (LVRT), Rev. 8, 31. 07. 2013 of GL Renewables Certification.
/5/	IEC 61400-21 Wind turbine generator systems – Part 21: Measurement and assessment of power quality characteristics of grid connected wind turbines
/6/	IEC 61400-12 Wind turbine generator systems – Part 12: Wind turbine power performance testing
/7/	Guidance Notes – Power Park Modules, issue 3, September 2012, National Grid, United Kingdom, available through internet at http://www2.nationalgrid.com/assets/0/745/746/3464/3466/3488/3475/08faa140-c02e-4e45-8ecb-1cf040388964.pdf
/8/	IEC TS 61400-13 Wind turbine generator systems – Part 13: Measurement of mechanical loads
/9/	FGW TG4 Technical guidelines for power generating units, Part 4: Demands on modelling and validating simulation models of the electrical characteristics of power generating units and systems, Rev. 6 or newer, Fördergesellschaft Windenergie und andere Erneuerbare Energien (FGW e.V.), Germany
/10/	bdew MV-Guideline "Technical Guideline, Generating Plants Connected to the Medium-Voltage Network, Guide Line for generating plants' connection to and parallel operation with the medium-voltage network", June 2008, BDEW Bundesverband der Energie- und Wasserwirtschaft e.V., Germany.
/11/	SDLWindV Verordnung zu Systemdienstleistungen durch Windenergieanlagen (SDLWindV), vom 03.07.2009, Bundesgesetzblatt Jahrgang 2009 Teil I, Nr. 39, ausgegeben zu Bonn am 10. Juli 2009, Seite 1734 Systemdienstleistungsverordnung vom 3. Juli 2009 (BGBl. I S. 1734), die zuletzt durch Artikel 3 der Verordnung vom 6. Februar 2015 (BGBl. I S. 108) geändert worden ist (Ordinance on System Services by Wind Energy Plants System Service Ordinance – SDLWindV) and Verordnung zur Änderung der Systemdienstleistungsverordnung, vom 25. Juni 2010, Bundesgesetzblatt Jahrgang 2010 Teil I, Nr. 34, ausgegeben zu Bonn am 30. Juni 2010, Seite 832 (Change Ordinance System Services by Wind Energy Plants)
/12/	RD661 10556, ROYAL DECRETO 661/2007, de 25 de mayo, por el que se regula la actividad de producción de energía eléctrica en régimen especial, BOE num. 126, issued 2007-05-26, page 22846, Spain (Royal ordinance for special electrical energy production scheme)
/13/	PVVC "PROCEDIMIENTOS DE VERIFICACIÓN, VALIDACIÓN Y CERTIFICACIÓN DE LOS REQUISITOS DEL PO 12.3 SOBRE LA RESPUESTA DE LAS INSTALACIONES EÓLICAS ANTE HUECOS DE TENSIÓN, Versión 10, issued by AEE 2012-01-26, Spain (Verification Validation and Certification Procedure for the requirements of the PO 12.3 on the response of Wind Farms in the event of voltage dips)
/14/	IEC 61400-22: 2010 Wind turbines – Part 22: Conformity testing and certification, Edition 1.0, 2010-05
/15/	Germanischer Lloyd Industrial Services GmbH, Renewables Certification „GL Rules and Guidelines - IV Industrial Services - Part 1 - Guideline for the Certification of Wind Turbines", Edition 2010.
/16/	[IEV 131-11-42] according to IEC Glossary, available on internet under http://dom2.iec.ch/terms
/17/	Germanischer Lloyd Industrial Services GmbH, Renewables Certification „GL Rules and Guidelines, IV, Part 2, Guideline for the Certification of Offshore Wind Turbines", Edition 2012
/18/	FGW TG2 Technical Guideline for Wind Turbines-Part 2: Establish power performance and standardised production (Technische Richtlinien für Windenergieanlagen – Teil 2: Bestimmung von Leistungskurve und standardisierten Energieerträgen) Fördergesellschaft Windenergie und andere Erneuerbare Energien (FGW e.V.), Germany
/19/	Technical Note (TN 65) „Certification of grid code compliance (GCC), Certification procedure", Revision 8, issued 2013-07-31 by Germanischer Lloyd Industrial Services GmbH Renewables Certification, Germany
/20/	„Generic Grid Code Format for Wind Power Plants" issued on 2009-11-27 by EWEA, http://www.ewea.org/fileadmin/ewea_documents/documents/publications/091127_GGCF_Final_Draft.pdf

Table 1-6 References (Continued)

/21/	„IGCC List, International Grid Code Comparison", issued on a regular basis by DNV GL, http://www.dnvgl.com/GridCodeListing.pdf
/22/	„Technical rule for connecting wind farm to power system", GB/T 19963, issued 2012 by China Electric Power Research Institute (CEPRI), China
/23/	„Technical rule for photovoltaic power station connected to Power Grid", Q/GDW 617-2011, issued 2011-05-06 by State Grid Corporation of China (SGCC), China
/24/	„Test procedure of wind turbine low voltage ride through ability ", draft issued by National Energy Bureau (NEB), China
/25/	„Guideline for Modeling and Validation of Wind Turbine Low Voltage Ride Through Characteristics", draft issued by National Energy Bureau (NEB), China
/26/	„Electric Simulation Model and Validation Method of Wind Farm", draft issued by National Energy Bureau (NEB), China
/27/	"Type and Component Certification of Wind Turbines according to IEC 61400-22", Service Specification DNVGL-SE-0074, December 2014
/28/	Implementation Guideline for Network Code "Requirements for Grid Connection Applicable to all Generators", issued 2013-10-16 by ENTSO-E
/29/	Technical Note „Certification of grid code compliance", Revision 9, issued 2014-12-04 by Germanischer Lloyd Industrial Services GmbH, GL Renewables Certification, Germany
/30/	Gehlhaar, Gardner, "Modular Verification of grid code compliance", available at http://www.gl-group.com/pdf/6A_2_Paper_SIW14-1085_Gehlhaar_(2).pdf
/31/	Grid Code listing can be seen in /21/ or at www.dnvgl.com/GridCodeListing.pdf
/32/	Service Specification "Certification of grid code compliance", DNVGL-SE-0124, DNV GL Norway 2015
/33/	IEC 62443-1-1:2009, 3.2.6, definition according to IEC Glossary, available on internet under http://dom2.iec.ch/terms
/34/	IEC 62278, ed. 1.0 (2002-09), definition according to IEC Glossary, available on internet under http://dom2.iec.ch/terms
/35/	IEC 62270, ed. 2.0 (2013-09), definition according to IEC Glossary, available on internet under http://dom2.iec.ch/terms
/36/	IEC 60633, ed. 2.0 (1998-12), definition according to IEC Glossary, available on internet under http://dom2.iec.ch/terms
/37/	Entsoe internet site for "Network Code on Requirements for Grid Connection Applicable to all Generators (RfG): https://www.entsoe.eu/major-projects/network-code-development/requirements-for-generators/Pages/default.aspx this document is going to become a European Commission regulation. The version adopted by the Cross-Border Electricity Committee can be found within the comitology register of European Commission. Draft implementing at comitology Register: D042395/02 (Draft implementing measure/act) in dossier CMTD(2015)1399 at DG Energy having the title: COMMISSION REGULATION (EU) .../... of XXX establishing a network code on requirements for grid connection of generators Date: 25 Jun 2015 - 26 Jun 2015 at the date of finalization of this standard, the Network Code on Requirements for Generators was adopted by Member States in Comitology. RfG was by then going through scrutiny from the European Parliament and Council and was being in the process of translation into the 29 languages of EU. Translations are available at comitology register.
/38/	IEC 62103, ed. 1.0 (2003-07), Electronic equipment for use in power installations
/39/	IEC 60050-601, International Electrotechnical Vocabulary. Chapter 601: Generation, transmission and distribution of electricity – General
/40/	2.4 in IEC 62270, Communication networks and systems for power utility automation -- Part 7-410: Hydroelectric power plants - Communication for monitoring and control
/41/	3.1 in IEC 62053-24, ed. 1.0 (2014-06)
/42/	3.2.1 in IEC 61000-3-13, ed. 1.0 (2008-02)
/43/	3.1.5 in IEC 62749, ed. 1.0 (2015-04), see also IEC 60050-617:2009, 617-02-09
/44/	IEC 61400 Wind Turbines – part 27-1 Electrical simulation models, as well as future part 27-2

SECTION 2 ASSESSMENT

2.1 General

Assessment according to this section can be performed by DNV GL. Prior to the assessment the scope of assessment is to be specified by the customer according to DNVGL-SE-0124 /32/ if certification according to the Service Specification shall be performed. DNV GL will support upon request in defining the scope of assessment.

The principle of certification scope according to /32/ is to limit the scope of this standard by the scope of the grid codes applied, depending on the GCC class chosen. The applicable scope of assessment for each certification is defined within the definition phase according to DNVGL-SE-0124 /32/. The scope is part of the contract with the customer and should be provided to DNV GL in the form as given in [3.1.3] of DNVGL-SE-0124 /32/. This means, that not all the assessment given below is mandatory in each case, but it shall follow the outcome of the definition phase according to the DNVGL-SE-0124 /32/.

As mandatory parts within this standard are described with the word "shall" an additional reminder is giving advice that these requirements are not mandatory for certification in any case, but only if applicable for the Service as defined in the Service Specification. The advice is given repeatedly in the text, intended as a reminder. This is done in the form of a sentence in brackets: (as far as being within the scope according to definition phase of /32/).

2.1.1 Types – power generating units

Type tests like full scale voltage dips are usually performed only once per type in order to prove the general capability for all units of this type. So it can be possible to transfer these test results from one type to another variant of this type. However, it is depending on the scope of assessment which tests shall be performed, subject to the test plan according to the DNVGL-SE-0124 /32/. Units, components and other equipment can be assessed on a type level, meaning only once for the type of technology developed to form a type to be built, sold and installed on a serial-production basis.

2.1.2 Projects – power generating plants

Plants are usually built clustering many units and jointly connecting them to the grid. For these a project based assessment needs to be performed. This means using results from the type based assessment, but taking the site-specific parameters into account.

Possible scopes of assessment are given in the DNVGL-SE-0124 /32/. Besides the use of grid codes the customer can define a set of GCC-Features according to the Appendix of this standard (success criteria and assessment can show the maximum capability on plant level, considering the maximum (or minimum) capability of a single unit).

Part of the assessment for plants are simulations including the units as well as further power plant equipment (e.g. master controllers) and components (e.g. cables or transformers). For this purpose validated simulation models are necessary. The validation of simulation models is described in [2.7] and Sec.3. Furthermore the specific grid parameters for the PCC (grid impedance, short-circuit power, etc.) need to be provided by the grid operator.

2.2 Operational area assessment

The nominal operational area of the unit shall be assessed for correct design concerning grid code compliance (as far as being within the scope according to definition phase of /32/). This is in principal the assessment of the appropriate rating.

For each assessment corresponding documentation shall be provided. This is documentation about the GCC-features contained in group R according to the App.A of this standard

Group R (Rating issues) is related to the overall operational area the unit's rating is designed for.

An assessment overview for rating and operational area design is given below in Table 2-1.

Table 2-1 Operational area and rating assessment

Designation according to the appendix	Short description (Detail definition in the appendix specification definition)	Form of verification evidence	Section within this standard
R1	voltage, frequency and power rating depending on duration (steady state)	declarations*)	[2.2.1] [2.2.2] [2.3]
R2 A R2 B	frequency rating (steady state)	declarations*)	[2.2.1]
R3 B R3 C	voltage rating (steady state)	declarations*)	[2.2.2]
R5	reactive power rating (steady state)	measurement	[2.4.4]
R6	power quality (limited to IEC 61400-21)	measurement (limited to IEC 61400-21)	[2.3]
*) Developer declaration for plants (e.g. based on a Type Certificate), manufacturer declaration for units			

Rating assessment for plants shall be based on that for units plus the additional equipment installed in the plant. Load flow calculation can be a good way to show the evidence of power and voltage ratings.

2.2.1 Frequency withstand ability

As the system frequency is not constant, the units as well as the plants need to be capable of being operated continuously or for certain durations within a specified frequency range specified by the grid codes. As corresponding tests are often not feasible (except long-term measurements installed on-site) this assessment is usually based on manufacturer declarations proving the requested ability. In both cases the reference points are the terminals of each single unit. The intention of this assessment is to assure, that units and other equipment are designed appropriately to withstand the maximum expected frequency deviation.

Within the group R of GCC-features according to the App.A of this standard the success criteria (GCC-feature) R2 (frequency rating) shall be assessed (as far as being within the scope according to definition phase of /32/). The capability of the unit to operate within the specified frequency range shall be verified. Therefore, manufacturer documentation or test bench records shall be submitted for each component under assessment.

For the evaluation of the operability of the plant with decreased or increased grid frequency the protection settings at the PCC shall be assessed according to the requirements of the relevant grid code or the RNO (as far as being within the scope according to definition phase of /32/).

2.2.2 Operational area for voltage

Documentation shall be provided for DNV GL assessment proving that the unit as well as the plant is able to operate continuously at voltages within a specified voltage range. Short voltage overshoots should be handled as OVRT according to [2.5.2]. Different cases occur:

— in case of plants the voltage range is related to the PCC. For plants all terminals of the units and main equipment within the plant shall be assessed (e.g. transformers, as far as being within the scope according to definition phase of /32/). This can be achieved by load flow calculations as an example.

— in case of units it is important, whether a transformer T1 is part of the unit or not (see Figure 2-1).

