DRAFT prEN50549-1

WG03 document in view of the preparation of FORMAL VOTE

EN 50549-1**: Requirements for generating plants to be connected in parallel with distribution networks - Part** 1**: Connection to a** LV **distribution network – Generating plants up to and including Type B**

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European foreword

This document (EN 50549-1:2018) has been prepared by CLC/TC 8X “System aspects of electrical energy supply”.

This document is currently submitted to vote.

The following dates are proposed:

• latest date by which the existence of this document has to be announced at national level	(doa)	dor + 6 months
• latest date by which this document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	dor + 12 months
• latest date by which the national standards conflicting with this document have to be withdrawn	(dow)	dor + 36 months (to be confirmed or modified when voting)

This document will supersede EN 50438:2013 and CLC/TS 50549-1:2015.

This document has been prepared as a deliverable to the EC mandate M/490.

This European Standard relates to both the RfG European Network Code and current technical market needs. Its purpose is to give detailed description of functions to be implemented in products.

This European Standard is also intended to serve as a technical reference for the definition of national requirements where the RfG European Network Code requirements allow flexible implementation. The specified requirements are solely technical requirements; economic issues regarding, e.g. the bearing of cost are not in the scope of this document.

CLC/TC 8X plans future standardization work in order to ensure the compatibility of this European Standard (EN) with the evolution of the legal framework.

1 Scope

This European Standard specifies the technical requirements for the protection functions and the operational capabilities for generating plants, intended to operate in parallel with LV distribution networks.

For practical reasons this EN refers to the responsible party where requirements have to be defined by an actor other than the DSO e.g. TSO, member state, regulatory authorities according to the legal framework. Typically the DSO will inform the producer about these requirements.

NOTE 1 This includes European network codes and their national implementation, as well as additional national regulations.

NOTE 2 Additional national requirements especially for the connection to the distribution network and the operation of the generating plant may apply.

The requirements of this European Standard apply, irrespective of the kind of energy source and irrespective of the presence of loads in the producer's network, to generating plants, generating modules, electrical machinery and electronic equipment that meet all of the following conditions:

– converting any energy source into AC electricity;

– generating modules capacity of type B or smaller according to COMMISSION REGULATION (EU) 2016/631 while considering national implementation for the decision regarding power limits between A and B types and B and C types;

– connected to and operated in parallel with an AC LV distribution network.

NOTE 3 Generating plants connected to a MV distribution network fall into the scope of EN 50549–2.

NOTE 4 Electrical energy storage systems (EESS) in meeting the conditions above are included

If generating modules of different type (A or B) are combined in one plant, different requirements apply for the different modules based on the type of each module.

EXAMPLE: If a generating plant consists of multiple generating modules (see 3.2.1), according to COMMISSION REGLUATION (EU) 2016/631 the situation might occur, that some generating modules are of type A and some are of type B.

Unless specified otherwise by the DSO and the responsible party, generating plants connected to a medium voltage distribution network with a maximum apparent power up to 150 kVA can comply with this European Standard as alternative to the requirements of EN 50549-2. A different threshold may be defined by the DSO and the responsible party.

This European Standard recognizes the existence of specific technical requirements (e.g. grid codes) of the DSO or another responsible party within a member state and these must be complied with.

Excluded from the scope are:

- the selection and evaluation of the point of connection;
- power system impact assessment e.g. assessment of effects on power quality, local voltage increase, impact on line protections operation;
- connection assessment, the set of technical verifications made as part of the planning of the connection;
- island operation of generating plants, both intentional and unintentional, where no part of the distribution network is involved;
- four-quadrant rectifier of drives feeding breaking energy back into the distribution network for limited duration with no internal source of primary energy;
- uninterruptible power supply with duration of parallel operation limited to 100 ms;

NOTE 5 Parallel operation due to maintenance of uninterruptible power supply units is not seen as part of normal UPS operation and therefore not considered in this EN.

- requirements for the safety of personnel as they are already adequately covered by existing European Standards.
- the connection of a generating unit, module or plant into a DC network

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 60255-127, Measuring relays and protection equipment — Part 127: Functional requirements for over/under voltage protection (IEC 60255-127)

EN 61000-4-30, Electromagnetic compatibility (EMC) — Part 4-30: Testing and measurement techniques — Power quality measurement methods (IEC 61000-4-30)

HD 60364-1, Low-voltage electrical installations — Part 1: Fundamental principles, assessment of general characteristics, definitions (IEC 60364-1)

HD 60364-5-551, Low-voltage electrical installations — Part 5-55: Selection and erection of electrical equipment — Other equipment — Clause 551: Low-voltage generating sets (IEC 60364-5-551)

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

Note: Terms and definitions are selected to achieve consistency with IEV (cf. www.electropedia.org) and CENELEC terminology, recognizing that terms in COMMISSION REGULATION (EU) 2016/631 may deviate.

3.1 General

3.1.1
distribution network
AC electrical network, including closed distribution networks, for the distribution of electrical power from and to third parties connected to it, to and from a transmission or another distribution network, for which a DSO is responsible

Note 1 to entry: A distribution network does not include the producer’s network.

3.1.2
closed distribution network
system which distributes electricity within an industrial, commercial or shared services site, that is geographically confined, and does not supply households customers (without excluding the option of a small number of households served by the system that have an employment or similar associations with the owner of the system)

Note 1 to entry: A closed distribution network will either be used to integrate the production processes of the network users for specific or technical reasons or distribute electricity primarily to the operator of the closed distribution network or his related undertakings.

[SOURCE: Directive 2009/72/EC, article 28, modified]

3.1.3
distribution system operator
DSO
natural or legal person responsible for the distribution of electrical power to final customers and for operating, ensuring the maintenance of and, if necessary, developing the distribution network in a given area

Note 1 to entry: As this document is applicable to distribution grids, DSO is used for relevant system operator according to article 2 (13) of COMMISSION REGULATION 2016/631.

Note 2 to entry: In some countries, the distribution network operator (DNO) fulfils the role of the DSO.

3.1.4
transmission system operator
natural or legal person responsible for operating, ensuring the maintenance of and, if necessary, developing the transmission system in a given area and, where applicable, its interconnections with other power systems, and for ensuring the long-term ability of the power system to meet reasonable demands for the transmission of electricity

3.1.5
responsible party
party, that according to the legal framework is responsible to define requirements or parameters according to COMMISSION REGLUALTION 2016/631 e.g. TSO, member state, regulatory authority

3.1.6
low voltage (LV) distribution network
electric distribution network with a voltage whose nominal r.m.s. value is $U_n \leq 1$ kV

3.1.7
medium voltage (MV) distribution network
electric distribution network with a voltage whose nominal r.m.s. value is 1 kV < Un ≤ 36 kV

Note 1 to entry: Because of existing network structures, the upper boundary of MV can be different in some countries.

3.1.8
power system stability
capability of a power system to regain a steady state, characterized by the synchronous operation of the generating plants after a disturbance

[SOURCE: IEV 603-03-01]

3.1.9
producer
natural or legal person who already has connected or is planning to connect an electricity generating plant to a distribution network

3.1.10
producer's network
AC electrical installations downstream from the point of connection operated by the producer for internal distribution of electricity

Note 1 to entry: When the internal distribution network is identical to an electrical network of a customer having his own generating plant, where one or more generating units are connected to this internal distribution network behind a point of connection, then this network may be also referred as prosumer's network.

3.1.11
downstream
direction in which the active power would flow if no generating units, connected to the distribution network, were running

3.1.12
point of connection
POC
reference point on the electric power system where the user's electrical facility is connected

Note 1 to entry: For the purpose of this standard, the electric power system is the distribution network.

[SOURCE: IEV 617-04-01 modified]

3.1.13
operating in parallel with the distribution network
situation where the generating plant is connected to a distribution network and operating

3.1.14
temporary operation in parallel with the distribution network
conditions in which the generating plant is connected during defined short periods to a distribution network to maintain the continuity of the supply and to facilitate testing

3.1.15
nominal value
value of a quantity used to designate and identify a component, device, equipment, or system

Note to entry: The nominal value is generally a rounded value.

[SOURCE: IEV 151-16-09]

3.2 Plant, module and unit

3.2.1
generating module
either a generating unit of synchronous generating technology or the sum of all generating units of non-synchronous generating technology connected to a common point of connection including all elements needed to feed electric power to the distribution grid

Note 1 to entry: In some documents this can mean a power-generating module.

Note 2 to entry: Generating modules in the context of this document can be of type A or type B according to the definition of COMMISSION REGULATION 2016/631, article 5.

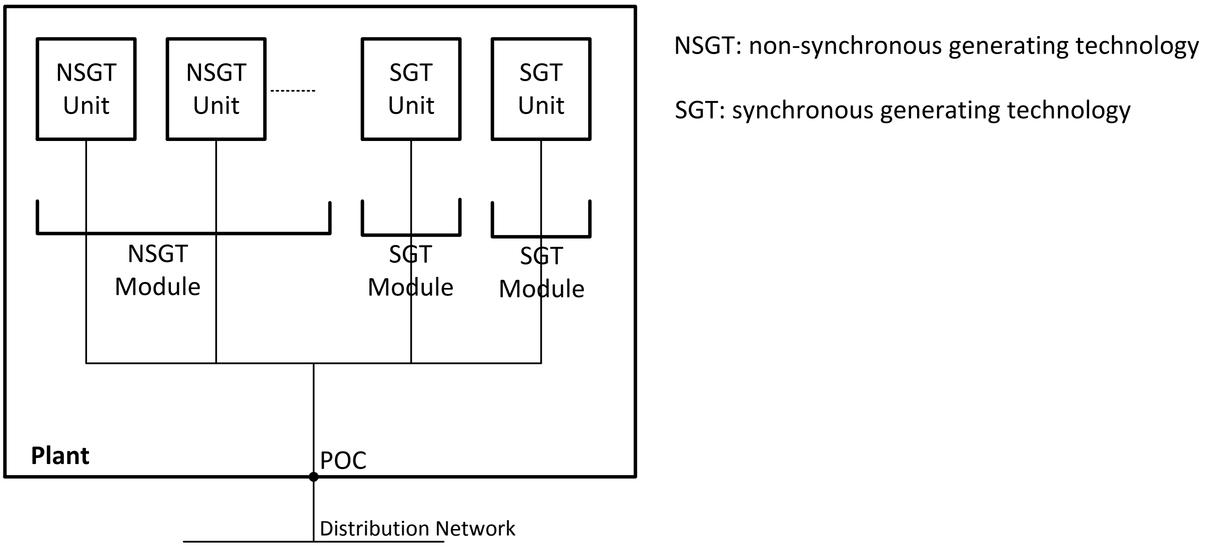

Figure 1 — Generating module at a common POC

3.2.2
generating plant
sum of generating modules connected at one point of connection, including auxiliaries and all connection equipment

Note 1 to entry: In some documents this can mean a power-generating plant.

Note 2 to entry: This definition is intended to be used for verification of compliance to the technical requirements of this standard. It may be different to the legal definition of a plant.

3.2.3
generating unit
smallest set of installations which can generate electrical energy running independently and which can feed this energy into a distribution network

Note 1 to entry: In some documents this can mean a power-generating unit.

Note 2 to entry: For example, a combined cycle gas turbine (CCGT) consisting of a gas turbine and a steam turbine or an installation of an internal combustion engine (ICE) followed by an organic rankine cycle (ORC) machine are considered both as a single generating unit.

Note 3 to entry: If a generating unit is a combination of technologies leading to different requirements, this has to be resolved case by case.

Note 4 to entry: A electrical energy storage EES operating in electricity generation mode and AC connected to the distribution network is considered to be a generating unit.

3.2.4
micro-generating plant
generating plant with generating units having nominal currents in sum not exceeding 16 A per phase

3.2.5
micro-generating unit
generating unit with nominal currents up to and including 16 A per phase

3.2.6
synchronous generating technology
technology where a generating unit is based on a synchronous machine which is directly coupled to an electric power system

3.2.7
non-synchronous generating technology
technology where a generating unit is connected non-synchronously to an electric power system

EXAMPLE induction machine (non-synchronously connected in COMMISSION REGULATION 2016/631), converter based technology (connected through power electronics in COMMISSION REGULATION 2016/631)

3.2.8
cogeneration
combined heat and power
CHP
combined generation of electricity and heat by an energy conversion system and the concurrent use of the electric and thermal energy from the conversion system

3.2.9
Linear Stirling engines
a Stirling engine whose prime mover performs a cyclic linear up and down movement through a magnetic field to generate AC electric power

3.2.10
electrical energy storage system
EES system
EESS
grid-integrated installation with defined electrical boundaries, comprising of at least one EES, whose purpose is to extract electrical energy from an electric power system, store this energy internally in some manner and inject electrical energy into an electrical power system and which includes civil engineering works, energy conversion equipment and related ancillary equipment.

Note 1 to entry: The EES system is controlled and coordinated to provide services to the electric power system operators or to the electric power system users.

Note 2 to entry: In some cases, an EES system may require an additional energy source during its discharge, providing more energy to the electric power system than the energy it stored.

[SOURCE: IEC 62933-1 ED1]

3.2.11
electrical energy storage
EES
installation able to absorb electrical energy, to store it for a certain amount of time and to release electrical energy during which energy conversion processes may be included

EXAMPLE A device that absorbs AC electrical energy to produce hydrogen by electrolysis, stores the hydrogen, and uses that gas to produce AC electrical energy is an EES.

Note 1 to entry: EES may be used also to indicate the activity of an apparatus described in the definition during performing its own functionality.

[SOURCE: IEC 62933-1 ED1]

3.3 Power

3.3.1
P
active power
under periodic conditions, mean value, taken over one period *T*, of the instantaneous power *p*

$$P = \frac{1}{T}\int_0^T p\,\mathrm{d}t$$

Note 1 to entry: Under sinusoidal conditions, the active power is the real part of the complex power $\underline{S}$, thus $P = \mathrm{Re}\,\underline{S}$.
Note 2 to entry: The coherent SI unit for active power is watt, W.
[SOURCE: IEV 131-11-42]

3.3.2
P_D
design active power
maximum AC active power output at an active factor of 0,9 or the active factor specified by the DSO or the responsible party for a certain generating plant or generating technology

3.3.3
P_{max}
maximum active power
maximum continuous active power, measured in a 10 min average, which a generating unit or the sum of all the generating units in a generating plant can produce, minus any loads associated solely with facilitating the operation of that generating plant and not fed into the network as specified in the connection agreement or as agreed between the DSO and the generating plant operator

3.3.5
P_M
momentary active power
actual AC active power output at a certain instant

3.3.6
P_A
available active power
maximum AC active power available from the primary energy source after power conversion subject to the availability and magnitude of that primary energy source at the relevant time

Note 1 to entry: The available active power considers all constraints regarding e.g. the primary energy source or the availability of a heat sink for CHP.

3.3.7
rated current
maximum continuous AC output current which a generating unit or generating plant is designed to achieve under normal operating conditions

3.3.8
S_{max}
maximum apparent power
maximum AC apparent power output, measured in a 10 min average, that the generating unit or the sum of all the generating units in a generating plant is designed to achieve under normal operating conditions

3.3.9
primary energy source
non-electric energy source supplying an electric generating unit

Note 1 to entry: Examples of primary energy sources include natural gas, wind and solar energy. These sources can be utilized, e.g. by gas turbines, wind turbines and photovoltaic cells.

3.4 Voltage

3.4.1
U_n
nominal voltage
voltage by which a supply network is designated or identified and to which certain operating characteristics are referred

3.4.2
f_n
nominal frequency
frequency used to designate and identify equipment or a power system

Note 1 to entry: For the purpose of this standard, the nominal frequency f_n is 50 Hz.

[SOURCE: IEV 151-16-09, modified]

3.4.3
void
3.4.4
reference voltage
value specified as the base on which residual voltage, thresholds and other values are expressed in per unit or percentage terms

Note 1 to entry: For the purpose of this standard, the reference voltage is the nominal voltage of the distribution network.

[SOURCE: EN 50160:2010, 3.18, modified]

3.4.5
voltage change
variation of the r.m.s. value of a voltage between two consecutive levels sustained for definite but unspecified durations

[SOURCE: IEV 161-08-01, modified]

3.4.7
under-voltage ride through
UVRT
ability of a generating unit or generating plant to stay connected during voltage dips

Note 1 to entry: In some documents the expression low voltage ride through (LVRT) is used for the same concept.

3.4.8
over-voltage ride through
OVRT
ability of a generating unit or generating plant to stay connected during voltage swells

Note 1 to entry: In some documents the expression high voltage ride through (HVRT) is used for the same concept.

3.5 Circuit theory

3.5.1
active factor
for a two-terminal element or a two-terminal circuit under sinusoidal conditions, ratio of the active power to the apparent power

Note 1 to entry: In a three phase system, this is referring to the positive sequence component of the fundamental.

Note 2 to entry: The active factor is equal to the cosine of the displacement angle.

[SOURCE: IEV 131-11-49, modified]

3.5.2
φ
displacement angle
under sinusoidal conditions, phase difference between the voltage applied to a linear two-terminal element or two-terminal circuit and the electric current in the element or circuit

Note 1 to entry: In a three phase system, this is referring to the positive sequence component of the fundamental.

Note 2 to entry: The cosine of the displacement angle is the active factor.

[SOURCE: IEV 131-11-48, modified]

3.5.3
power factor
under periodic conditions, ratio of the absolute value of the active power P to the apparent power S:

$$\lambda = \frac{|P|}{S}$$

Note 1 to entry: Under sinusoidal conditions, the power factor is the absolute value of the active factor.

[SOURCE: IEV 131-11-46]

3.5.4
fundamental components of a three-phase system

3.5.4.1
phasor
representation of a sinusoidal integral quantity by a complex quantity whose argument is equal to the initial phase and whose modulus is equal to the root-mean-square value

Note 1 to entry: For a quantity $a(t) = A\sqrt{2}\cos(\omega t + \Theta_0)$ the phasor is $A \exp j\Theta_0$.

Note 2 to entry: The similar representation with the modulus equal to the amplitude is called “amplitude phasor”.

Note 3 to entry: A phasor can also be represented graphically.

[SOURCE: IEV 131-11-26, modified]

3.5.4.2

positive sequence component of the fundamental

for a three-phase system with phases L1, L2 and L3, the symmetrical sinusoidal three-phase set of voltages or currents having frequency equal to the fundamental frequency and which is defined by the following complex mathematical expression:

$$\underline{X}_1 = \frac{1}{3}\left(\underline{X}_{\mathrm{L1}} + \underline{\mathrm{a}}\,\underline{X}_{\mathrm{L2}} + \underline{\mathrm{a}}^2\,\underline{X}_{\mathrm{L3}}\right)$$

where

$\underline{a} = e^{j2\pi/3}$ is the 120 degree operator,

X_{L1}, X_{L2} and X_{L3} are the complex expressions of the fundamental frequency phase quantities concerned, that is, current or voltage phasors

Note 1 to entry: In a balanced harmonic-free system, only positive sequence component of the fundamental exists. For example, if phase voltage phasors are symmetrical $\underline{U}_{L1} = Ue^{j\theta}$, $\underline{U}_{L2} = Ue^{j(\theta+4\pi/3)}$ and $\underline{U}_{L3} = Ue^{j(\theta+2\pi/3)}$ then $\underline{U}_1 = (Ue^{j\theta} + e^{j2\pi/3}\,Ue^{j(\theta+4\pi/3)} + e^{j4\pi/3}\,Ue^{j(\theta+2\pi/3)})/3 = (Ue^{j\theta} + Ue^{j\theta} + Ue^{j\theta})/3 = Ue^{j\theta}$

[SOURCE: IEV 448-11-27]

3.5.4.3

negative sequence component of the fundamental

for a three-phase system with phases L1, L2 and L3, the symmetrical sinusoidal three-phase set of voltages or currents having frequency equal to the fundamental frequency and which is defined by the following complex mathematical expression:

$$\underline{X}_2 = \frac{1}{3}\left(\underline{X}_{\mathrm{L1}} + \underline{\mathrm{a}}^2\,\underline{X}_{\mathrm{L2}} + \underline{\mathrm{a}}\,\underline{X}_{\mathrm{L3}}\right)$$

where

$\underline{a} = e^{j2\pi/3}$ is the 120 degree operator

X_{L1}, X_{L2} and X_{L3} are the complex expressions of the fundamental frequency phase quantities concerned, that is, current or voltage phasors

Note 1 to entry: Negative sequence voltage or current components may be significant only when the voltages or currents, respectively, are unbalanced. For example, if phase voltage phasors are symmetrical $\underline{U}_{L1} = Ue^{j\theta}$, $\underline{U}_{L2} = Ue^{j(\theta+4\pi/3)}$ and $\underline{U}_{L3} = Ue^{j(\theta+2\pi/3)}$ then the negative sequence component $\underline{U}_2 = (Ue^{j\theta} + e^{j4\pi/3}\,Ue^{j(\theta+4\pi/3)} + e^{j2\pi/3}\,Ue^{j(\theta+2\pi/3)})/3 = Ue^{j\theta}\,(1 + e^{j2\pi/3} + e^{j4\pi/3})/3 = 0$.