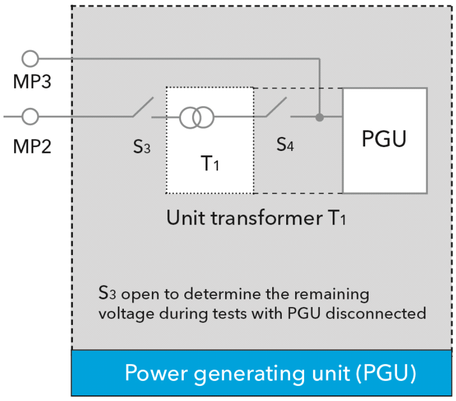


Figure 2-1 Typical unit

Corresponding assumptions shall be made for the worst cases at the terminals of the unit (assumptions, as PCC cannot be regarded as a given point for assessment of a unit only). For wind turbines the assessment shall at least take the following components into account:

- generator
- main frequency converter
- rotor blade pitch drive (including motor, converter and control if electrically powered, or hydraulic pump and valve control system if hydraulic powered)
- yaw drive.

For units other than wind turbines, documentation of above mentioned components shall be provided if applicable. Documents may include, but shall not be limited to rating plate data, environmental assumptions and corresponding calculations.

2.3 Grid code compliance features concerning power quality

Interaction with the power system and corresponding influence on power quality are to be assessed and evaluated according to IEC 61400-21 /5/, according to IEC 61400-12 /6/ or according to FGW TG3 /3/ for a unit (as far as being within the scope according to definition phase of /32/).

Some grid codes set specific limits for a number of power quality characteristics (i.e. flicker, harmonics etc.) at the PCC of a plant.

Usually corresponding measurements are done in line with the assessment of a single unit. In such case the power quality characteristics are listed but not evaluated due to their dependence on electrical network conditions at the specific test site.

For power plants it shall be assessed, if the requirements are fulfilled at the PCC, based on the measured values of the single units (as far as being within the scope according to definition phase of /32/). The specific grid properties at the PCC (based on the information of the local grid operator RNO) shall be taken into account.

2.4 Power assessment

This subsection deals with grid code requirements according to the App.A of this standard, success criteria group D of dynamic GCC-features.

Power Assessment means the assessment of active and reactive power in normal operation state. Nevertheless the dynamic behavior of control processes of different control functions is included as well.

An overview for assessment of power dynamics is given in below Table 2-2.

Table 2-2 Overview related to GCC-features relevant for power assessment, see App.A

Designation according to the App.A	Short description	Form of verification evidence	Section within this standard
D3 A...D3F	active power control	measurement	[2.4.1]
D5 A...D5K D6 A...D6K	frequency control	measurement	[2.4.2]
D8	reactive power control (general)	measurement depends on scope	[2.4.4] [2.4.5]
D9 D D9 M D9 N	reactive power control (power factor control: cos phi)	measurement, depends on scope	[2.4.5]
D10 D D10 M D10 N	reactive power control (Q)	measurement, depends on scope	[2.4.5]
D11 E D11 F D11 I D11 U	reactive power control (voltage control: Q(U))	measurement	[2.4.5]

2.4.1 Active power

This subsection deals with active power requirements according to the App.A of this standard. The minimum scope of assessment according to Table 2-2, first line are following features (D3-A-F):

— D3A Reference update rate,

— D3B maximum start-up ramp rate,

— D3C maximum shut down-ramp rate,

— D3D maximum normal ramp-down rate,

— D3E active power limitation control mode and

— D3F active power balance control mode

shall be assessed (as far as being within the scope according to definition phase of /32/). The definitions of these features are described in the App.A.

The features may be tested according to e.g. FGW TG3 /3/. If in the grid code no limits are mentioned, no definitions of e.g. the value of maximum gradient and no other GCC-features as needed for assessment, the corresponding information given in FGW TG8 /2/ shall be applied. However, values, thresholds and corresponding requirements shall be taken from the grid codes and definitions as agreed in definition phase according to /32/, not from /2/. Success criteria from /2/ shall be used analogously only, taking assessment scope into account.

2.4.2 Frequency control

Usually the system frequency is in the normal tolerance band in the range of mHz (depending on the system stiffness). However, due to electrical load changes in the system (consumers) and corresponding power balance (generators) as well as following to fault events the frequency is varying dynamically. The ability of a unit plant or module to actively influence the frequency by changing the active power during normal generating mode of the units shall be assessed (as far as being within the scope according to definition phase of /32/). The assessment shall be made on unit level. For assessment on plant level each unit and/ or the relevant plant control shall be assessed (as far as being within the scope according to definition phase of /32/).

Therefore, manufacturer documentation, testing with injected frequency signal (e.g. according to FGW TG 3, /3/) or test bench records shall be submitted for each component under assessment.

2.4.3 Artificial inertia response

This subsection is an optional part of assessment. The artificial inertia response is emulating behaviour similar to inherent inertia response known from synchronous, directly grid connected rotating electrical machines. Such artificial inertia response is also called synthetic inertia. The automatic active power response of a unit following a system frequency deviation as required in grid codes shall be assessed (increase or decrease of active power output) (as far as being within the scope according to definition phase of /32/). The inertia response and the frequency bound control of the output shall be evaluated by assessing the control signals only (see App.A of this standard (GCC-feature D5 and optionally D7). The control function shall be triggered by a grid simulator. For active power response during under- or over-frequencies the method proposed in FGW TG3 /3/ may be adapted for units.

Depending on the assessed grid codes, differing set points for frequency and active power compared to those described in FGW TG3 /3/ may be required. If no requirements on the accuracy of the target value of the active power are formulated in the grid code, the tolerances given in FGW TG8 /2/ shall be applied analogously.

The minimum scope of assessment is given in App.A D7 below.

2.4.4 Reactive power capability

For units the reactive power capability shall be measured under rated voltage conditions as described in FGW TG3 /3/. For the remaining voltage range according [2.2.2] the assessment is based on manufacturer declarations. The assessment shall cover the complete operational area [2.2] of voltage and active power.

For plants the capability of the complete power plant shall be determined with complex load flow calculations based on the capability of the single units and all relevant components like cables, transformers and compensation equipment.

The minimum scope of assessment is given in Table 2-2 above (as far as being within the scope according to definition phase of /32/). Tests to be performed at the unit or plant should be taken from [3.4.1].

2.4.5 Reactive power control

The different control modes for the reactive power exchange of the unit shall be assessed in consideration of the App.A of this standard (GCC-feature D8). Requirements of the control modes as listed in Table 2-2 above shall be assessed (as far as being within the scope according to definition phase of /32/).

Optionally, also other control modes according to the App.A of this standard can be assessed, e.g. others from D9 and D11.

Some grid codes or local grid operators (RNO) require certain power control ranges or control modes (e.g. cos φ, Q(U) etc.) at the PCC. Based on the active and reactive power capabilities of the single units it shall be assessed, whether the required control mode is implemented at the PCC, too (as far as being within the scope according to definition phase of /32/). Therefore, the communication and control interface [2.8] of the plant shall be taken into account.

If no requirements for the accuracy of the set point control are defined in the grid code the tolerances given in FGW TG8 /2/ shall be applied.

2.5 Behavior during faults (grid support)

This section deals with the behavior of units and plants during fault conditions. Usually in case the voltage leaves the continuous operational area due to grid faults, this is called an under voltage ride through (UVRT) or an over voltage ride through (OVRT) event. Nevertheless the corresponding limit could be specified even within the continuous voltage range by the underlying Grid Code. UVRT and OVRT shall be assessed for single units as described in this section, based on corresponding measurements (see Sec.3) (as far as being within the scope according to definition phase of /32/ [1.5]).

The behavior of the plant during faults at the PCC (or further away in the grid) shall be assessed (as far as being within the scope according to definition phase of /32/) based on simulations using the validated simulation model. The validation of the simulation model is based on the measured and assessed behavior during faults at single units. For this, the requirements of the grid code or the local grid operator shall be taken into account (e.g. reactive current injection during voltage dips and related requirements during faults. Depending on the grid code or GCC features also reactive power or reactive energy might be relevant for assessment.

If a validated simulation model is available, it shall be used for the assessment of the plant. It shall be assessed, if the requirements are fulfilled at the PCC concerning the criteria of the defined grid code requirements or GCC-features (as far as being within the scope according to definition phase of /32/).

Simulations of phase-to-earth-faults according to [3.3.4.6] shall be conducted on plant level. For this, corresponding impedances shall be provided by the responsible local system operator. In case a grid code does not require phase-to-earth fault verification such simulations are not mandatory. An overview on the assessment for fault behavior is given in Table 2-3 below.

Furthermore system and relay protection is a part of the assessment.

Table 2-3 Overview of assessments, related to GCC, features

Designation according to the App.A	Short description	Form of verification evidence	Section within this standard
D12 A, C, G-I	under-voltage ride-through (UVRT)	measurement	[2.5.1]
D13	consumption during UVRT	measurement	[2.5.1]
D14	injection during UVRT	measurement	[2.5.1]
D16 A-E	protection relays	measurement	[2.6]
M	model validation	measurement, simulation, manufacturer declaration	[2.7]

2.5.1 Under voltage ride through

Besides the pure capability of riding through under voltage events, under voltage ride through (UVRT) also includes additional requirements like reactive or active current injection during faults for the purpose of supporting the electrical system (grid support). Minimum requirement for units is the assessment of the GCC-features according to Table 2-3 based on tests made according to FGW TG3 /3/ or Table 3-1 (as far as being within the scope according to definition phase of /32/). The tests, which have to be performed, are to be defined in agreement with DNV GL in individual cases for units (test plan). Corresponding grid code requirement definitions can be found in the App.A of this standard: GCC-feature D12. The selected tests in accordance with Sec.3, shall fulfill the requirements of the applied grid code and assessment scope.

The assessment may be based either on full-scale onsite tests (units) or on simulations (plants) performed by means of a validated simulation model (i.e. validated against tests according to [2.7]). The selected method will be stated on the certificate. If grid code requirements defined according to the App.A of this standard, GCC-feature D13, are to be assessed, corresponding test result data has to be post-processed and provided to DNV GL for evaluation. The same is valid for injection GCC-features according to the App.A of this standard: GCC-feature D14.

If dynamic simulations for plants are required, they shall be performed using software simulation models validated against test results of the unit. The simulation results shall be assessed for compliance (as far as being within the scope according to definition phase of /32/).

In line with the UVRT and OVRT assessment, the protection systems shall be taken into account as well (see [2.6]). For units the protection at the unit is relevant and for plants both, the protection at the unit as well as at the PCC is relevant.

2.5.2 Over voltage ride through

Assessment for over voltages may be performed analogously to those for UVRT, if required. As long as the grid codes do not explicitly ask for corresponding verifications, the assessment of over voltage ride through (OVRT) is optional.

2.5.3 Short circuit current contribution

The short circuit current is determined during under-voltage ride-through testing. The procedure according to FGW TG3 /3/ may be used. For units the result shall be stated in the certificate, for plants the results of corresponding power plant simulations or calculations shall be stated in the project certificate.

For plants the short circuit current contribution shall be assessed (as far as being within the scope according to definition phase of /32/). Both parts of short circuit current have to be taken into account, those coming from the grid and those coming from the units. The latter shall be based on the measured short circuit current during the UVRT tests of the single units. The short circuit current ratings of electrical components between each unit and the PCC or POC have to be assessed (e.g. circuit breaker, cable etc.).

2.6 System and relay protection

Apart from design related disconnections there are often requirements of blocking connection, disconnection or reconnection. This subsection deals with the conditions under which a unit may or shall disconnect or shall stay connected to the grid during grid faults (i.e. deviations in voltage or frequency over a certain period) but also start-stop and islanding according to the App.A of this standard (GCC-feature D2).

Independent of the concept for grid disconnection (e.g. separate protection equipment or included to the control) the protection function shall be assessed (as far as being within the scope according to definition phase of /32/). In case it is implemented in the control of the unit it must be ensured that the protection works independently and has a higher priority than other control functions of the unit.

The functionality of the grid protection shall be assessed and evaluated according to FGW TG3 /3/ (as far as being within the scope according to definition phase of /32/). Depending on requirements of the relevant grid code or the local grid operator other protection values than those described in FGW TG3 /3/ may have to be applied. If no requirements on the accuracy of the grid protection system are defined in the relevant grid code, the tolerances in FGW TG8 /2/ shall be applied analogously. Other tests may be necessary dependent on the protection concept in agreement with the RNO (as far as being within the scope according to definition phase of /32/).

Guidance note:
"Grid protection" within this section is to be understood as such, what the system operators need to have independently verified. This seems to be depending on the system operator, hence GCC-class I should be ordered. In case of GCC-class II assessment is ordered the grid code will be checked based on the scope of this DNV GL standard and DNV GL service specification DNVGL-SE-0124. In a third case the definition would be made by the applicant if assessment without GCC-class has been ordered. See DNVGL-SE-0124 /32/ for details (Definition Phase).

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

2.7 Simulation model validation against tests

An open simulation model of the unit shall be provided for independent assessment and validation. This can be generic (e.g. according WECC or IEC 61400-27 /44/) or manufacturer-specific and non-generic. Black box models can be accepted only in case the content and structure is opened and explained towards the certification body during the assessment. If generic models are used as a basis, important parameter settings and adjustment procedures shall be verified by the certification body during assessment.

This simulation model shall be capable of representing the electrical behavior of the unit to be assessed. Details and validation procedures according to FGW TG4 /9/, PVVC /13/ or any other acceptable validation procedure shall be applied. The simulation model shall be described according to the App.A of this standard (GCC-features M1 to M4) including model documentation according to GCC-feature M3. In case of black-box models a description on the internal dynamics is necessary additionally.

The following requirements shall be checked during simulation model assessment (as far as being within the scope according to definition phase of /32/):

— in general the behavior during UVRT see App.A of this standard: D12
— consumption GCC-features, see App.A of this standard: D13
— injection GCC-features, see App.A of this standard: D14
— system and relay protection, see App.A of this standard: D16
— and optionally temporary over voltages OVRT, see App.A of this standard: D15.

After successful validation and plausibility testing by DNV GL, the simulation model is called validated simulation model.

The validated software model shall be used for simulations on plant level (as far as being within the scope according to definition phase of /32/).

In case a validated simulation model is not required by the grid code, it is not mandatory on unit level. But in case the UVRT-assessment shall be performed on plant level, a validated simulation model would be needed.