[SOURCE: IEV 448-11-28]

3.5.4.4

zero sequence component of the fundamental

for a three-phase system with phases L1, L2 and L3, the in-phase sinusoidal voltage or current component having the fundamental frequency and equal amplitude in each of the phases and which is defined by the following complex mathematical expression:

$$\underline{X}_0 = \frac{1}{3}\left(\underline{X}_{\mathrm{L1}} + \underline{X}_{\mathrm{L2}} + \underline{X}_{\mathrm{L3}}\right)$$

where

X_{L1}, X_{L2} and X_{L3} are the complex expressions of the fundamental frequency phase quantities concerned, that is, current or voltage phasors

[SOURCE: IEV 448-11-29]

3.6 Protection

3.6.1
protection system
arrangement of one or more protection equipment, and other devices intended to perform one or more specified protection functions

Note 1 to entry: A protection system includes one or more protection equipment, instrument transformer(s), wiring, tripping circuit(s), auxiliary supply(s) and, where provided, communication system(s). Depending upon the principle(s) of the protection system, it may include one end or all ends of the protected section and, possibly, automatic reclosing equipment.

Note 2 to entry: The circuit-breaker(s) are excluded.

[SOURCE: IEV 448-11-04]

3.6.2
protection relay
measuring relay which detects faults or other abnormal conditions in a power system or of a power equipment

Note 1 to entry: A protection relay is a component part of a protection system.

Note 2 to entry: An interface protection relay is a protection relay acting on the interface switch.

[SOURCE: IEV 447-01-14]

3.6.3
circuit-breaker
mechanical switching device, capable of making, carrying and breaking currents under normal circuit conditions and also making, carrying for a specified duration and breaking currents under specified abnormal circuit conditions such as those of short circuit

[SOURCE: IEV 441-14-20]

3.6.4
interface protection system
protection system that acts on the interface switch

3.6.5
interface protection relay
combination of different protection relay functions which opens the interface switch of a generating unit and prevents its closure, whichever is appropriate in case of:

– a fault on the distribution network (with reference to POC voltage level);

– an islanding situation;

– the presence of voltage and frequency values outside the corresponding regulation values

3.6.6
basic protection
protection against electric shock under fault-free conditions

[SOURCE: IEV 195-06-01]

3.6.7
basic insulation
insulation of hazardous-live-parts which provides basic protection

Note 1 to entry: This concept does not apply to insulation used exclusively for functional purposes.

[SOURCE: IEV 195-06-06]

3.6.8
disconnection
separation of the active parts of the main circuit of the generating unit or plant from the network with mechanical contacts providing at least the equivalent of basic insulation

Note 1 to entry: Passive components like filters, auxiliary power supply to the generating unit and sense circuits can remain connected.

Note 2 to entry: For the design of basic insulation all voltage sources should be considered.

3.6.9
switch
device for changing the electric connections among its terminals

[SOURCE: IEV 151-12-22]

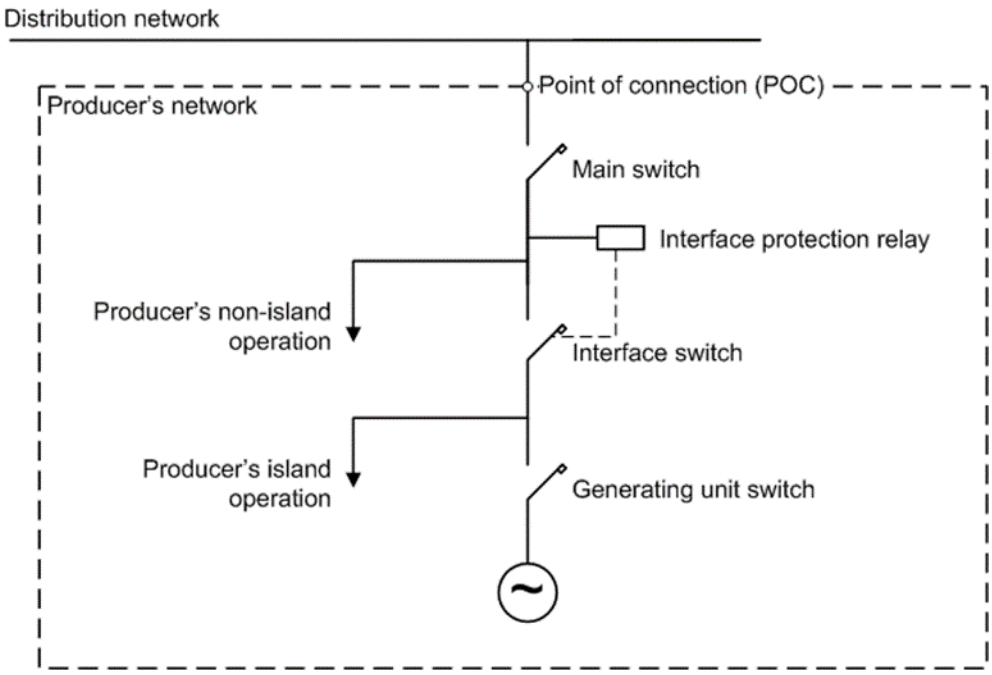

Figure 2 — Example of an generating plant connected to a distribution network (schematic view of switches)

3.6.9.1
main switch
switch installed as close as possible to the point of connection, for protection against internal faults and disconnection of the whole plant from the distribution network

Note 1 to entry: See also Figure 2.

3.6.9.2
interface switch
switch (circuit breaker, switch or contactor) installed in the producer’s network, for separating the part(s) of the producer’s network containing at least one generating unit from the distribution network

Note 1 to entry: See also Figure 2.

Note 2 to entry: In some situations, the interface switch may be used to enable island operation of part of the producer’s network, if technically feasible.

3.6.9.3
generating unit switch
switch installed electrically close to the terminals of each generating unit of the generating plant, for protection and disconnection of that generating unit

Note 1 to entry: See also Figure 2.

3.6.10
observation time
time during which all the voltage and the frequency values are observed to be within a specified range prior to a generating plant connection to the distribution network or start to generate electric power

3.6.11
Interface protection system timing

3.6.11.1
energizing quantity
input value by which the protection function is activated when it is applied under specified conditions

Note 1 to entry: See also Figure 3.

[SOURCE: IEV 442-05-58 modified]

3.6.11.2
start time
duration of the time interval between the instant when the energizing quantity of the measuring relay in reset condition is changed, under specified conditions, and the instant when the start signal asserts

Note 1 to entry: See also Figure 3.

[SOURCE: EN 60255-151, modified]

3.6.11.3
time delay setting
intentional delay that might be adjustable by the user

Note 1 to entry: See also Figure 3.

3.6.11.4
operate time
duration of the time interval between the instant when the energizing quantity of a measuring relay in reset condition is changed, under specified conditions, and the instant when the relay operates

Note 1 to entry: See also Figure 3.

Note 2 to entry: Operate time is start time plus time delay setting.

[SOURCE: IEV 447-05-05, modified]

3.6.11.5
disconnection time
sum of operate time of the protection system and the opening time of the interface switch

Note 1 to entry: See also Figure 3 where the CB opening time indicates the opening time.

3.6.11.6
reset time
duration of the time interval between the instant when the energizing quantity of a measuring relay in operate condition is changed, under specified conditions, and the instant when the relay resets

Note 1 to entry: See also Figure 3.

[SOURCE: IEV 447-05-06, modified]

3.6.11.7
disengaging time
duration of the time interval between the instant a specified change is made in the value of the input energizing quantity which will cause the relay to disengage and instant it disengages

Note 1 to entry: See also Figure 3.

[SOURCE: IEV 447-05-10]

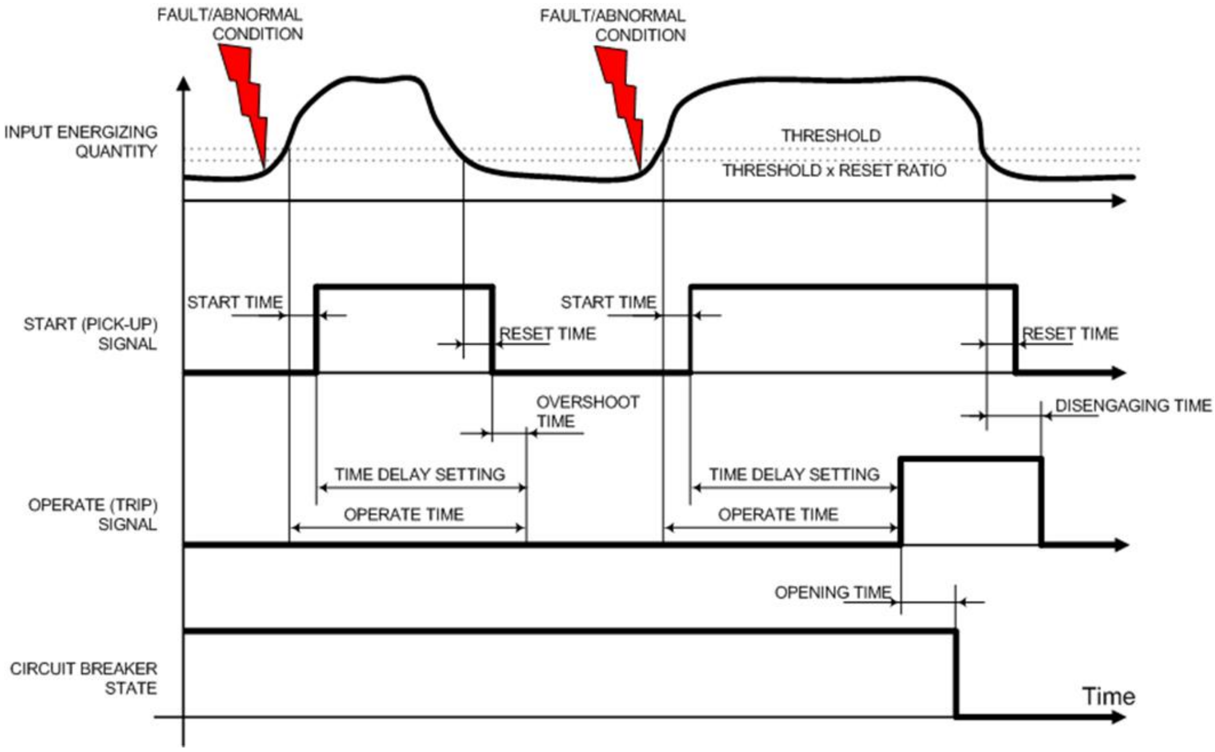

Figure 3 — Main times defining the interface protection performance

3.6.12
islanding
situation where a section of the distribution network, containing generating plants, becomes physically disconnected from the rest of distribution network and one or more generating units maintain a supply of electrical energy to the isolated section of the distribution network

3.7 Control

3.7.1
generating plant controller
functional controller which ensures the completion of performance requirements at the POC of a generating plant, usually by utilizing external measurement signals from the POC to generate reference to a sub structure, e.g. the generating units

3.7.2
droop
ratio of the per-unit change in frequency $(\Delta f)/f_n$ (where f_n is the nominal frequency) to the per-unit change in power $(\Delta P)/P_{ref}$ (where P_{ref} is the reference power):

$s= - (\Delta f/f_n) / (\Delta P/P_{ref})$

[SOURCE: IEV 603-04-08, modified]

3.7.3
step response behaviour

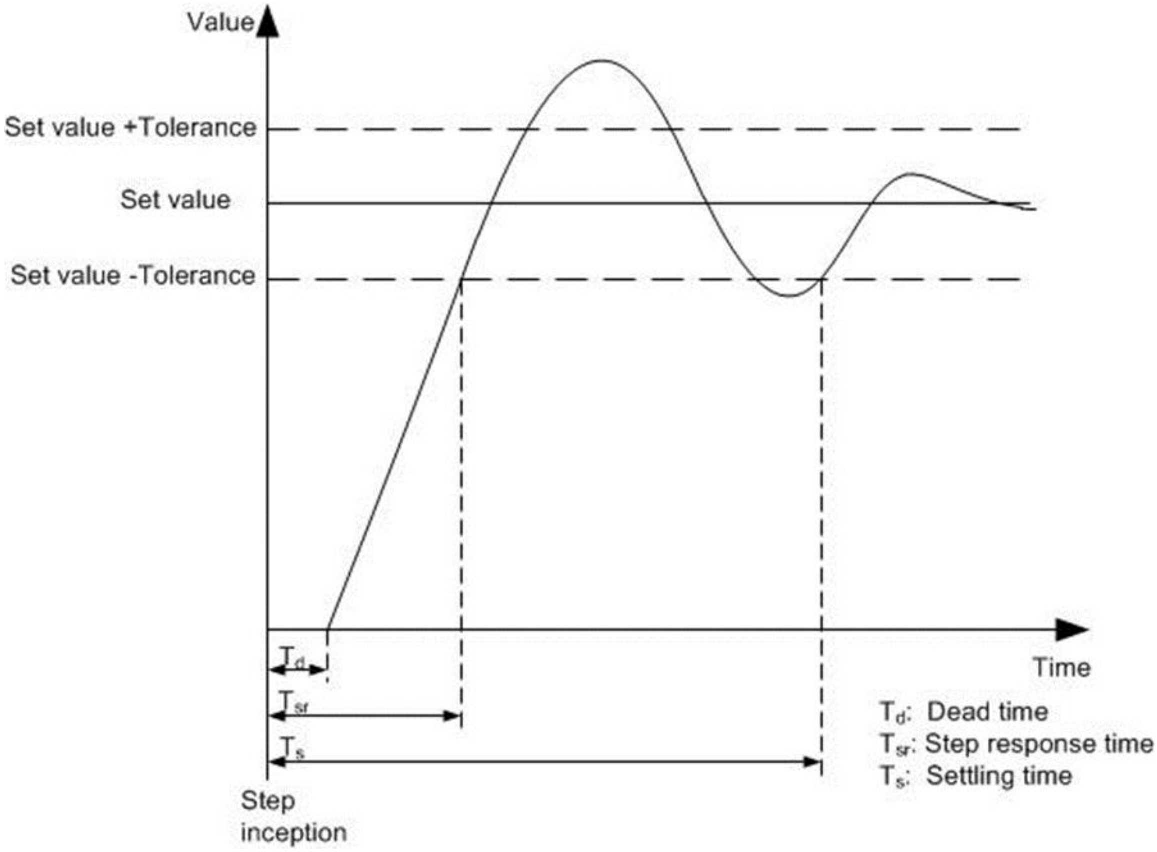

Figure 4 — Timing, step response time and settling time

3.7.3.1
dead time
time from a sudden change of a control quantity until the instant the corresponding change of an output quantity begins

Note 1 to entry: See also Figure 4

3.7.3.2
step response time
time from a sudden change of a control quantity until the instant the corresponding change of an output quantity has reached the tolerance band of the set value for the first time

Note 1 to entry: See also Figure 4.

3.7.3.3
settling time
time from a sudden change of a control quantity until the instant, from where on the corresponding change of an output quantity remains within the tolerance band of the set value

Note 1 to entry: See also Figure 4.

3.8
single fault tolerance
built-in capability of a system to provide continued correct execution of its function in the presence of a single fault

[SOURCE: IEV 394-33-13, modified]

3.9
common cause failures
failures of multiple items, which would otherwise be considered independent of one another, resulting from a single cause

Note 1 to entry: Common cause failures can also be "common mode failures" (IEV 192-03-19).

Note 2 to entry: The potential for common cause failures reduces the effectiveness of system redundancy.

[SOURCE: IEV 192-03-18]

4 Requirements on generating plants

4.1 General

This clause defines the requirements on generating plants to be operated in parallel with the distribution network. Where settings or a range of configurability is provided and respecting the legal framework the configurations and settings may be provided by the DSO. Where no settings are provided by the DSO, the specified default settings shall be used; if no default settings are provided, the producer shall propose settings and inform the DSO.

The requirements of Clause 4 apply during normal operation of the generating units and do not apply in case of maintenance or units out of operation. The provisions apply to EESS in generation mode. In charging mode EESS should have the same characteristics, unless stated otherwise in the clauses of this European Standard.

The applicability is independent of the duration the generating unit operates in parallel with the distribution network. It is the responsibility of the DSO to relax, if deemed appropriate, the requirements for an individual generating unit or plant whose operation in parallel only lasts for a short time (temporary operation in parallel). The relaxed requirements shall be agreed between the DSO and the producer, along with the maximum allowable duration of the temporary operation in parallel. For the short-term parallel operation an appropriate device shall automatically disconnect the generating unit or plant as soon as the maximum allowable duration has elapsed.

If different requirements on the generating plant interfere with each other, the following hierarchy in descending order shall be applied:

1. Generating unit protection, including regarding the prime mover;
2. interface protection (see 4.9) and protection against faults within the generating plant;
3. voltage support during faults and voltage steps (see 4.7.4);
4. the lower value of: remote control command on active power limitation for distribution grid security (see 4.11) and local response to overfrequency (see 4.6.1);
5. local response to underfrequency if applicable (see 4.6.2);
6. reactive power (see 4.7.2) and active power (P(U) see 4.7.3) controls;
7. other control commands on active power set point for e.g. market, economic reasons, self-consumption optimization.

The system shall be so designed that under foreseeable conditions no self-protection trips prior to the fulfilment of the requirements of this European Standard and all settings provided by the DSO or responsible party.

For cogeneration plants embedded in industrial sites, active power requirements shall be agreed between the responsible party and the producer. In such a case the priority list is adapted accordingly.

Besides the requirements of Clause 4, additional requirements apply for connecting a generating plant to the distribution network, e.g. assessment of the point of connection. However, this is excluded from the scope of this European Standard but some guidance is provided in the informative Annex A.

4.2 Connection scheme

The connection scheme of the generating plant shall be in compliance with the requirements of the DSO. Different requirements may be subject to agreement between the producer and the DSO depending on the power system needs.

Inter alia, the generating plant shall ensure the following:

- synchronization, operation and disconnection under normal network operating conditions, i.e. in the absence of faults or malfunctions;
- faults and malfunctions within the generating plant shall not impair the normal functioning of the distribution network;
- coordinated operation of the interface switch with the generating unit switch, the main switch and switches in the distribution network, for faults or malfunctions within the generating plant or the DSO network during operation in parallel with the distribution network; and
- disconnection of the generating plant from the distribution network by tripping the interface switch according to 4.9.

In order to satisfy the above functions, coordinated but independent switches and protection equipment may be applied in the generating plant, as shown in the example in Figure 2.