Optional the validation could be extended to other static and dynamic events (e.g. active and reactive power control functions) in case corresponding measurement results are available and the simulation model represents these functions.

Guidance note:
It is recommended to validate a model of the unit against tests. Such validated software model can be used for further grid code compliance certification, because simulation results can be used quite easily instead of testing. Furthermore simulation is less expensive than testing.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

2.8 Communication and plant control interface

A communication and control interface should be available at the point of common coupling (PCC) for monitoring of the point of operating (see also [A.4]) and to implement the control functions of the plant related to the PCC, e.g. in a plant control.

The following measured values shall be assessed (as far as being within the scope according to definition phase of /32/):

- reactive power Q or power factor cos φ
- voltage U
- active power P
- currently available maximum active power (active power control capability).

The following set point values shall be assessed (as far as being within the scope according to definition phase of /32/):

- required reactive power control functions, e.g.
  - reactive power set point
  - power factor cos φ
  - cos φ (P)
  - Q(U)
- requirements for active power control (active power reduction by set point control).

The communication interface e.g. the implementation of set point control shall be explained clearly by the plant operator. For the assessment [2.4.3] [2.4] shall be considered as well (as far as being within the scope according to definition phase of /32/).

2.9 Assessment for 50 Hz / 60 Hz units

If tests for units were performed with connection to a 50 Hz grid, the validated software model can be used for simulations in a 60 Hz environment for both, units and plants in case an EMT model is available. A corresponding small scale low voltage dip test of the auxiliary supply system for units according to [3.3.6] can be performed optionally in a 60 Hz grid. The same shall apply vice versa, if full scale measurements, tests and validation were performed in a 60 Hz grid (as far as being within the scope according to definition phase of /32/).

SECTION 3 TESTS

3.1 General

For verification this standard refers to international test and evaluation methods given in the standards and guidelines mentioned in [1.5]. Measurement reports by accredited testing laboratories for the tests given in Sec.3 and maybe other tests, which are to be agreed upon, are part of the assessment documentation. These have to be provided to DNV GL for assessment. Test plan preparation is described in [3.2.1] of DNVGL-SE-0124 /32/ and should be carried out prior to testing at the beginning of the verification phase. The test plan should be aligned with the scope of assessment agreed for the certification according to [3.1.2] in DNVGL-SE-0124 /32/.

3.2 National testing procedures

3.2.1 General

Some test procedures are demanded nationally; most of them have UVRT-tests included. Alternatively the procedure according to [3.3] may be used to cover several national fault test procedures with one test (multi-national approach). In any case we strongly recommend taking the latest versions of the guidelines for reference.

3.2.2 China

Test procedure for wind turbines to be installed in China can be found in the guideline "Test procedure of wind turbine low voltage ride through ability" /24/. For PV solar installations the following test procedure can be used: "Technical rule for photovoltaic power station connected to Power Grid", /23/.

3.2.3 Germany

The test procedures and requirements as explained in FGW TG8 /2/ shall be followed for GCC certification in Germany according to /10/ or /11/.

3.2.4 Spain

The test procedure as well as the project certification procedure in Spain is given in /13/ (PVVC). As type certificate is not defined in Spain this can be issued according to DNVGL-SE-0124 /32/ if requirements according to the Spanish PVVC /13/ are used.

3.2.5 Great Britain

For United Kingdom without Northern Ireland the "Guidance Note for Power Park Modules" shall be used /7/ in connection with the corresponding grid code which is listed at www.dnvgl.com/GridCodeListing.pdf.

3.3 Fault testing

3.3.1 General

Different faults can occur in the electrical power system. Fault testing is important to proof fault resistance of units. Most common faults can be tested according to this section, namely UVRT [3.3.4] and OVRT [3.3.5].

Units to be operated in the following areas shall be tested according to the procedure defined here: countries, regions, balancing areas or other geographical areas under responsibility of the RNO in charge and which do not explicitly require using their national procedure, or if they do not have their own test procedure defined.

This procedure can be used for all countries worldwide. The scope of testing can be reduced in some cases, depending on the GCC-class and the grid codes or other requirements applied according to the individual contract or test plan. But the scope shall follow the descriptions given in DNVGL-SE-0124 /32/.

3.3.2 Fault test equipment and measurement requirements

For testing faults the following set-up shall be applied (Figure 3-1).

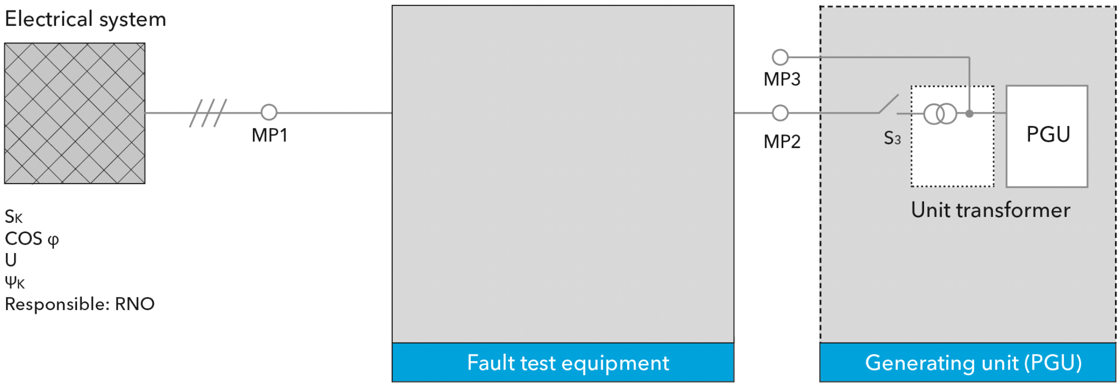


Figure 3-1 Fault-test set up and measurement points MP

The most common test equipment to generate voltage drops (at least for wind turbines) is the voltage divider based solution shown in Figure 3-3, in general consisting of two switches (circuit breakers) and two impedances Z_1 (serial impedance) and Z_2 (short-circuit impedance). This is why the following descriptions are often related to this case. In case a different test setup is used (e.g. a grid simulator or in case of OVRT-testing) it needs to be agreed how to adapt the requirements and the testing procedure.

By choosing the test arrangements effort shall be made to prevent unacceptable disturbances during the tests in the grid (acceptable level to be agreed with the RNO of the test site). This can be implemented for instance by interposing serial impedance Z_1 into the test circuit (see Figure 3-3) in the case of UVRT testing. This impedance limits the impact on the grid and shall be attuned depending on the short circuit impedance of the grid and the level of acceptance concerning disturbances during the tests. The voltage at the unit should not leave the normal operating range caused by the serial impedance prior to the voltage drop when the unit runs at rated power. The impedances shall have a ratio of $X/R > 3$ (i.e. for Z_1 as well as for Z_2 this requirement shall be valid, see Figure 3-3 as example).

The voltage drop can be achieved by using an impedance (Z_2) as voltage devider duing short-circuiting two and three phases at the unit side of the impedance Z_2. The voltage drop shall be accomplished as fast as possible (within the typical dynamics of a mechanical circuit breaker). To determine the starting point for the voltage drop the current through the impedance Z_2 shall be taken into account. In case a different test setup is used, the starting point shall be determined based on the instantaneous voltage values at the terminals of the unit. The Figure 3-2 is showing the positive sequence representation of the voltage and the corresponding tolerances.

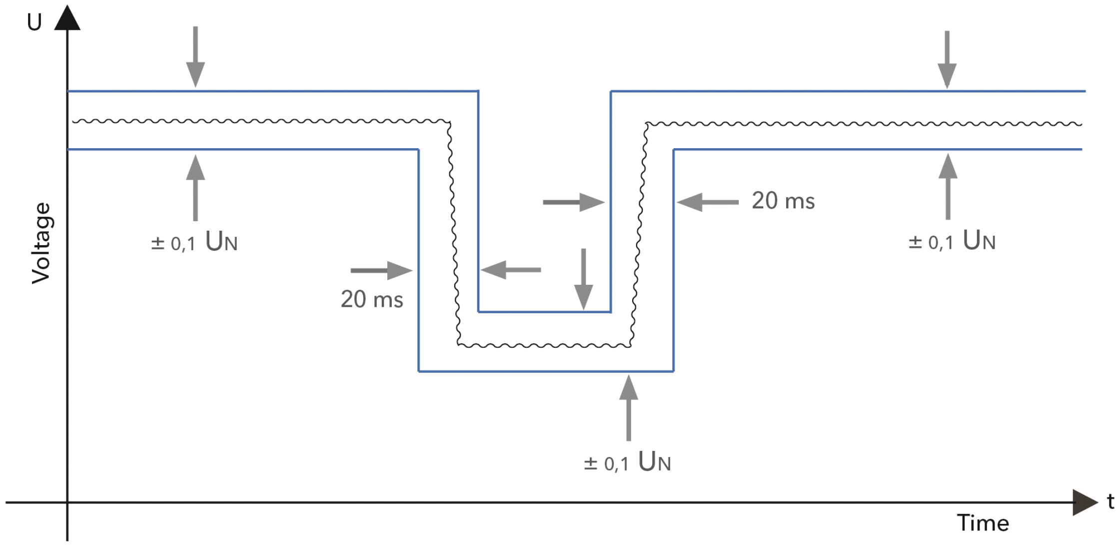


Figure 3-2 Tolerances on voltage dip testing

Phase-to-earth testing may be performed with similar devices if safety for the testing staff is granted and if the earth fault protection system tolerates such (this has to be agreed with the RNO of the test site).

The voltage drop shall be initiated at the measuring point MP2. For units other than wind turbines it also can be initiated at MP3 (see Figure 3-1). Power factor changes shall be monitored during testing according to [3.3.3].

The circuit breakers which are used for the test (especially S_2 in Figure 3-3) shall be designed for the expected short circuit currents.

Guidance note:
Typically functional tests are performed firstly with disonnected unit performed with disconnected unit (S_4 open). These tests show the safe-functionality of the test equipment and serve as safety measure in order to determine U_{res}. For safety and security reasons, tests with lower risk should be done first. See also /1/ or /15/.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

3.3.3 Measurements during all fault tests

All measurements shall be performed by an institute, accredited according to DIN EN ISO / IEC 17025 for measurements of electrical characteristics (power quality) on units.

The power factor shall be determined and documented for each test. The power factor at the grid side of the test equipment shall not change significantly during each test recording. At least the whole time range from five seconds before connecting the impedance Z_1 before the start of the voltage drop until the effect of the voltage drop has abated shall be recorded (see Figure 3-3).

Guidance note:
It is recommended to record 15 seconds before and 15 seconds after the onset of the emulated fault (before and after switching S_2).

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

During each of the tests the following instantaneous values shall be recorded at least at MP2, better they should be recorded at all measuring points MP1, MP2 and MP3 according to Figure 3-1 with a sampling rate of at least 5 kHz of all three phases:

— currents
— voltages.

During the tests the following instantaneous values may be measured and recorded additionally (sampling rate must be at least 10 Hz) in case an assessment with regards to the structural integrity according to the second Guidance Note in [1.3] should be performed:

— rotational speed: in case of wind turbines generator speed or low -shaft speed values, corresponding values for other units such as wave or ocean current plants
— pitch angle of one rotor blade in the case of wind turbines, corresponding value for other units
— measurement of the mechanical torque in the rotor shaft as specified in IEC TS 61400-13 /8/ for wind turbines, corresponding value for other units

Guidance note:
The recording of these additional values are intended to enable a comparison between the actual unit behaviour and the assumed unit behaviour during the load simulations related to structural integrity see Guidance note 2 at page 6, within section 1.3 of this standard.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

Furthermore signals representing the available (primary) power shall be measured, especially in case of testing in the field (e.g. wind speed or solar radiation). In case of test bench testing the voltage of the corresponding source shall be recorded (e.g. in case a PV-simulator is used in case of PV-inverter testing).

In case of synchronous generator directly coupled to the grid additional measured values (load angle) shall be agreed with DNV GL.

3.3.4 Voltage dip testing

For proving the capability of UVRT the unit shall be tested by using test equipment according to Figure 3-1. Additionally the details as described in [3.3.2] apply. Very often the test setup shown in Figure 3-3 is used.

The principal switching sequence for the voltage divider based setup is the following:

Before starting the voltage dip, S_1 is opened (so the serial impedance limits the impact on the grid). Afterwards S_2 is closed starting the dip and after the specified duration S_2 is opened again ending the dip. Finally the serial impedance is bypassed again by closing S_1.

Prior to performing the dip testing according to the test plan, determination of remaining voltage levels U_{rem} at the testing site shall be performed by “no load tests”. This shall be done by performing a first set of tests with disconnected unit (S_4 open) in order to verify the locally adjusted settings of the voltage divider. After all relevant remaining voltage levels U_{rem} fulfil the specification of the test plan the real voltage dip testing can start with the connected unit being in operation.

The setting of Z_2 shall be adjusted properly in order to reach U_{rem} as specified in the test plan and as determined in the determination test with S_4 being open as described above.

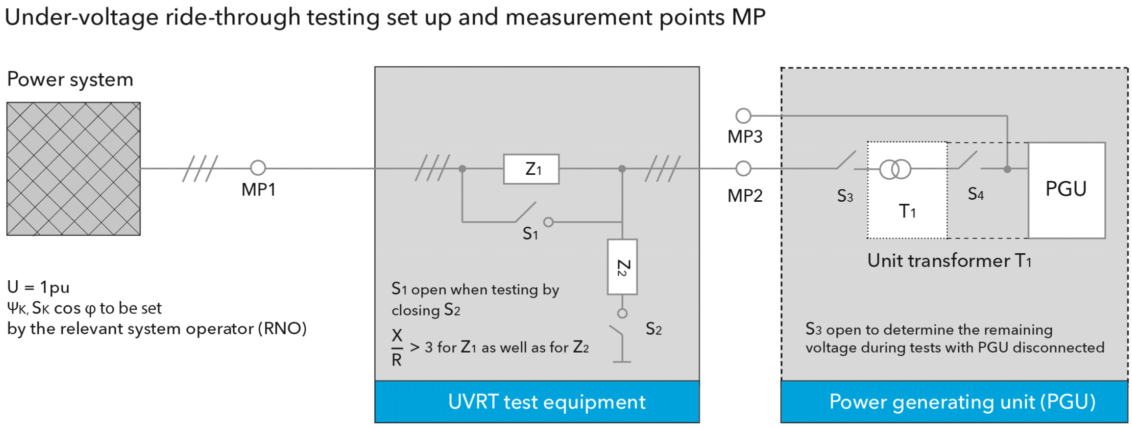


Figure 3-3 Under voltage ride through testing set up and measurement points MP

The tests shall be done for 3 voltage levels (α, β and γ) and for 2 durations (t1 and t2) with two loading levels (low power and high power) as 3-phase voltage drop (3p) and as 2-phase voltage drop (2p).