4.3 Choice of switchgear

4.3.1 General

Switches shall be chosen based on the characteristics of the power system in which they are intended to be installed. For this purpose, the short circuit current at the installation point shall be assessed, taking into account, *inter alia*, the short circuit current contribution of the generating plant.

4.3.2 Interface switch

Switches shall be power relays, contactors or mechanical circuit breakers each having a breaking and making capacity corresponding to the rated current of the generating plant and corresponding to the short circuit contribution of the generating plant.

The short-time withstand current of the switching devices shall be coordinated with rated short circuit power at the point of connection.

In case of loss of auxiliary supply power to the switchgear, a secure disconnection of the switch is required immediately.

Where means of isolation (according to HD 60364-5-551) is not required to be accessible to the DSO at all times, automatic disconnection with single fault tolerance according to 4.13 shall be provided.

NOTE 1 For PV-inverters, further requirements are stated in EN 62109–1 and EN 62109–2 with respect to the interface switch.

The function of the interface switch might be combined with either the main switch or the generating unit switch in a single switching device. In case of a combination, the single switching device shall be compliant to the requirements of both, the interface switch and the combined main switch or generating unit switch. As a consequence, at least two switches in series shall be present between any generating unit and the POC.

NOTE 2 This does not refer to the number of series-connected switches in order to ensure single fault tolerance as required in 4.13 but to the number of different switching devices itself.

4.4 Normal operating range

4.4.1 General

Generating plants when generating power shall have the capability to operate in the operating ranges specified below regardless of the topology and the settings of the interface protection.

4.4.2 Operating frequency range

The generating plant shall be capable of operating continuously when the frequency at the point of connection stays within the range of 49 Hz to 51 Hz.

In the frequency range from 47 Hz to 52 Hz the generating plant should be capable of operating until the interface protection trips. Therefore, the generating plant shall at least be capable of operating in the frequency ranges, for the duration and for the minimum requirement as indicated in Table 1.

Respecting the legal framework, it is possible that for some synchronous areas more stringent time periods and/or frequency ranges will be required by the DSO and the responsible party. Nevertheless, they are expected to be within the boundaries of the stringent requirement as indicated in Table 1 unless producer, DSO, TSO and responsible party agree on wider frequency ranges and longer durations.

NOTE 1 For small isolated distribution networks (typically on islands) even more stringent time periods and frequency ranges may be required.

As long as generating modules with linear Sterling engines are recognized as emerging technology according to COMMISSION REGULATION (EU) 2016/631 Title 6, they are permitted to disconnect below 49,5 Hz and above 50,5 Hz.

This permission does not affect the requirements for interface protection according to clause 4.9. In this case over and under frequency machine protection might trip prior to interface protection. If an integrated interface protection device is used, the reduction of the configuration range of the interface protection in clause 4.9 is acceptable.

NOTE 2: The status of emerging technology in COMMISSION REGULATION (EU) 2016/631 Title 6 depends on the cumulative maximum capacity of this technology. Once the threshold in cumulative maximum capacity is reached the status will be withdrawn

Table 1 — Minimum time periods for operation in underfrequency and overfrequency situations

Frequency Range	Time period for operation Minimum requirement	Time period for operation stringent requirement
47,0 Hz – 47,5 Hz	not required	20 s
47,5 Hz – 48,5 Hz	30 min [a]	90 min
48,5 Hz – 49,0 Hz	30 min [a]	90 min [a]
49,0 Hz – 51,0 Hz	Unlimited	Unlimited
51,0 Hz – 51,5 Hz	30 min [a]	90 min
51,5 Hz – 52,0 Hz	not required	15 min

[a] Respecting the legal framework, it is possible that longer time periods are required by the responsible party in some synchronous areas.

4.4.3 Minimal requirement for active power delivery at underfrequency

A generating plant shall be resilient to the reduction of frequency at the point of connection while reducing the maximum active power as little as possible.

The admissible active power reduction due to underfrequency is limited by the full line in Figure 5 and is characterized by a maximum allowed reduction rate of 10 % of P_{max} per 1 Hz for frequencies below 49,5 Hz.

It is possible that a more stringent power reduction characteristic is required by the responsible party. Nevertheless this requirement is expected to be limited to an admissible active power reduction represented by the dotted line in Figure 5 which is characterised by a reduction rate of 2 % of the maximum power P_{max} per 1 Hz for frequencies below 49 Hz.

If any technologies intrinsic design or ambient conditions have influence on the power reduction behaviour of the system, the manufacturer shall specify at which ambient conditions the requirements can be fulfilled and eventual limitations. The information can be provided in the format of a graph showing the intrinsic behaviour of the generating unit for example at different ambient conditions. The power reduction and the ambient conditions shall comply with the specification given by the responsible party. If the generating unit does not meet the power reduction at the specified ambient conditions, the producer and the responsible party shall agree on acceptable ambient conditions.

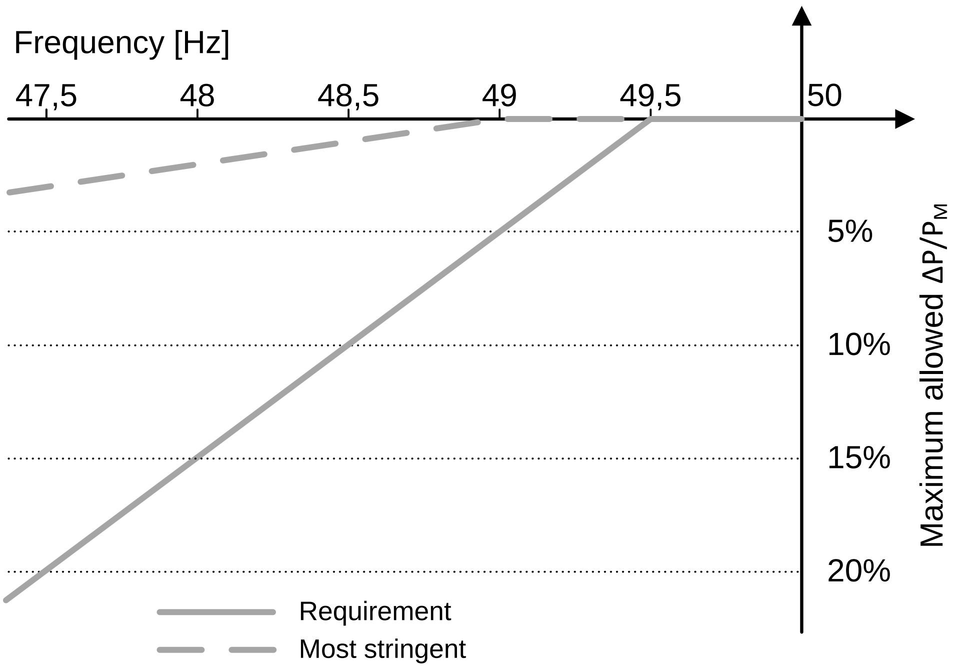

Figure 5 — Maximum allowable power reduction in case of underfrequency

4.4.4 Continuous operating voltage range

When generating power, the generating plant shall be capable of operating continuously when the voltage at the point of connection stays within the range of 85 % U_n to 110 % U_n. Beyond these values the under and over voltage ride through immunity limits as specified in clause 4.5.3 and 4.5.4 shall apply.

In case of voltages below U_n, it is allowed to reduce the apparent power to maintain the current limits of the generating plant. The reduction shall be as small as technically feasible.

For this requirement all phase to phase voltages and in case a neutral is connected, additionally all phase to neutral voltages shall be evaluated.

NOTE The specified accepted reduction of output power is an absolute minimum requirement. Further power system aspects might require maintained output power in the entire continuous operation voltage range.

The producer shall take into account the typical voltage rise and voltage drop within the generating plant.

4.5 Immunity to disturbances

4.5.1 General

In general, generating plants should contribute to overall power system stability by providing immunity towards dynamic voltage changes unless safety standards require a disconnection.

The following clauses describe the required immunity for generating plants taking into account the connection technology of the generating modules.

The following withstand capabilities shall be provided regardless of the settings of the interface protection.

NOTE An event on the HV and EHV transmission network can affect numerous small scale units on MV and LV level. Depending on the penetration of dispersed generation, a significant loss of active power provision can be caused.

4.5.2 Rate of change of frequency (ROCOF) immunity

ROCOF immunity of a power generating plant means that the generating modules in this plant stay connected with the distribution network and are able to operate when the frequency on the distribution network changes with a specified ROCOF. The generating units and all elements in the generating plant that might cause their disconnection or impact their behaviour shall have this same level of immunity.

The generating modules in a generating plant shall have ROCOF immunity for a ROCOF equal or exceeding the value specified by the responsible party. If no ROCOF immunity value is specified, the following ROCOF immunity shall apply, making distinction between generating technologies:

- Non-synchronous generating technology: at least 2 Hz/s
- Synchronous generating technology: at least 1 Hz/s

The ROCOF immunity is defined with a sliding measurement window of 500 ms.

NOTE 1 For control action based on frequency measurement shorter measurement periods are expected to be necessary.

NOTE 2 For small isolated distribution networks (typically on islands) higher ROCOF immunity values may be required.

NOTE 3 ROCOF is used as a means to detect loss of mains situations in some countries. The ROCOF immunity requirement is independent of the interface protection settings. Disconnection settings of the interface protection relay always overrule technical capabilities. So, whether the generating plant will stay connected or not will also depend upon those settings.

4.5.3 Under-voltage ride through (UVRT)

4.5.3.1 General

Generating modules classified as Type B modules according to COMMISSION REGULATION 2016/631 shall comply with the requirements of 4.5.3.2 and 4.5.3.3. Generating modules classified as Type A and smaller according to COMMISSION REGULATION 2016/631 should comply with these requirements. The actual behaviour of Type A modules shall be specified in the connection agreement.

NOTE 1 Based on the chosen banding threshold it is considered necessary to include generating modules classified as Type A. Exemption is only acceptable for CHP and generating units based on rotating machinery below 50 kW as EN 50465 for gas appliance requests disconnection in case of under voltage.

The requirements apply to all kinds of faults (1ph, 2ph and 3ph).