The duration is set by using the switching commands of switch S_2 in Figure 3-3.

For an overview, the Table 3-1 can be used and details are explained in the following Sections.

Table 3-1 Voltage-dip test overview (and categories for [3.3.4.8])

Category	Loading	Dip type	Voltage for test voltage levels	Test durations
1	low power	3p	U_α, U_β, U_γ, optional 0% *)	$t_{1\alpha}$, $t_{1\beta}$, $t_{1\gamma}$, $t_{2\alpha}$, $t_{2\beta}$, $t_{2\gamma}$
2	high power	3p	U_α, U_β, U_γ, optional 0% *)	$t_{1\alpha}$, $t_{1\beta}$, $t_{1\gamma}$, $t_{2\alpha}$, $t_{2\beta}$, $t_{2\gamma}$
3	low power	2p not involving earth	U_α, U_β, U_γ, optional 0% *)	$t_{1\alpha}$, $t_{1\beta}$, $t_{1\gamma}$, $t_{2\alpha}$, $t_{2\beta}$, $t_{2\gamma}$
4	high power	2p not involving earth	U_α, U_β, U_γ, optional 0% *)	$t_{1\alpha}$, $t_{1\beta}$, $t_{1\gamma}$, $t_{2\alpha}$, $t_{2\beta}$, $t_{2\gamma}$
5	both	1p to earth	U_β, U_γ	$t_{1\beta}$, $t_{1\gamma}$, $t_{2\beta}$, $t_{2\gamma}$
*) applicable only in case U_γ is not equal to 0%.The column category is important related to success criteria for assessment. For details upon the use of category see [3.3.4.8].				

Optionally a test with duration t_1 can be exchanged by a second test with the duration t_2.

Guidance note:
See [3.3.1] (and definition phase according to DNVGL-SE-0124 /32/ for possibilities to reduce the scope of testing in co-operation with DNV GL using GCC classes.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---

3.3.4.1 Test voltage levels

During the test the voltage shall drop down to U_α, U_β, U_γ (tolerance range ± 0.10 x U_n). These defined test voltage levels shall be compared to the remaining voltage U_{rem} during the corresponding no-load tests in order to check the tolerance range.

A no-load test is the first test of each test voltage level with the test equipment connected to the grid but with no unit connected. For each configuration of the test equipment for a test voltage level a no-load test shall be performed.

The values for the test voltage levels are calculated by the following equations (3.1), (3.2) and (3.3), see also Figure 3-4.

Small voltage dip (α dip) down to the test voltage level $U\alpha$ as defined in equation (3.1)

$$U_\alpha = 0.7 * (U_N - U_\gamma) + U_\gamma \qquad (3.1)$$

Half voltage dip (β dip) down to the test voltage level U_β as defined in equation (3.2):

$$U_\beta = 0.5 * (U_N - U_\gamma) + U_\gamma \qquad (3.2)$$

Minimum test requires a voltage dip (γ dip) down to the test voltage level $U\gamma$ as defined in (3.3):

$$U_\gamma = \text{ Minimum voltage according to grid code requirement} \qquad (3.3)$$

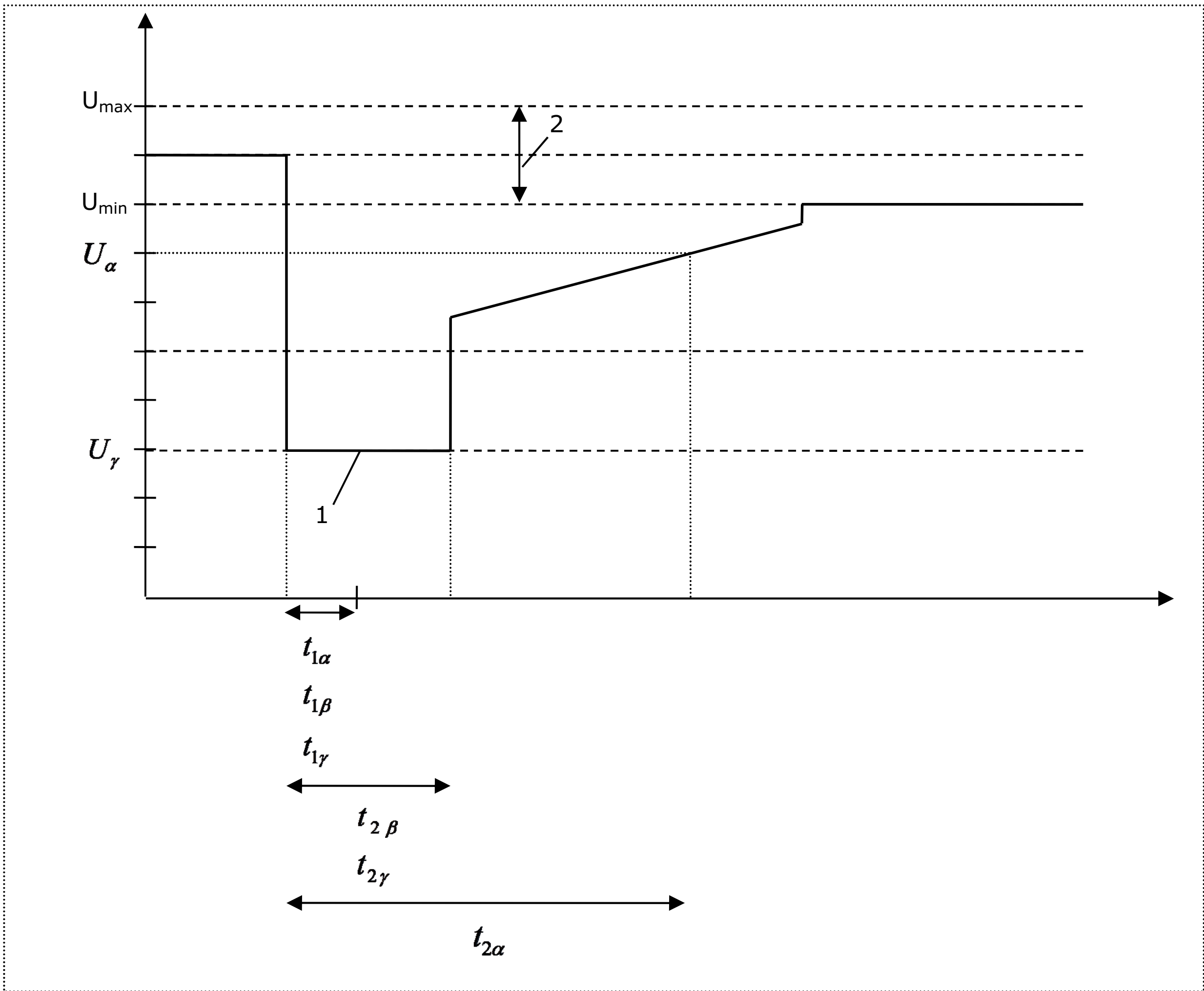


Figure 3-4 Voltage dip definitions see also next Section

1	Example of a limiting curve for UVRT according to grid codes
2	Example tolerance band for voltage at PCC as required by grid codes (U_{min}...U_{max})
U_n	Nominal grid voltage
U_α	Test voltage level during α dips
U_β	Test voltage level during β dips
U_γ	Test voltage level during γ dips, lowest voltage of the limiting curve (UVRT)
U_{LL}	Voltage value at PCC
t_1	Shortest test times, $t_{1\alpha}$ for α dip, $t_{1\beta}$ for β dip and $t_{1\gamma}$ for γ dip
t_2	Longest test times, $t_{2\alpha}$ for α dip, $t_{2\beta}$ for β dip and $t_{2\gamma}$ for γ dip

The test voltage levels shall be generated with heavy test equipment according to [3.3.2]. For each certification the values of all test voltage levels shall be determined and documented, e. g. in a test plan.

3.3.4.2 Fault Test durations

Two durations t of each voltage drop shall be tested in each test voltage level (Uα, Uβ and Uγ), see Table 3-2. The short time t_1 is optional, if the long time t_2 is tested twice instead.

Table 3-2 Voltage dip durations

	shortest test time (optional) $t_{1\alpha} = t_{1\beta} = t_{1\gamma}$		longest test time $t_{2\alpha} > t_{2\beta} \geq t_{2\gamma}$	
Voltage dip duration t [s]	in shortest possible time *) t_1 see Figure 3-4		t at the voltage level line of U_α, U_β, U_γ, t_2 see Figure 3-4	
*) shortest possible time of the test switch gear, this test duration can be omitted if t_2 is used two times instead				

The longest test time $t_{2\alpha}$ depends on the respective grid code and will be defined for each certification process as part of the definition phase in /32/.

During the no-load test a voltage dip is starting with the voltage drop down to the remaining voltage level U_{rem} which shall be sufficiently close to the test voltage level as defined in [3.3.4.1] based on the definition phase according to DNVGL-SE-0124 /32/. After the voltage dip duration is over, the voltage reaches normal values again. This is regarded as voltage recovery.

For each test the voltage dip duration shall be determined by using the time representations of the currents going through Z_2 (recommended) according to Figure 3-3 or by using the time representations of the voltage at MP_2. If both methods are used and these two values are determined at different points in time, the last point shall be regarded as voltage recovery.

3.3.4.3 Loading level (low power, high power)

Different problems may occur at different operating points of the unit during a voltage drop. Thus the tests shall be repeated at different operating points. For the tests the operating point of the unit is defined by the electrical active output power according to the Table 3-3 given below. The test shall be performed at two different power levels (i.e. loading levels) for each test, at minimum. For units with combustion engines the low power load level has to be agreed with DNV GL.

Table 3-3 Loading level for voltage dip tests

	low power	high power
P=	0.1...0.3 P_r *)	$P > 0.9\ P_r$
*)generator speed below synchronous speed in the case of a doubly fed induction generator for wind turbines		

3.3.4.4 Auto-reclosure cycle tests (if required by the grid code)

If the grid code requires auto-reclosing-cycles at least two of the above listed tests with remaining voltages U_{rem} in the range of U_β or U_γ shall be carried out in a way to simulate automatic re-closure cycles. Should there be no detailed requirements given in the grid code, two double dips shall be performed with a pause of 300 ms between voltage recovery at the end of the first dip and the beginning of voltage drop of the second dip in both cases, at minimum (see Figure 3-5). One of these both tests shall be done with high power and one with low power according to Table 3-3. At the beginning of the third voltage drop the unit is allowed to disconnect and shall show the ability to shut down properly after that.

If no contradictory requirements are set by the grid code, a maximum of 2 voltage dips within 10 minutes shall be assumed. In other words: it can be assumed, that after the second dip of an auto-reclosing cycle the unit is not required to ride through under voltage events for the remaining time of 10 minutes after the first fault has occurred.

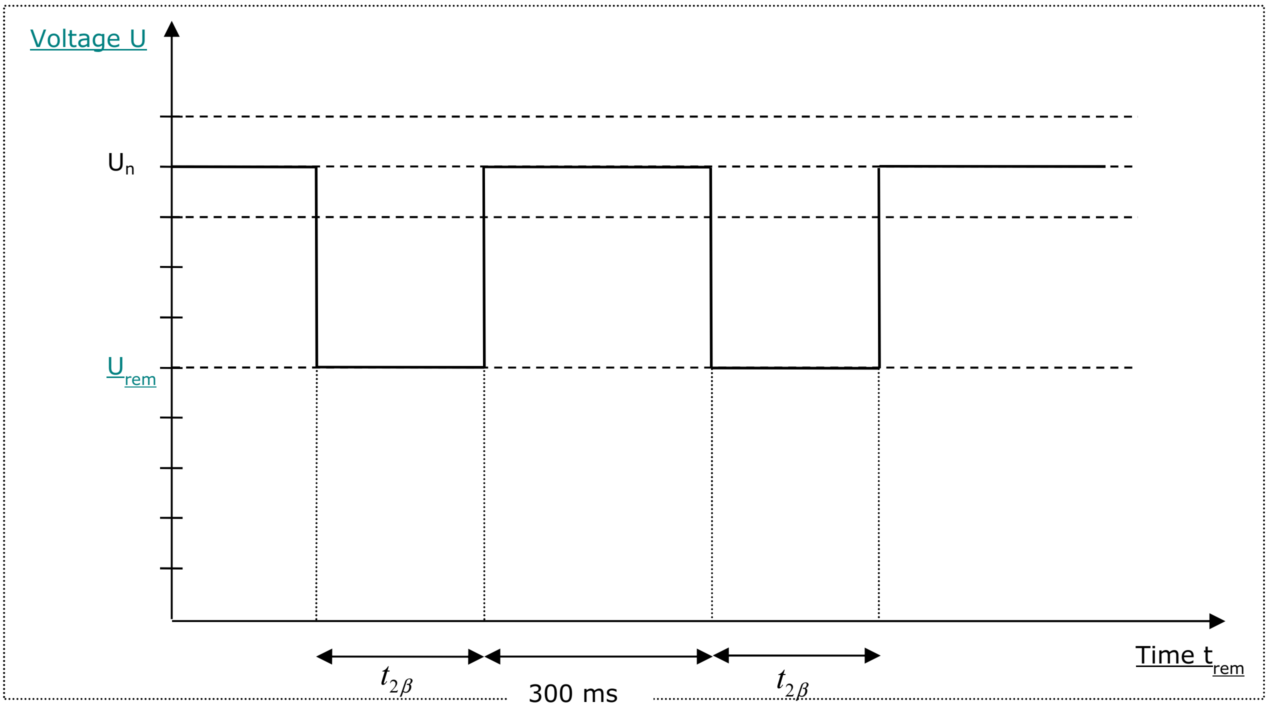


Figure 3-5 Example for one auto-reclosing-cycle test

3.3.4.5 0% Test

The 0% test is an optional test in those cases, where the corresponding grid code requires U_γ > 0%. The 0%-test shall be performed using the following GCC-features:

- test durations shall be the short test time (100ms) and the longest reasonable test time. Two single voltage drops shall be passed successfully
- test voltage level shall be below U_{rem} = 5% U_n with low power only [3.3.4.3].