NOTE 2 A more distinctive differentiation for 1ph, 2ph and 3ph faults is under consideration.

NOTE 3 These requirements are independent of the interface protection settings. Disconnection settings of the interface protection relay will always overrule technical capabilities. So, whether the generating plant will stay connected or not will also depend upon those settings.

NOTE 4 The FRT curves in Figure 6, Figure 7 and Figure 8 describe the minimum requirements for continued connection of the generating plant to the grid. They are not designed for parameterising the interface protection.

4.5.3.2 Generating plant with non-synchronous generating technology

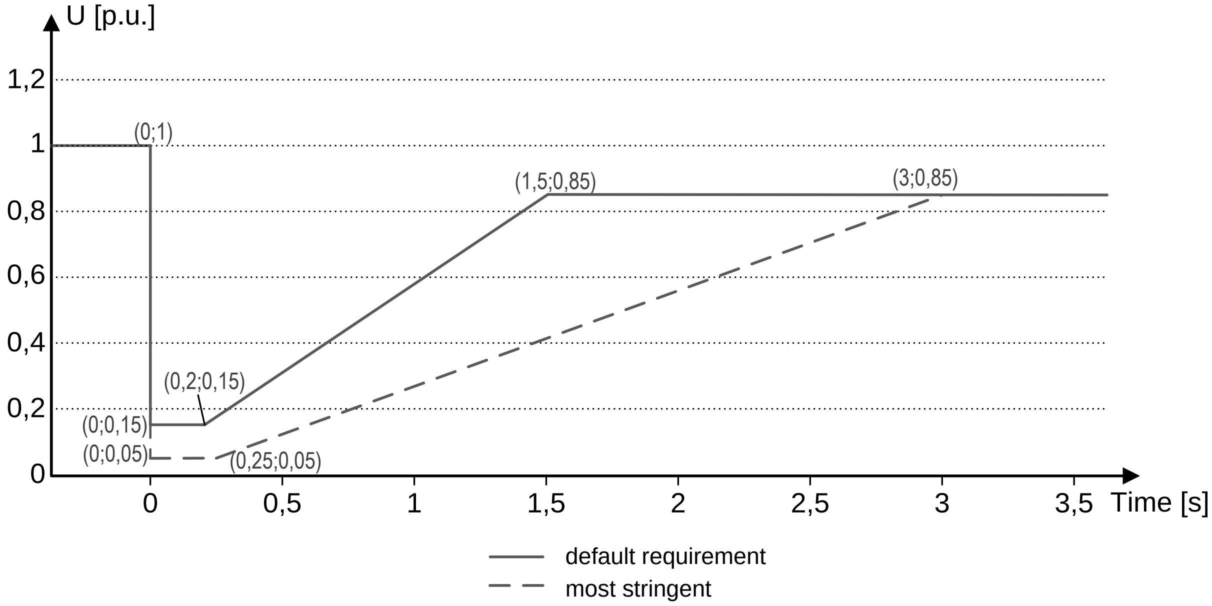

Figure 6 — Under-voltage ride through capability for non-synchronous generating technology

Generating modules shall be capable of remaining connected to the distribution network as long as the voltage at the point of connection remains above the voltage-time curve of Figure 6. The voltage is relative to U_n. The smallest phase to neutral voltage, or if no neutral is present, the smallest phase to phase voltage shall be evaluated.

The responsible party may define a different UVRT characteristic. Nevertheless, this requirement is expected to be limited to the most stringent curve as indicated in Figure 6.

This means that the whole generating module has to comply with the UVRT requirement. This includes all elements in a generating plant: the generating units and all elements that might cause their disconnection.

For the generating unit, this requirement is considered to be fulfilled if it stays connected to the distribution grid as long as the voltage at its terminals remains above the defined voltage-time diagram.

After the voltage returns to continuous operating voltage range, 90 % of pre-fault power or available power whichever is the smallest shall be resumed as fast as possible, but at the latest within 1 s unless the DSO and the responsible party requires another value.

4.5.3.3 Generating plant with synchronous generating technology

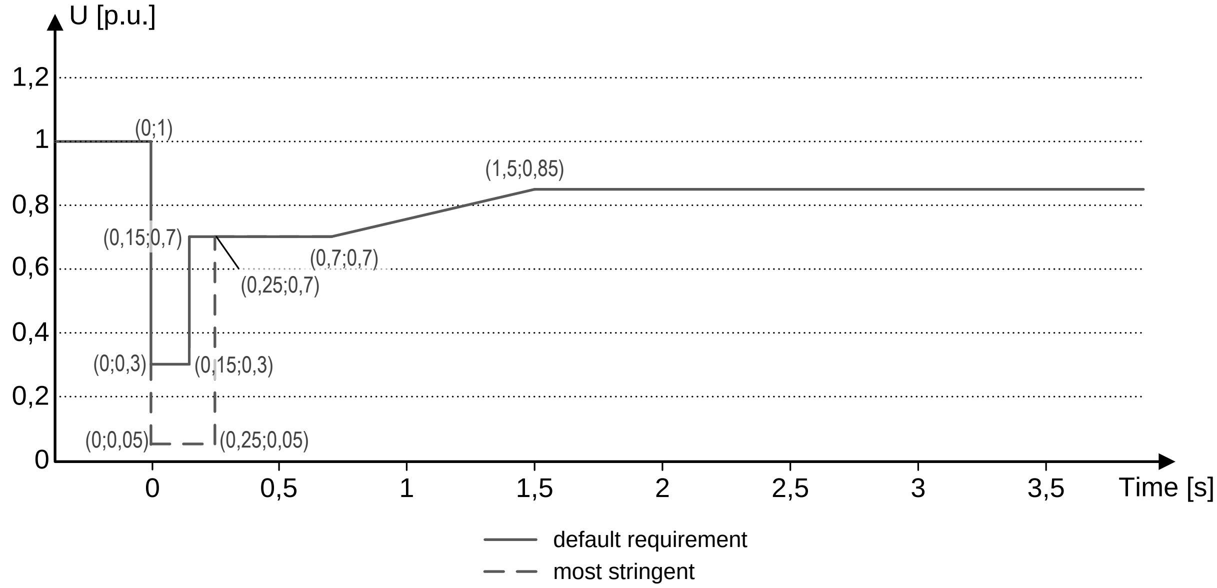

Figure 7 — Under-voltage ride through capability for synchronous generating technology

Generating modules shall be capable of staying connected to the distribution network as long as the voltage at the point of connection remains above the voltage-time curve of Figure 7. The voltage is relative to U_n. The smallest phase to neutral voltage or if no neutral is present the smallest phase to phase voltage shall be evaluated.

The responsible party may define a different UVRT characteristic. Nevertheless, this requirement is expected to be limited to the most stringent curve, indicated in Figure 7.

This means that the whole generating module has to comply with the UVRT requirement. This includes all elements in a generating plant: the generating units and all elements that might cause its disconnection.

For the generating unit, this requirement is considered to be fulfilled if it stays connected to the distribution grid as long as the voltage at its terminals remains above the defined voltage-time diagram.

After the voltage returns to continuous operating voltage range, 90 % of pre-fault power or available power whichever is the smallest shall be resumed as fast as possible, but at the latest within 3 s unless the DSO and the responsible party requires another value.

4.5.4 Over-voltage ride through (OVRT)

Generating modules, except for micro-generating plants, shall be capable of staying connected to the distribution network as long as the voltage at the point of connection remains below the voltage-time curve of Figure 8.

The highest phase to neutral voltage or if no neutral is present the highest phase to phase voltage shall be evaluated.

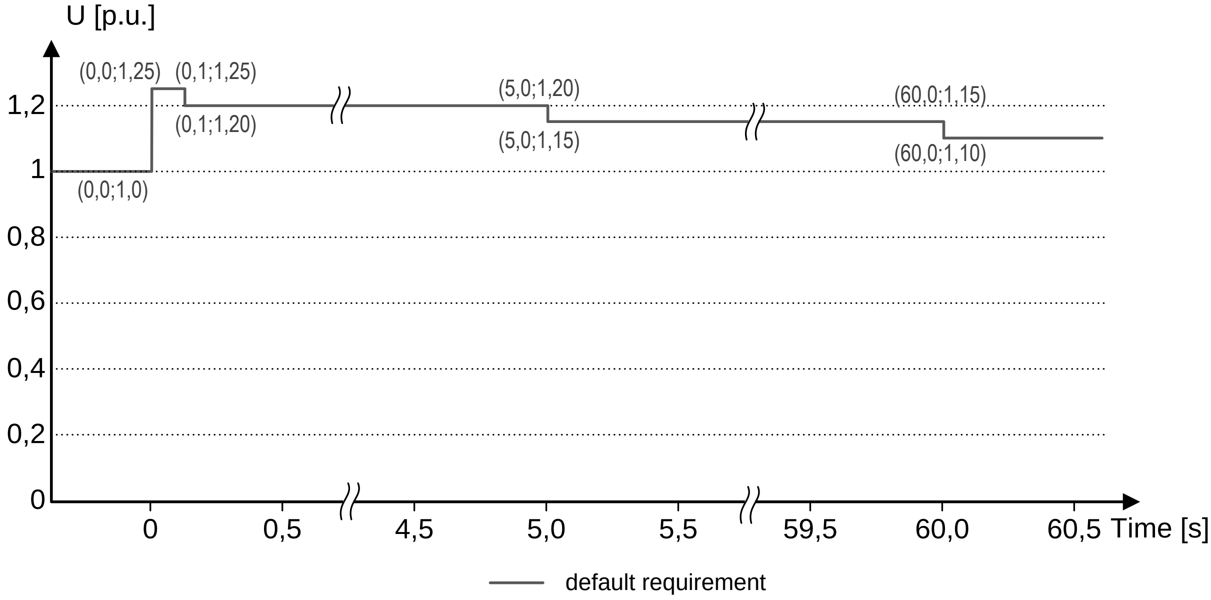

Figure 8 — Over-voltage ride through capability

This means that not only the generating units shall comply with this OVRT requirement but also all elements in a generating plant that might cause its disconnection.

NOTE 1 Based on the chosen banding threshold it is considered necessary to include generating modules classified as Type A. Exemption is only acceptable for CHP and generating units based on rotating machinery below 50 kW as EN 50465 for gas appliance requests disconnection in case of over voltage.

NOTE 2 These requirements are independent of the interface protection settings. Disconnection settings of the interface protection relay will always overrule technical capabilities. So, whether the generating plant will stay connected or not will also depend upon those settings.

NOTE 3 This is a minimum requirement. Further power system stability aspects might be relevant. The technical discussion is still ongoing. A voltage jump of +10 % of Un from any stable point of operation is considered. In case of steady state voltages near the maximum voltage before the event, this will result in an over voltage situation for many seconds. In later editions of this document, more stringent immunity might be required.

4.6 Active response to frequency deviation

4.6.1 Power response to overfrequency

Generating plants shall be capable of activating active power response to overfrequency at a programmable frequency threshold f_1 at least between and including 50,2 Hz and 52 Hz with a programmable droop in a range of at least s=2 % to s=12 %. The droop reference is P_{ref}. Unless defined differently by the responsible party, in the case of synchronous generating technology and electrical energy storage, $P_{ref}=P_{max}$. In the case of all other non-synchronous generating technology $P_{ref}=P_M$, the actual AC output power at the instant when the frequency reaches the threshold f_1. If the available primary power decreases during a high frequency period below the power defined by the droop function, lower power values are permitted. The power value calculated according to the droop is therefore a maximum limit.

The maximum power limit is:

$$P_{max-limit} = P_M + \Delta P$$

with $\Delta P = \frac{1}{s} \cdot \frac{(f_1 - f)}{f_n} \cdot P_{ref}$

with f the actual frequency

NOTE 1 In other documents power response to overfrequency can also be described as frequency control or Limited Frequency Sensitive Mode - Overfrequency (LFSM-O).

NOTE 2 Respecting the legal framework, it is possible that, as an alternative to P_M, the maximum active power P_{max} is required as P_{ref} by the DSO and the responsible party.

NOTE 3 The active power droop relative to the reference power might also be defined as an active power gradient relative to the reference power. A droop in the range of 2 % to 12 % represents a gradient of 100 % to 16,7 % P_{ref} /Hz so with g defined by $g\left[\frac{P}{P_{ref}}/Hz\right] = \frac{1}{s \cdot f_n}$ we get $\Delta P = g \cdot P_{ref} \cdot (f_1 - f)$.

The generating plant shall be capable of activating active power response to overfrequency as fast as technically feasible with an intrinsic dead time that shall be as short as possible with a maximum of 2 s and with a step response time of maximum 30 s, unless another value is defined by the relevant party. An intentional delay shall be programmable to adjust the dead time to a value between the intrinsic dead time and 2 s.

NOTE 4 The following response times are considered feasible, for PV and battery inverters below 1 s for ΔP of 100 % P_{max} and for wind turbines 2 s for ΔP < 50 % P_{max}.

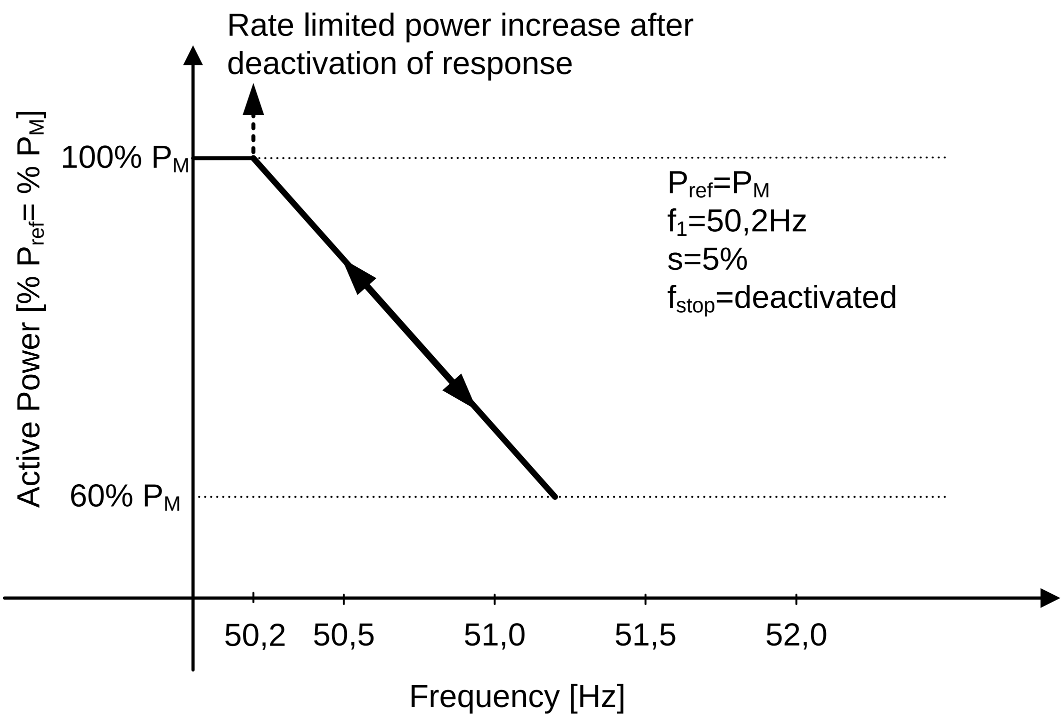

Figure 9 — Example of Active power frequency response to overfrequency

After activation, the active power frequency response shall use the actual frequency at any time, reacting to any frequency increase or decrease according to the programmed droop with an accuracy of ± 10 % of the nominal power (see Figure 9). The resolution of the frequency measurement shall be ± 10 mHz or less. The accuracy is evaluated with a 1min average value. At POC, loads if present in the producer's network might interfere with the response of the generating plant. The effect of loads is not considered for the evaluation of the accuracy, only the behaviour of the generating plant is relevant.

NOTE 5 With the provision above, the intentional delay is only active for the activation of the function, once the function is operating, the established control loop is not intentionally delayed.

NOTE 6 The option of an intentional delay is required since a very fast and undelayed active power frequency response in case of loss of mains would correct any excess of generation leading to a generation-consumption balance. In these circumstances, an unintended islanding situation with stable frequency would take place, in which the correct behaviour of any loss of mains detection based on frequency might be hindered.

NOTE 7 The intentional delay is considered relevant for power system stability. For that reason, legal regulations might require a mutual agreement on the setting between DSO, responsible party and TSO.

Generating plants reaching their minimum regulating level shall, in the event of further frequency increase, maintain this power level constant unless the DSO and the responsible party requires to disconnect the complete plant or if the plant consists of multiple units by disconnecting individual units.

The active power frequency response is only deactivated if the frequency falls below the frequency threshold $f_{1.}$

If required by the DSO and the responsible party an additional deactivation threshold frequency f_{stop} shall be programmable in the range of at least 50 Hz to f_1. If f_{stop} is configured to a frequency below f_1 there shall be no response according to the droop in case of a frequency decrease (see Figure 10). The output power is kept constant until the frequency falls below f_{stop} for a configurable time t_{stop}.

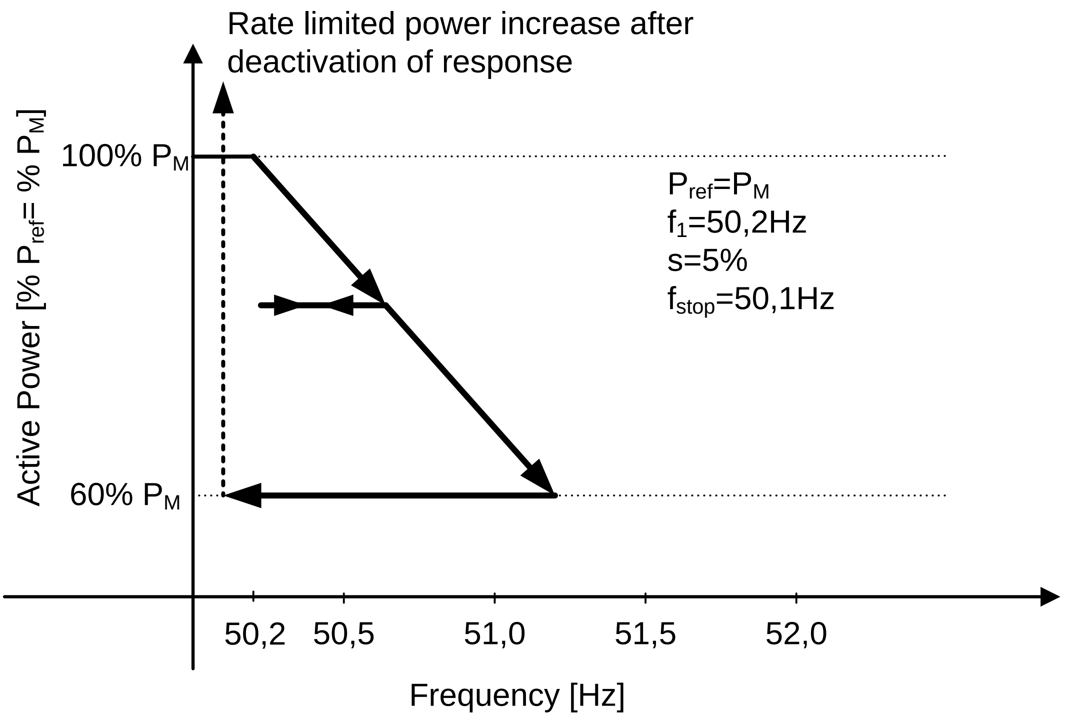

Figure 10 — Example of active power frequency response to overfrequency with configured deactivation threshold

If at the time of deactivation of the active power frequency response the momentary active power P_M is below the available active power $P_{A,}$ the active power increase of the generating plant shall not exceed the gradient defined in 4.10.2.