3.3.4.6 Phase-to-earth fault verification

Phase-to-earth fault verification:
It is recommended to test phase-to-earth faults. If the system operator does not insist on verification, the test and the simulation are optional. If the system operator insists on phase-to-earth fault verification the following phase-to-earth fault tests shall be conducted or simulated as a minimum.

The tests shall be carried out with U_β according to [3.3.4] [3.3.4.1], using the following GCC-features only:

- test duration shall be the short test time (e.g. 100 ms) and the long test time (1 s) or extra-long (>1 s) if necessary for trip test (if no black-out-detection is implemented in the fault-control of the unit) [3.3.4.7]
- two consecutive dip tests shall be passed successfully
- test voltage level shall be U_β with low primary energy potential only, 1p.

3.3.4.7 Trip test

The trip-test is explained in the following. After successfully riding through the first part of a voltage dip (voltage dropped to a defined test voltage level) a unit could get in trouble in the case that the voltage does not recover and the turbine shall switch off during or after the fault (within the fault mode of the unit's control). In such cases it is important, that the unit is tested for a case with a voltage dip of such duration (i.e. simulating a black-out) and that the unit's control is cutting off during the fault-mode to shut down the unit for protection reasons. In this test (trip test) the unit shall show the ability to shut down during fault mode. This can be achieved in two ways:

- shut down due to the fact, that the voltage dip duration is longer than required by the grid code (extra-long, t>1 s)

- shut down, due to the fact, that the control detected the voltage to be outside the UVRT definition curve of the grid code.

In the second case, it is possible to reduce the test time for the until-cut-off test (trip-test) compared to the longest UVRT test, provided corresponding explanations and documentation is provided for DNV GL assessment and the result is plausible.

The specification of until-cut-off test (trip-test) may be combined with the phase-to-earth test with the following GCC-features:

- maximum duration or less, depending on the fault-mode concept
- test voltage level U_β with low power, 1~
- test voltage level U_γ with high power, 2~.

3.3.4.8 Criteria for successful testing

For each certification process the different test values and success criteria shall be defined depending on the respective grid codes before the tests are performed. This is usually done when drafting the test plan. The assessment is based on symmetrical component values of voltage and current. Furthermore the measurement results are to be divided in transient and stationary areas. The time of transient processes shall be determined.

After the performance of the tests the testing laboratory shall determine and document, if the test results have fulfilled the following two criteria. This is a prerequisite to be accepted for assessment within certification:

- If the unit is regularly online 10 seconds after the test is over (standard production mode). This shall be stated as one criterion whether the test is passed or not.
- If the unit did not disconnect during 2 consecutive tests (2 durations (t1 and t2) or (t_2 and t_2)) within one category (see Table 3-1). If disconnection took place the tests of this category are only regarded as passed, if the subsequent 4 tests of the same category did not lead to disconnection of the unit from the grid. If disconnection takes place again within these following 4 tests, the tests of this category are regarded as invalid. In case of a failed test and unexpected behavior of the unit, the test shall be aborted and the reason of the failure shall be corrected for prevention of danger before new testing can take place.

3.3.4.9 Measurement report and measurement data

The electronic version of the measurement data shall be provided if requested by DNV GL (usually for the purpose of simulation model validation).

A testing overview shall be given in the measurement report with the following details. The data sets shall be numbered and the reference to the corresponding test specification shall be given for each test (as defined e. g. in the test plan). Each test set shall have a date and time stamp. Times between consecutive tests are to be explained in the report, if they seem to be not plausible.

The following values shall be given in the measurement report:

- voltage
- current
- active and reactive power
- reactive current at medium voltage side of the unit transformer (winding connected to the distribution system), close to the transformer or to the medium voltage switchgear (MP 2 in Figure 3-1)
- reactive current at the low voltage side connected to the generator (MP3 in Figure 3-1)
- switching commands of switch S_2 according to Figure 3-3 if possible.

The values shall be given as symmetrical component values (depending on the fault type) according to IEC 61400-21 /5/.

Additionally phase values of voltage and current measured at all sides of the machine transformer (medium and low voltage) shall be given in the measurement report. These phase values shall be given as RMS (root-mean-square), calculated according to Eq. C.7 of IEC 61400-21:2008-08 /5/ and averaged with a continuous averaging window of one full period.

Main components rating plate data and other details shall be documented according to the list provided in FGW TG3 /3/ Annex A. The testing laboratory shall verify that the data given in the manufacturer's certificate on specific data are correct for the unit under test. Especially the validity of the software version for main components such as converter, control system, grid protection etc. shall be checked by the testing laboratory. A corresponding condition or remark shall be given in the measurement report. Rating plate details of all components according to the scope of certification according to DNV GL DNVGL-SE-0124 shall be documented in the report.

Definitions according to [1.4] shall be used additionally, definitions according to the App.A of this standard are recommended.

The test equipment shall be described in the report and shall comply with [3.3.2], power factor values shall be given in the report for each test.

Requirements of Sec.3 shall be applied.

Results according to [3.3.4.2] shall be given in the report (e.g. voltage dip duration).

The testing laboratory performing the tests and the measurements has the obligation to check all details as required within this standard concerning test and measurement when issuing a measurement report according to this standard.

3.3.4.10 Validity of fault measurements for different units

The measurements of one unit could be used for the certification of further units of the same series. Therefore, the additional unit to be certified shall be technically equivalent to the measured unit (e.g. same topology, same control software etc.). Only differences which do not have a negative influence on the measured and assessed electrical behavior are allowed. An appropriate argumentation about the technical equivalence of the units to be certified shall be provided for assessment to DNV GL. Especially in case UVRT-tests shall be transferred, further proofs of evidence might be necessary (e.g. simulations regarding different rotor blade diameters). The scope of measurements for more than one unit should be specified in advance.

3.3.5 Over voltage ride through

In some grid codes it is required that units shall withstand voltages above U_{max} (see the App.A of this standard: criteria for definition of OVRT, over-voltage ride-through). This can be tested in an optional OVRT test. Details shall be agreed with DNV GL prior to testing. If this test has been passed successfully, then it will be mentioned in the type certificate.

3.3.6 Evidence for UVRT in 60 Hz based on 50 Hz tests

If tests were performed in a 50 Hz environment the validated software model (GCC) can be used for simulations for a 60 Hz area only under certain conditions, for validation see [2.7], [2.9]. Optionally the corresponding small scale under voltage dip tests of the auxiliary supply system according to this standard should be performed and passed successfully in a 60 Hz grid. Before small scale under voltage dip tests are performed, the generation unit including auxiliary supply system shall have been operational for at least 24 hours. The same shall apply vice versa, if full scale measurements and tests were performed in a 60 Hz grid.

Under voltage ride through (UVRT) tests and measurements shall be made at a unit in either a 50 Hz or a 60 Hz grid according to this standard. Results can be utilized for the respective other grid frequency.

For validation of a simulation model, simulations shall be carried out with a simulation model of the same cases as tested and measured in the categories 1 and 2 according to Table 3-1. Furthermore a plausibility check of the simulation model is required.

Comparison of the results from tests and measurements in a 50 Hz grid with simulations in a 50 Hz grid shall be performed for the validation of the simulation model. This validation process shall be performed as described in this standard.

The model shall be adopted for simulations in the 60 Hz grid, including system GCC-features – short circuit impedance, transformer characteristics, system frequency etc. The changes in the adapted model shall be assessed by DNV GL for plausibility (as far as being within the scope according to definition phase of /32/).

It shall be assessed if success criteria are fulfilled according to the respective grid codes and the simulation in 60 Hz (as far as being within the scope according to definition phase of /32/).

Tests and measurements on a unit of the same type (same generator, main frequency converter hard- and software as well as medium voltage transformer) connected to a 60 Hz grid shall be carried out with a reduced scope compared to test and measurement. Tests are necessary only if components of the 60 Hz variant are changed compared to the 50 Hz variant.

It shall be assessed if success criteria are fulfilled according to the respective grid codes. Minimum success criterion is the continuous, uninterrupted operation of the unit until recovery of maximum available output power after voltage has recovered.

3.4 Other test procedures

Additional tests can be defined for the certification if no test requirements are given in national or international standards or guidelines. The scope shall be defined as described in the DNVGL-SE-0124 /32/ prior to testing.

3.4.1 Power control testing

The unit behaviour on set point changes may be tested and evaluated according to FGW TG3 /3/. Depending on the assessed grid code set points different from those described in FGW TG3 /3/ may be defined for each grid code. If no requirements on the accuracy of the target value are formulated in the grid code, the tolerances given in FGW TG8 /2/ shall be applied.

3.4.2 Tests related to the European Union commission regulation

Tests for ACER / ENTSO-E Network Codes or the corresponding EU commission regulation /37/ shall be defined applying corresponding procedures.

APPENDIX A GCC-FEATURES (SUCCESS CRITERIA)

Below given Table A-1 gives a structured overview what kind of GCC-features are available and how they are grouped by short codes.

Table A-1 Introduction to GCC-feature listing

The most left column of the following GCC-feature listing gives the short code numbering (titled with #) of the GCC-feature which could be chosen as criterion for certification. Together with the column titled with "Requirement" it is possible to address each single GCC-feature of the listing for a detailed set of criteria for certification by ordering more than one GCC-feature as criterion for certification. Following technical terms and definitions are taken from the Generic Grid Code Format (Link: http://www.ewea.org/fileadmin/ewea_documents/documents/publications/091127_GGCF_Final_Draft.pdf) issued by EWEA. They were adapted to this DNV GL standard and different numbering has been applied due to that.	
#	*Description*
# G1 - G5:	general grid code specifications
# R1 - R14:	frequency, voltage and power rating (steady state performance)
# D1 - D11:	dynamic performance of frequency gradient and power ramp rates during normal operation and FRT
# D12 - D16:	dynamic performance of frequency gradient and power ramp rates during FRT describing the energy conversion during the fault
# Int:	communication and control interface
# P:	plant status
# M:	model related information data
# S:	site specific data
# C:	certification and performance verification
# Z:	additional Definitions to be specified and described

A.1 General GCC-features –G–

The GCC-features concerning general grid code issues are nominated with the character G and listed below in Table A-2.

Table A-2 GCC-feature listing

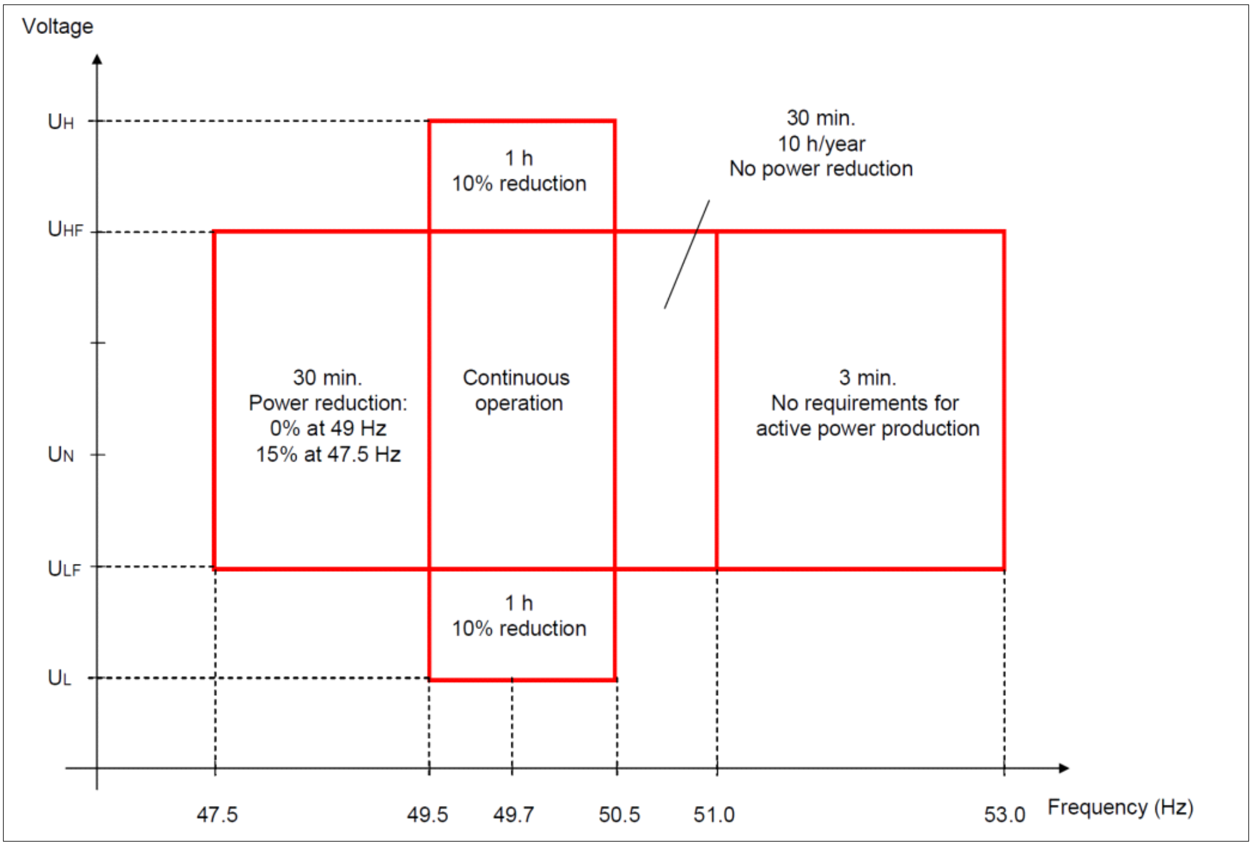
#	*Requirement*	*Description*	*kind of UNIT*
G	*General*	*General grid code specifications*	
G1	grid code identification	This is the official name of the grid code. Having defined a date of issuing this is the date when the grid code becomes valid. Moreover general definitions can be contained such as global definitions which can generally be placed in the beginning of the grid code. Parameter definitions relating to individual parameters will be placed where needed when specifying the individual parameters. The point of connection POC is the point at which a renewable plant or module connects to a power system or facility. Grid code requirements shall apply at POC, unless otherwise stated. Issues related to short circuit power (S_k) are normally regarded as project specific parameters.	X
G2	geographical area	Specify the geographical region in which the grid code shall be valid, a full country, a region, a certain state and similar.	TXT
G3	MW size limit	Some grid codes are specifying a certain MW threshold above which the grid code shall be valid.	W
G4	system voltage level limit	Some grid codes are only valid above, below or within a certain voltage threshold (or range) as grid codes define.	V
G5	type of network grounding	Some grid codes have a specification of the type of network grounding at the different voltage levels, e.g. isolated, directly, effectively or impedance grounded.	TXT

A.2 GCC-features related to rating –R–

GCC-features related to rating issues are listed below in Table A-3 starting with the short code character R.

Table A-3 GCC-features concerning rating

R	*Rating*	*Frequency, voltage and power rating*	*KIND OF UNIT*
R1	voltage-frequency-power-time figure (U/f/P/t - figure)	Corresponding figures may be given in grid codes, specifying the operating area for simultaneous values of voltage, frequency, output power and time. The voltage shall be specified in grid codes in absolute values [kV]. The figure below is an example only to indicate the intention with this parameter set (source: Danish grid code above 100 kV)	TXT V, Hz, W, s TXT



R2	frequency rating: A	Maximum system frequency in grid codes defines the absolute maximum system frequency at which the renewable unit or plant shall be able to operate.	Hz
	B	Minimum system frequency is the absolute minimum system frequency at which the renewable unit or plant shall be able to operate.	Hz
	C	The frequency/time-diagram according to grid codes is a frequency versus time figure which is sometimes specified. However, it is preferable to have this information included in the U/f/P/f-figure.	TXT
R3	voltage rating A	Nominal system voltage should be specified if used for certain p.u. specifications. It should be observed that different systems typically use slightly different nominal system voltages.	V or per unit
	B	Absolute maximum system operating voltage ($U_{max,H}$) should be specified in absolute value [kV] (not in p.u)	V
	C	Absolute minimum system operating voltage ($U_{min,L}$) should be specified in absolute value [kV] (not in p.u.).	V

Table A-3 GCC-features concerning rating (Continued)

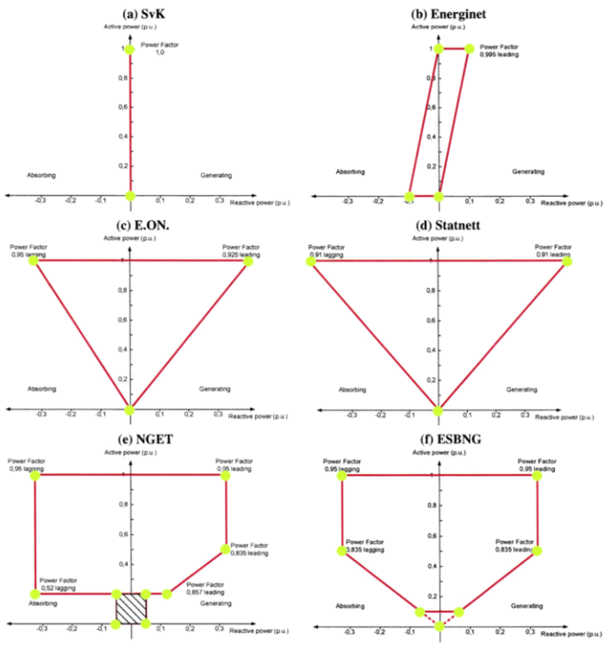
R	*Rating*	*Frequency, voltage and power rating*	*KIND OF UNIT*
R4	power rating A	The U/f/P/t-figure is specifying the degree of over-magnetization (U_{max}/f_{min}). The parameter is not strictly necessary and should be implicitly available through this U/f/P/t-figure.	TXT
	B	Continuous rated power at minimum voltage (P_c/U) specifies the minimum voltage at which it shall be possible to deliver continuous nominal active power.	V
	C	Maximum active power reduction during frequency drops specifies the maximum allowable reduction in active power during a frequency drop. Most likely a figure is needed to specify the characteristic of the frequency drop.	W
R5	reactive power rating	The steady-state reactive power capability shall be specified in a PQ-chart. The PQ-chart shall be valid for the full active power operating area. If the intended requirement is not solely clear from the PQ-chart only, the PQ-chart shall be associated with a text thoroughly explaining the requirement. If part of the steady-state requirement is required to be dynamical (fast) it shall be stated also (example grid code of Alberta - Canada). The fact that the technical minimum production varies for different unit types needs to be considered in the specification. The figures below are included as an example only to indicate the intention of this parameter.  The reactive power capability versus the grid operation voltage in the POC-point including the effects of voltage control shall be specified in a single UQ-chart. If the intended requirement is not solely clear from the UQ-chart in itself, the UQ-chart shall be associated with a text thoroughly explaining the requirement.	TXT

Table A-3 GCC-features concerning rating (Continued)

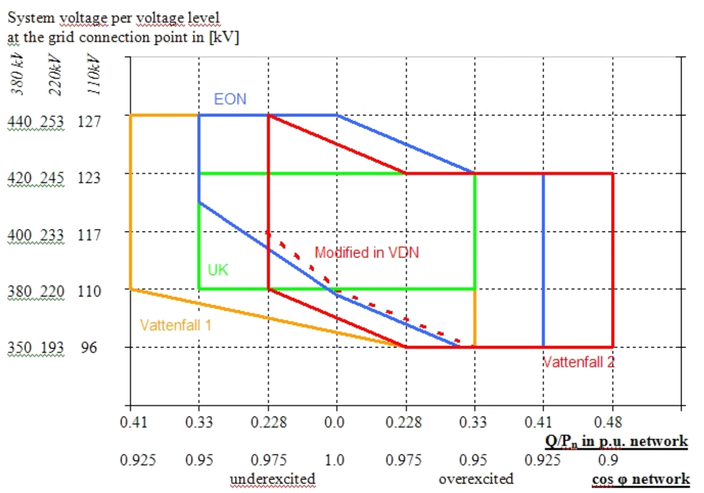
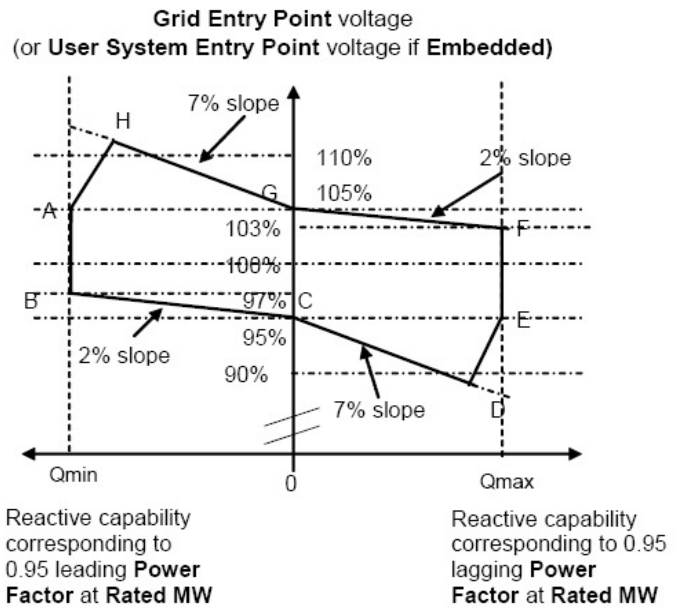
R	*Rating*	*Frequency, voltage and power rating*	*KIND OF UNIT*
R5	continued from above (R5)	The figures are included as an example only to indicate the intention of this parameter.  The figure below from the UK grid code is included as an example to indicate the effect of slope modifications.  Figure CC.A.7.2.2b	

Table A-3 GCC-features concerning rating (Continued)

R	*Rating*	*Frequency, voltage and power rating*	*KIND OF UNIT*
R6	power quality parameters A	Maximum steady state voltage jump/step (ΔU) is the maximum shift in voltage amplitude due to switching with reactive components e.g. a transformer, cap-bank or shunt reactor. Maximum inrush current amplitude ($I_{inrush-max}$) is referred to any requirement on the maximum inrush current amplitude compared to rated plant current.	V
	B	This GCC feature defines requirements on damping of inrush current ($I_{inrush-damping}$).	A
	C	Short term flicker (P_{st}) shall be calculated according to IEC 61868. Performance verification shall be carried out according to IEC 61400-21.	A
	D	Long term flicker (P_{lt}) shall be calculated according to IEC 61868. Performance verification shall be carried out according to IEC 61400-21.	TXT
	E	$$u_{a,cos} = \frac{2}{T}\int_{t-\tau}^{t} u_a(t)\cos(2\pi f_1 t)\,dt$$ The maximum relative negative sequence voltage, at which the plant shall be able to continuously operate with. The way of calculation shall be as follows	TXT
	F	$$u_{a,sin} = \frac{2}{T}\int_{t-\tau}^{t} u_a(t)\sin(2\pi f_1 t)\,dt$$ $$u_{1-,cos} = \frac{1}{6}\left[2u_{a1,cos} - u_{b1,cos} - u_{c1,cos} + \sqrt{3}(u_{c1,sin} - u_{b1,sin})\right]$$ $$u_{1-,sin} = \frac{1}{6}\left[2u_{a1,sin} - u_{b1,sin} - u_{c1,sin} + \sqrt{3}(u_{b1,cos} - u_{c1,cos})\right]$$ $$U_{1-} = \sqrt{\frac{3}{2}\left(u_{1-,sin}^2 + u_{1-,cos}^2\right)}$$	V
	G	A table might be needed for specifying maximum individual harmonic voltage distortion (D_n).	TXT
	H	The way of calculating total harmonic voltage distortion (THDu) shall be stated. The maximum harmonic order shall be specified (IEC 61000-3-6).	TXT
	I	The way of calculating total harmonic current distortion (THDi (TDD)) shall be stated. The maximum harmonic order shall be specified according to (IEC 61400-21).	TXT
	J	The way of calculating discrete inter-harmonics shall be stated. Maximum DC-component in the load current shall be stated. HVDC aspects are expected to be handled in a dedicated HVDC grid code. This could be in a format similar to the present document but with the technical parameters adapted to HVDC applications.	TXT

A.3 GCC-features related to dynamic performance –D–

In Table A-4 such GCC-features are listed as D1 through D11 which define a dynamic performances of frequency gradient and power ramp rates during normal operation.

Table A-4 Dynamic performance GCC-features D1 through D11

#Dx	*Y*	*Description*	
D1	frequency gradient A	Minimum positive frequency gradient (Minimum $df/dt_{positive}$) specifies the value at which the plant shall be able to withstand without tripping (positive: situation with rising frequency)	Hz/s
	B	Minimum negative frequency gradient (Minimum $df/dt_{negative}$) specifies the value at which the plant shall be able to withstand without tripping (negative: situation with falling frequency)	Hz/s
D2	start–stop and islanding with load requirements	Description of start and stop procedures.	TXT
	A	Signal to block against restart: The signal is used to prevent unintended start-up in connection with e.g. a power system restoration after blackout or other similar system emergency situations.	TXT
	B	Reconnection time after trip/blackout: From time to time a maximum reconnection time after a trip or blackout is specified. Such a requirement should be based upon a commercial agreement (payment for ancillary services) or otherwise based upon ready for operation signal from the plant owner. After a trip/blackout it is fair that the plant owner has time to inspect or to perform fault finding before the plant is reconnected.	s
	C	Islanding with load requirement: This parameter specifies requirements in relation to potential situations where a unit or plant may island with consumer loads connected.	y/n
D3	control of active power A	Active power Reference update rate (received from outside): This parameter is the update rate of the external active power reference. (In this respect this is to be considered as the signal provided from a TSO and not e.g. an internal customer signal.)	H
	B	Maximum start-up ramp rate (active power): This ramp rate defines the maximum increase of MW/min (or per 10 min) during start-up.	W/s
	C	Maximum shut-down ramp rate (active power): This ramp rate defines the maximum decrease of MW/min (or per 10 min) during shut-down (provided occurrence of suitable wind / solar intensity conditions). Maximum normal ramp-up rate (active power): This ramp rate defines the minimum ramp-up rate to be required during normal operation for remotely controlled plants.	W/s
	D	Maximum normal ramp-down rate (active power): This ramp rate defines the maximum ramp-down rate to be required during normal operation for remotely controlled facilities, modules or plants, provided suitable wind or solar intensity or any other renewable source conditions.	W/s
	E	Active power limitation control mode: This is a special active power control mode. If this control mode is required, functionality and parameters and any interdependence to other required control requirements shall be clearly specified. The method of calculation of actual production shall be well defined (e.g. floating average, 1-minute, 10-minute average and so on). The figure is to be considered as an example only.	W/s
	F	Active power balance control mode: If this control mode is required, functionality and parameters and any interdependence to other required control requirements shall be clearly specified.	y/n

Table A-4 Dynamic performance GCC-features D1 through D11

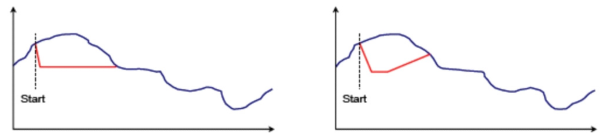
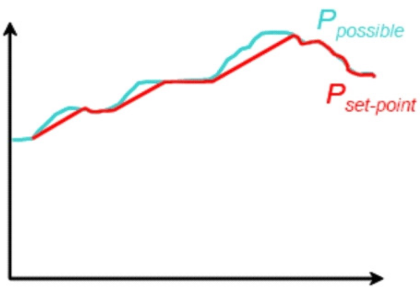
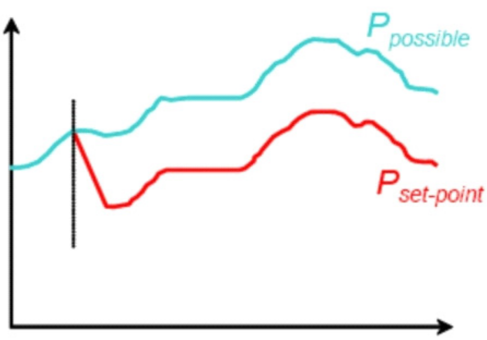
#Dx	*Y*	*Description*	
D3	control of active power (continued)	This mode is assumed to be identical to remote control of the plant according to some schedule or the plant being part of a frequency secondary control arrangement. The method of calculation of actual production shall be well defined (e.g. floating average, 1-minute, 10-minute average and so on). The figure shall be considered as an example only.  	TXT y/n
D3	G	Active power gradient control mode: If this control mode is required, functionality and parameters and any interdependence to other required control requirements shall be clearly specified. The method of calculation of actual production shall be well defined (e.g. floating average, 1-minute, 10-minute average and so on). The figure shall be considered as an example only  	y/n TXT TXT
	H	Active power delta control mode: This is a special active power control mode. If this control mode is required, functionality and parameters and any interdependence to other required control requirements shall be clearly specified. The method of calculation of actual production shall be well defined (e.g. floating average, 1-minute, 10-minute average and so on). The figure shall be considered as an example only.  	y/n TXT
	I	Other limitation modes: Any other method other than the above described power control modes should be described accordingly.	y/n TXT

Table A-4 Dynamic performance GCC-features D1 through D11

#Dx	*Y*	*Description*	
D4	run back A	Minimum run-back ramp rate (active power): Run-back is a special pre-armed automatic system protection scheme (SPS) used to protect against loss of thermal transfer capability or transient angle instability. This type of functionality is sometimes called a 'remedial action scheme' (RAS), i.e. it has to be pre-installed and being fully automatic the functionality shall be guaranteed at any time. In such cases a remote signal will order the plant to run back the active power with a certain minimum ramp down rate to a predetermined power level, e.g. 50%, and stay there until the run-back signal is cleared.	y/n TXT
	B	If required, this parameter specifies the minimum ramp down rate of active power in pu/s based upon rated power per turbine.	W/s %
	C	Maximum run-back starting point (active power): This parameter is the maximum initial active power before a run-back is ordered. This parameter will normally be the rated power of the unit/plant, i.e. 100%.	per unit/s %
	D	Minimum run-back stopping point (active power): This parameter is the lowest possible run-back level which can be pre-programmed. This parameter will normally lie in the order of 50-20% based upon rated power of the unit/plant. This parameter should not necessarily be very low to assist the power system in a proper way.	%
	E	Due consideration needs to be given to unit's technical minimum production at any time, i.e. independent of the wind speed / solar intensity at any time (high wind speed situations).	W
D5	frequency control A	General description of functionality: Description of frequency control modes: Some grid codes have more than one frequency control mode (UK is an example).	TXT
	B	Frequency control requirement limit (voltage level, MW level): This parameter specifies a minimum voltage and/or a MW limit from which frequency control shall be available.	V or W
D5	C	Frequency control parameters: frequency control – definition of performance parameters. Various parameters shall be specified in a figure. It shall be clearly stated whether parameters refer to available or rated power	TXT
	D	Active range for frequency control: Specify the frequency range in which the frequency control shall be active	Hz
	E	Frequency measurement accuracy: Specify the accuracy for the frequency measurement.	Hz
	F	Frequency reference set-point range: Specify the range of the frequency set-point.	Hz
	G	Frequency reference resolution: Specify the frequency reference resolution.	Hz
	H	Frequency control dead-band: Specify the dead-band range.	Hz
	I	Frequency control power static / gain / droop: The power static shall be specified. Remark: appropriate terms and corresponding units shall be used.	Hz/s
	J	Frequency control ramp rate: Specify the minimum positive and negative control speed (active power output). This parameter might be identical to the normal ramp rate.	W/s
	K	Maximum frequency control initial delay (dead time): Specify the maximum initial delay from the moment a disturbance is initiated until the moment that a response in the active power output can been detected.	s
	L	Maximum frequency phase jump (robustness): Specify a maximum phase jump that the frequency measuring shall be able to withstand not giving wrong measurements.	°/s

Table A-4 Dynamic performance GCC-features D1 through D11

#Dx	*Y*	*Description*	
D6	frequency control active power set-point range	Specify the range the power set-point shall be able to be curtailed to, e.g. 100 to 50% of the rated output of plant. Attention shall be given to limitations due to the technical minimum production in high wind speeds / solar intensity.	%
D7	inertia response	Inertia description: Describing the functionality. Inertia control parameters: Parameters needed to specify inertia control performance shall be defined.	TXT TXT
D8	controls utilizing the reactive power capability of the plant	Description of the intended utilization of the plant's reactive power capability. Three typical control schemes are generally available: Power factor control (D9) Reactive power control (D10) Voltage control (D11) It shall be clearly stated which of these schemes is applicable for the plant, e.g. depending on nominal voltage at POC fault level at POC installed capacity at POC Power factor control and reactive power control modes should usually not be required to provide the same dynamic timescales as voltage control mode. If voltage stability is a critical issue the voltage control mode should be considered by the TSO. It should be noted that whilst voltage control has a dynamic range of seconds, power factor control typically has a range of minutes, and reactive (MVAR) control has a range in the order of 15 minutes. Switching between control modes: If switching between control modes is requested, it shall be clearly defined which mode shall be used under which condition and how the transitions shall be carried out.	TXT y/n y/n y/n y/n y/n y/n TXT
D9	power factor control mode	Description of power factor control: The functionality shall be described.	TXT
	A	Power factor control requirement limit (voltage level, MW level, system state): This parameter specifies a minimum voltage and/or a MW limit from which power factor control has to be available.	V or W
	B	Reference point for power factor measurement: Specify information regarding the reference point for power factor measurement. This point should ideally be free of choice according to what might be the most optimal solution.	TXT
	C	Reference point for power factor control: This is the point in which the power factor has to be controlled. This should be identical to the POC unless otherwise stated or agreed upon.	TXT
	D	Power factor control accuracy: This parameter specifies how accurate the average value (e.g.15 minutes) of power factor shall be controlled under defined operation conditions.	%
	E	Coordination with step-up transformer OLTC: Coordination with step-up transformer OLTC is sometimes asked for or allowed in grid codes. The technical possibilities if available should be clearly specified in this requirement.	TXT
D9	F	Power factor calculation method: The frequency of measurements and the averaging time shall be defined.	TXT
	G	Power factor measurement accuracy: The signal might be provided by a second or third party.	%
	H	Power factor reference set-point range: typically +/- 5% or +/- 10%.	%
	I	Power factor reference resolution.	%
	J	Power factor reference update rate (received from outside).	Hz

Table A-4 Dynamic performance GCC-features D1 through D11

#Dx	*Y*	*Description*	
	K	Maximum power factor control initial delay (dead time): This parameter specifies the maximum time allowed from the initiation of a step change until a change in the output can be detected.	s
	L	Maximum rise time ($T_{rise-max}$).	s
	M	Maximum settling time ($T_{settling\ max}$): maximum time delay between a change in the power factor reference set-point until the plant output is within the maximum steady state error.	s
	N	Maximum steady state power factor control error: maximum allowable steady state power factor error, typically 2% or 5%.	%
	O	for wind turbines: Zero-power factor control (no rotor movement): This parameter specifies if power factor control also shall be available during periods with no rotor movement. This may be relevant to meet power factor requirements when the plant consumes auxiliary power from the grid and thus behaves as a net load.	y/n
D9	P	Requirements for switched discrete components: description, if there are requirements in relation to switched discrete components such as cap-bank, shunt reactors (discharge times, switching out, special control schemes etc.)	TXT
D10	reactive power control mode	description of reactive power control used for general description	txt
	A	reactive power control requirement limit (voltage level, MW level, system state): minimum voltage and/or a MW limit from which reactive power control has to be available.	txt
	B	reference point for reactive power measurement Specify information regarding the reference point for reactive power measurement. This point should ideally be free to choose according to what might be the most optimal solution.	txt
	C	reference point for reactive power control It should be identical to the POC unless otherwise stated or agreed upon.	txt
D10	D	reactive power control accuracy This parameter specifies how accurate the average value (e.g.15 minutes) of reactive power shall be controlled under defined operation conditions.	%
	E	coordination with step-up transformer OLTC Coordination with step-up transformer OLTC is sometimes asked for or allowed in grid codes. The technical possibilities if available should be clearly specified in this field.	txt
	F	reactive power calculation method The frequency of measurements and the averaging time shall be clearly defined.	Hz s
	G	reactive power measurement accuracy: reactive power measurement accuracy. The signal might be provided by a second or third party.	%
	H	reactive power reference set-point range: typically +/- 5% or +/- 10%.	%
	I	reactive power reference resolution: resolution of the reactive power reference.	%
	J	reactive power reference update rate (received from outside).	s
	K	maximum reactive power control initial delay (dead time): maximum time allowed from initiation of a disturbance until a change in the output can be detected.	s
	L	maximum rise time ($T_{rise-max}$): maximum reactive power rise time.	s
	M	maximum settling time ($T_{settling\ max}$): maximum time from a change in the reactive power reference set-point or a small signal disturbance have occurred and until the plant output is within the maximum steady state error.	s
D10	N	maximum steady state reactive power control error: maximum allowable steady state reactive power error, typically 2% or 5%.	%

Table A-4 Dynamic performance GCC-features D1 through D11

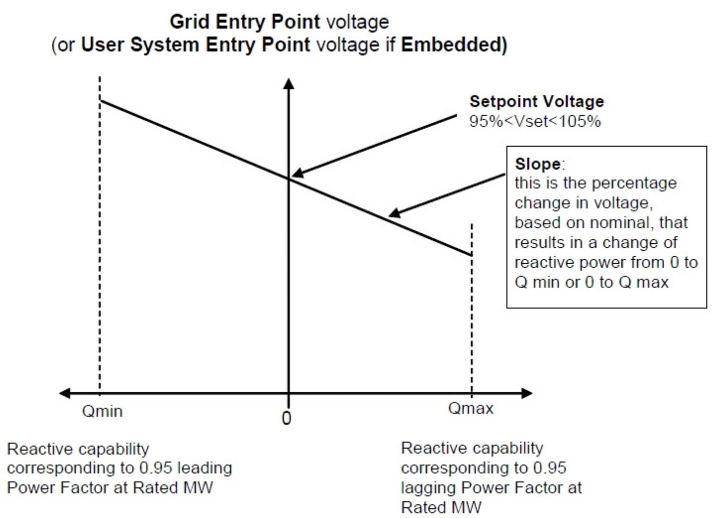
#Dx	*Y*	*Description*	
	O	zero-power reactive power control (no rotor movement): specification, if reactive power control also has to be available during periods with no rotor movement. This may be relevant to meet reactive power requirements when the plant consumes auxiliary power from the grid respectively if the plant behaves as a load.	txt
	P	requirement to on-off discrete components: specification, if there are requirements in relation to on-off discrete components such as cap-bank, shunt reactors (discharge times, switching out, special control schemes etc.).	txt
	Q	review-approval This requirement should state clearly how the review and approval of the voltage control is to be performed.	txt
D11	voltage control mode	description of voltage control mode	txt
	A	voltage control requirement limit (voltage level, MW level): minimum voltage and/or a MW limit from which voltage control has to be available.	V or W
	B	reference point for voltage measurement Specify information regarding the reference point for voltage measurement. This point should ideally be free of choice according to what might be the most optimal solution.	txt
	C	reference point for voltage control It should be identical to the POC-point unless otherwise stated or agreed upon.	txt
D11	D	coordination with step-up transformer OLTC Coordination with step-up transformer OLTC is sometimes asked for or allowed in grid codes. The technical possibilities if available should be clearly specified in this field.	txt
	E	voltage measurement accuracy The signal might be provided by a second or third party.	%
	F	voltage reference set-point range typically +/- 5% or +/- 10%.	%
	G	voltage reference resolution	%
	H	voltage reference update rate (received from outside).	Hz
	I	slope reference set-point range This parameter specifies the slope set-point range, typically 1-10%. An exact definition of the slope should be given, for example in a figure. The figure below from the UK grid code is given as an example only. 	%

Table A-4 Dynamic performance GCC-features D1 through D11

#Dx	*Y*	*Description*	
	J	slope reference resolution: typically 1%.	%
D11	K	minimum equivalent open loop gain If desirable this parameter can be used as a type of indirect measure of the maximum allowed steady state error. Another way of specifying is by the reactive power calculation method.	
	L	maximum voltage control initial delay (dead time): maximum time allowed from the moment a disturbance has initiated until a change in the output can be detected.	s
	M	minimum small signal rise time ($T_{rise\text{-}min\text{-}small\text{-}signal}$): minimum voltage rise time for small signal disturbances.	s
	N	maximum small signal rise time ($T_{rise\text{-}max\text{-}small\text{-}signal}$): maximum voltage rise time for small signal disturbances.	s
	O	minimum large signal rise time ($T_{rise\text{-}min\text{-}large\text{-}signal}$): minimum voltage rise time for large signal disturbances. Definition of large signal shall be included.	s
	P	maximum large signal rise time ($T_{rise\text{-}max\text{-}large\text{-}signal}$): maximum voltage rise time for large signal disturbances.	s
	Q	small signal settling time ($T_{settling\ small\ signal}$): maximum time lapse from the moment when a change in the voltage reference setpoint or a small signal disturbance has occurred until the moment that the plant output is within the maximum steady state error.	s
	R	large signal settling time ($T_{settling\ large\text{-}signal}$): maximum time between the moment when a change in the voltage reference setpoint or a large signal disturbance has occurred until the moment that the plant output is within the maximum steady state error.	s
	S	voltage control response behaviour This parameter specifies if the behaviour of the voltage response to be of a non-oscillatory nature. Figures with examples that fulfil this and not fulfil these criteria should be included in the grid code. Alternatively, damping criteria and calculation method shall be stated.	txt
	T	maximum voltage control overshoot control of the maximum allowable overshoot in the voltage. The criteria or definition of overvoltage shall be clearly specified i.e. peak value or exposed time duration above a certain value. It shall be defined in relation to the maximum initial voltage.	V txt
D11	U	maximum steady state voltage control error: maximum allowable steady state voltage error.	%
	V	limiting of reactive output (excessive voltages) This parameter might specify allowance to perform some type of reactive power run-back – e.g. if a overload capacity is available. Seen from the grid it is better to provide less reactive power on a continuous basis than tripping from the grid.	txt
	W	shift of voltage control settings This parameter specifies if there is a requirement to shift between two or more sets of pre-programmed settings This parameter might also cover requirements in relation to remote transmitting voltage set-points and slope settings.	txt
	X	For wind turbines zero-power voltage control (no rotor movement) This parameter specifies if voltage control also has to be available during periods with no rotor movement. It shall be pointed out that such services should be subject to payment for ancillary services.	txt
	Y	requirement to switched discrete components This parameter specifies if there are requirements in relation to switched discrete components such as cap-bank, shunt reactors (discharge times, switching out, special control schemes etc.)	txt

Table A-4 Dynamic performance GCC-features D1 through D11

#Dx	*Y*	*Description*	
	Z	review-approval This requirement should state clearly how the review and approval of the voltage control is to be performed.	txt
D12	**fault ride through FRT (OVRT or UVRT)**		
	fault ride through FRT (or UVRT)	fault ride-through description Used for general description. Statistics of number and type of grid faults should be specified, e.g. according to [3.2.5] of the standard with a test plan. See also D13 for Spanish style FRT requirement parameters	txt
D12	A	FRT voltage profile for under voltages (UVRT) The voltage / time FRT-profile (at POC) for the lowest phase RMS voltage or phase to phase RMS voltage shall be available for both balanced and unbalanced faults. If voltages are specified in pu it shall be clear what 1 pu is referring to. Furthermore, where applicable, the proceeding of the fault process from a higher level system bus down to a given POC-point – shall be clearly specified.	txt Y/n V txt
D12	B	FRT voltage profile for over voltages (OVRT) The voltage/time FRT-profile (at POC) for the highest phase RMS voltage or phase to phase RMS voltage shall be available for both balanced and unbalanced faults. If voltages are specified in p.u. it shall be clear what 1 p.u. is referring to. Furthermore, where applicable, the proceeding of the fault process from a higher level system bus down to a given POC-point – shall be clearly specified. In general this aspect is related to grid strength, protection settings, insulation coordination, voltage control, islanding and the voltage level actual in a given case.	txt y/n V TXT
	C	FRT fault sequence The various fault sequences and combinations are to be defined clearly. Special conditions related to radial connected plants, shall be specified.	txt
	D	Re-closure Any re-closure sequence in use (1 phase, 3 phase, blocking) shall be specified for all voltage levels covered by the grid code.	txt
	E	FRT short time interruption (STI) STI shall be considered as a special FRT variant, used as one of the first methods to cope with the FRT requirement. STI normally means a physical separation of the unit from the grid. STI shall be clearly specified by e.g. the interruption criteria, FRT profile and the active power recovery time.	txt
	F	grid voltage before FRT event FRT shall be possible from any grid voltage in the steady state range.	V
	G	P/Q power production before FRT event: plant P/Q production before a FRT is initiated. FRT shall be possible from any state in the P/Q steady state range.	txt
	H	FRT active power recovery time: maximum allowed time from 90% voltage until 90% of the pre-fault power level is restored.	s
	I	FRT – post fault oscillatory behaviour (active power): oscillatory behaviour of active power after fault clearing. Figures with examples that fulfil this and not fulfil these criteria should be included in the grid code. Alternatively, damping criteria and calculation method shall be stated.	W(t)
	J	maximum voltage phase jump (robustness) This parameter specifies the maximum phase shift the plant shall be able to withstand without tripping. (Phase jump robustness).	°/s

A.3.1 GCC-features related to dynamic consumption –D13x–

These GCC-features are describing the energy conversion during the fault, mainly required for Spain.

A.3.1.1 GCC-features releted to balanced fault consumption (during 3 phase faults) –D13Ax–

The GCC-features listed in Table A-5 describe balanced fault consumption values being nominated as D13 followed by two additional characters for detail naming.

Table A-5 Dynamic performance GCC-features related to balanced fault consumpption -D13Ax-

# D13	*Ax*	*Description*	*kind*
D13	AA	definitions of consumption parameters For each of the relevant consumption parameters a clear specification shall be given about calculation and verification method.	txt
	AB	— net consumption Q (power)	VA
	AC	— net consumption P (power)	W
	AD	— net consumption EP (energy)	Ws
	AE	— net consumption EQ (energy)	VAs
	AF	— net consumption IQ	A
	AG	— average I_Q/I_{rated}	p.u

A.3.1.2 GCC-features related to consumption during asymmetrical faults –D13Bx–

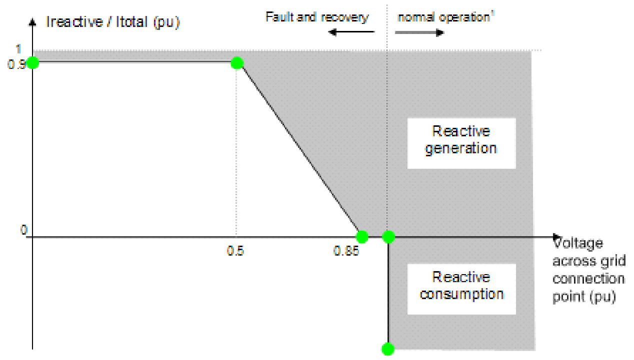
Assymetrical faults are 1 and 2 phase faults with ground connection or even without ground connection. Corresponding GCC-features are listed in

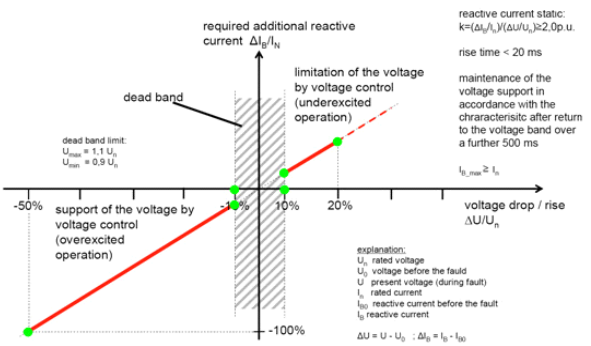
# D13	*Bx*	*Description*	*kind*
D13	BA	Asymmetrical faults (1- and 2-phase faults with ground connection / without ground connection):	txt
	BB	definitions For each of the relevant consumption parameters a clear specification shall be given about calculation and verification method.	txt
	BC	— net consumption Q (power)	VA
	BD	— net consumption P (power)	W
	BE	— net consumption EP (energy)	Ws
	BF	— net consumption EQ (energy)	VAs
	BG	— net consumption I_Q	A
	BH	— average I_Q/I_r	p.u.

A.3.2 General GCC-features related to dynamic injection –D14x–

GCC-features listed in below Table A-6 are describing dynamic injection and are nominated with D14 followed by one character.

Table A-6 Dynamic injection GCC-features

<table>
<tr><th># D14</th><th>x</th><th>Description</th><th>kind</th></tr>
<tr><td>D14</td><td>A</td><td>definitions of injection parameters
A figure shall be available.
Voltage and current must be clearly defined.
The reactive current / P-Q interrelation shall be clearly defined especially for very low voltages (e.g. below 10% nominal voltage).
The figures below are to be considered as examples only:
Spain:


Germany:


</td><td>TXT</td></tr>
<tr><td>D14</td><td>B</td><td>maximum reactive current in-feed during FRT:
maximum reactive current in-feed in the POC-point in p.u. based upon rated current.
If this requirement is not a fixed requirement but is supposed to be optimized on a case by case basis the criteria for optimization shall be clearly specified.
The reactive current / P-Q interrelation shall be defined.
Voltage definitions should be considered with care as the voltage can drop close to zero.</td><td>A
p.u.</td></tr>
<tr><td></td><td>C</td><td>reactive current injection dead time:
time from significant change in voltage until measurable change of reactive current output.</td><td>s</td></tr>
<tr><td></td><td>D</td><td>reactive current injection rise time:
rise time of the reactive current (10 to 90%).</td><td>s</td></tr>
<tr><td></td><td>E</td><td>reactive current injection settling time
Currently this parameter is only seen in Germany where it is under consideration. The intention with the parameter is to specify the ability to maintain the required current when the required level is reached.</td><td>s</td></tr>
</table>

Table A-6 Dynamic injection GCC-features (Continued)

# *D14*	*x*	*Description*	*kind*
	F	reactive current injection post fault support time: post fault support time (current injection mode) after 90% of the pre-fault voltage level has been reached.	s
D14	G	active current injection: active current injection during the fault time. Stability in this transient situation may limit the ability to inject active current, e.g. depending on the location of the fault. Remark: in the UK grid code the active current injection is specified in terms of active power; in the Spanish grid code in terms of active current.	A

A.3.3 Other dynamic GCC-features –D–

D15 and D16 describe two more dynamic GCC-features not listed before, see Table A-7.

Table A-7 Other dynamic GCC-features

#	*x*	*Description*	*kind*
D15	**temporary over-voltages - TOV**		
	A	temporary over-voltage description	txt
	B	maximum temporary over-voltage (TOV) amplitude:. absolute maximum TOV amplitude to be expected.	V
	C	TOV time duration insulation withstand capability It shall be specified in a figure.	txt
D16	**system and relay protection**		
D16	A	description	txt
	B	under frequency protection – f<< Under frequency limit – the plant shall or may trip dependent upon requirement.	Hz
	C	over frequency protection – f>> Over frequency limit – the plant shall or may trip dependent upon requirement.	Hz
	D	under voltage protection – U<< Under voltage limit – the plant shall or may trip dependent upon requirement.	V
	E	over voltage protection – U>> Over voltage limit – the plant shall or may trip dependent upon requirement.	V
	F	other protection systems Any other protection systems requirement if applicable shall be specified here.	TXT

A.4 Other GCC-features – Int, P, M, S, C, Z –

There are more GCC-features, they are all described in below Table A-8.

Table A-8 Other GCC-features

#	*x*	*Description*	*kind*
Int	**Communication and control interface**		**txt**
Int	1	communication and control interface requirement	txt
Int	2	Power production at PCC	txt
Int	3	possible Power production at PCC	txt
Int	4	lost Power production at PCC (time series)	txt
Int	5	Q production at PCC	txt
Int	6	voltage at PCC	txt
Int	7	main transformer tap position	txt
Int	8	main transformer fault indication	txt
Int	9	circuit breaker position indicator	txt

Table A-8 Other GCC-features (Continued)

#	*x*	*Description*	*kind*
Int	10	current measurement at PCC	txt
Int	11	frequency at PCC	txt
Int	12	status of compensation equipment	txt
P	**Plant status information**		**txt**
P1	number of WT's / solar modules…	stopped due to high or low wind / solar intensity	txt
	A	stopped due to maintenance	txt
	B	stopped due to forced outage	txt
	C	out of operation	txt
	D	with limited capacity	txt
	E	relevant topology information – internal network	txt
	F	relevant plant alarms	txt
	G	frequency response mode signal	txt
	H	frequency response mode status indication	txt
P2	meteorological information	wind speed / solar radiation	txt
	A	wind direction	txt
	B	ambient temperature	°C
	C	atmospheric pressure	Pa
P2	D	simulation models, certification / verification, commissioning and performance verification	txt
	E	integration and design simulation models	txt
M	**Model data and descriptions**		**txt**
M1	type of model	rms-type WTG model	y/n
	A	emt-type WTG model	y/n
	B	rms-type aggregated plant model	y/n
M2	simulation platform		
	A	simulation platform	txt
	B	minimum time step	s
	C	maximum time step	s
M3	model document ation		
	A	black-box	txt
	B	white-box	txt
	C	model verification	txt
	D	updating requirement	txt
M4	system planning simulation models		txt
	A	description	txt
	B	modelling description	txt
	C	modelling parameters	txt
	D	modelling documentation	txt
	E	model verification	txt

Table A-8 Other GCC-features (Continued)

#	*x*	*Description*	*kind*
	F	updating requirement	txt
S	**Site specific data**		**TXT**
S	1	plant short circuit data – POC-point data needed for plant representation in system studies and for relay protection setting studies.	VA
C1	**Certification/ verification, description**		**txt**
	A	plant simulation / fictive benchmark test circuit	txt
	B	full scale test on individual turbine (container test)	txt
	C	full scale plant test	txt
C2	**Commissioning**		
	A	performance testing	TXT
	B	description	TXT
	D	transient fault recorder	TXT
	E	performance testing:	TXT
	F	— rated power	y/n
	G	— power factor	y/n
	H	— power quality	y/n
	I	— ramp rate	y/n
	J	— frequency gradient	y/n
	K	— limitation modes	y/n
	L	— run-back	y/n
	M	— reactive power control	y/n
	N	— voltage control	y/n
	O	— fault ride through	y/n
	P	— maximum phase jump	y/n
	Q	— frequency control	y/n
	R	— inertia	y/n
	S	— temporary overvoltage	y/n
	T	— system and relay	y/n
Z	**Additional definitions to be specified and described**		