Settings for the threshold frequency f_1, the droop and the intentional delay are provided by the DSO and the responsible party. If no settings are provided, the default settings in Table 2 should be applied.

NOTE 8 When applying active power response to overfrequency, the frequency threshold f_1 should be set to a value from 50,2 Hz up to 50,5 Hz. Setting the frequency threshold f_1 to 52 Hz is considered as deactivating this function.

Table 2 — Standard settings for frequency response to overfrequency

Parameter	Range	Default setting
Threshold frequency f_1	**50,2 Hz to 52 Hz**	**50,2 Hz**
Deactivation threshold f_{stop}	**50,0 Hz to f_1**	**Deactivated**
Deactivation time t_{stop}	**0 to 600 s**	**30s**
Droop	**2 % to 12 %**	**5 %**
Intentional delay	**0 s to 2 s**	**0 s**

The enabling and disabling of the function and its settings shall be field adjustable and means shall be provided to protect these from unpermitted interference (e.g. password or seal) if required by the DSO and the responsible party.

NOTE 9 PV generating units are considered to have the ability to reduce power over the full droop range.

NOTE 10 Protection setting overrules this behaviour.

Alternatively for the droop function described above, the following procedure is allowed for generating modules if permitted by the DSO and the responsible party:

- the generating units shall disconnect at randomized frequencies, ideally uniformly distributed between the frequency threshold f_1 and 52 Hz;

NOTE 11 The usage of a disconnection limit above 51,5Hz does not necessarily imply the requirement to operate at this frequency. Operating range is defined in clause 4.4.4. If the randomized disconnection value is above the operating range and interface protection setting, the unit is disconnected according to chapter 4.9 at the value set by the interface protection.

- in case the frequency decreases again, the generating unit shall start its reconnection procedure once the frequency falls below the specific frequency that initiated the disconnection; for this procedure, the connection conditions described in 4.10 do not apply;

- the randomization shall either be at unit level by changing the threshold over time, or on plant level by choosing different values for each unit within a plant, or on distribution system level if the DSO specifies a specific threshold for each plant or unit connected to its distribution system.

NOTE 12 This procedure could be applied for generating modules for which it is technically not feasible to reduce power with the required accuracy in the required time or for reasons within the distribution network for example to prevent unintentional island operation.

NOTE 13 The behaviour will, for a part of the network with many such units, result in a similar droop as specified above for controllable generating units and hence will provide for the necessary power system stability. Due to its fast reaction capability it contributes significantly to the avoidance of a frequency overshoot.

Storage units that are in charging mode at the time the frequency passes the threshold f_1 shall not reduce the charging power below P_M until frequency returns below f_1. Storage units should increase the charging power according to the configured droop. In case the maximum charging capacity is reached or to prevent any other risk of injury or damage of equipment, a reduction of charging power is permitted.

4.6.2 Power response to underfrequency

EESS generating units in generating plants shall be capable of activating active power response to underfrequency. Other generating units/plants should be capable of activating active power response to underfrequency. If active power to underfrequency is provided by a generating plant/unit, the function shall comply with the requirements below.

NOTE 1: In other documents power response to underfrequency is also described as frequency control or Limited Frequency Sensitive Mode - Underfrequency (LFSM-U).

Active power response to underfrequency shall be provided when all of the following conditions are met:

- if generating, the generating unit is operating at active power below its maximum active power P_{max};

- if generating, the generating unit is operating at active power below the available active power P_A;

NOTE 2 In case of storage units, the available power includes the state of charge of the storage.

- the voltages at the point of connection of the generating plant are within the continuous operating voltage range; and

- if generating, the generating unit is operating with currents lower than its current limit.

NOTE 3 These conditions apply to each generating unit individually since the specified conditions need to be met by each generating unit individually to allow the unit to increase power.

In the case of EESS generating units, active power frequency response to underfrequency shall be provided in charging and generating mode.

NOTE 4 In the case of EESS generating units, the charging is regarded as a point of operation with negative active power. In charging mode the active power consumption is reduced according to the configured droop. Depending on the depth of the underferquency event a change to generating mode will happen. In this case the state of charge of the storage is part of the conditions above.

NOTE 5 This clause provides additional detail to the draft network code on electricity emergency and restoration Article 15 3 (a). If during the comitology process of the code there are changes made to Article 15, this EN will be revised if necessary.

The active power response to underfrequency shall be delivered at a programmable frequency threshold f_1 at least between and including 49,8 Hz and 46,0 Hz with a programmable droop in a range of at least 2 % to 12 %. The droop reference P_{ref} is P_{max}. If the available primary power or a local set value increases during an underfrequency period above the power defined by the droop function, higher power values are permitted. The power value calculated according to the droop is therefore a minimum limit.

The minimum power limit is,

$$P_{min-limit} = P_M + \Delta P$$

with $\Delta P = \frac{1}{s} \times \frac{(f1-f)}{fn} \times Pref$

with f the actual frequency

NOTE 6 In the case of active power response to underfrequency, P_{max} is used as P_{ref} to allow for system support even in case of low power output in the moment the event begins.

NOTE 7 The active power droop relative to the reference power might also be defined as an active power gradient relative to the reference power. A droop in the range of 2 % to 12 % represents a gradient of 100 % to 16,7 % P_{ref} /Hz so with g defined by $g\left[\frac{P}{P_{ref}}/Hz\right] = \frac{1}{s \cdot f_n}$ we get $\Delta P = g \cdot P_{ref} \cdot (f_1 - f)$.

NOTE 8 In the case of an increase of active power generation, the hierarchy of requirements in clause 4.1 apply.

The generating unit shall be capable of activating active power response to underfrequency as fast as technically feasible with an intrinsic dead time that shall be as short as possible with a maximum of 2 s and with a step response time of maximum 30 s unless another value is defined by the relevant party. An intentional initial delay shall be programmable to adjust the dead time to a value between the intrinsic dead time and 2 s.

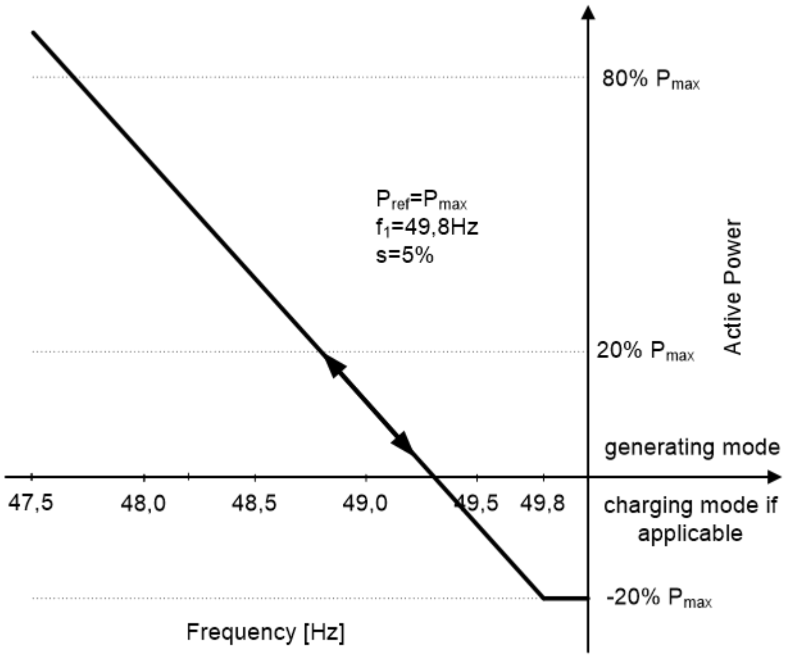

Figure 11 — Example of active power frequency response to underfrequency in case of storage device with 20 % power charging at passing of threshold frequency f_1

After activation, the active power frequency response shall use the actual frequency at any time, reacting to any frequency increase or decrease according to the programmed droop with an accuracy of ± 10 % of the nominal power. The accuracy is evaluated with a 1min average value. The resolution of the frequency measurement shall be ± 10 mHz or less. At POC loads, if present in the producer’s network, might interfere with the response of the generating plant. The effect of loads is not considered for the evaluation of the accuracy, only the behaviour of the generating plant is relevant.

NOTE 9 With the provision above, the intentional delay is only active for the activation of the function, once the function is operating, the established control loop is not intentionally delayed.

NOTE 10 The option of an intentional delay is required since a very fast and undelayed active power frequency response in case of loss of mains would correct any shortage of generation leading to a generation-consumption balance. In these circumstances, an unintended islanding situation with stable frequency would take place, in which the correct behaviour of any loss of mains detection based on frequency might be hindered.

NOTE 11 The intentional delay is considered relevant for power system stability. For that reason, legal regulations might require a mutual agreement on the setting between DSO, responsible party and TSO.

Generating modules reaching any of the conditions above during the provision of active power frequency response shall, in the event of further frequency decrease, maintain this power level constant.

The active power frequency response is only deactivated if the frequency increases above the frequency threshold f_1.

Settings for the threshold frequency f_1, the droop and the intentional delay are defined by the DSO and the responsible party, if no settings are provided, the function shall be disabled.

NOTE 12 When applying active power response to underfrequency, the frequency threshold f_1 should be set to a value from 49,8 Hz up to 49,5 Hz. Setting the frequency threshold f_1 to 46 Hz is considered as deactivating this function.

The activation and deactivation of the function and its settings shall be field adjustable and means shall be provided to protect these from unpermitted interference (e.g. password or seal) if required by the DSO and the responsible party.

4.7 Power response to voltage changes

4.7.1 General

When the contribution to voltage support is required by the DSO and the responsible party, the generating plant shall be designed to have the capability of managing reactive and/or active power generation according to the requirements of this clause.

4.7.2 Voltage support by reactive power

4.7.2.1 General

Generating plants shall not lead to voltage changes out of acceptable limits. These limits should be defined by national regulation. Generating units and plants shall be able to contribute to meet this requirement during normal network operation.

Throughout the continuous operating frequency (see 4.4.2) and voltage (see 4.4.4) range, the generating plant shall be capable to deliver the requirements stipulated below. Outside these ranges, the generating plant shall follow the requirements as good as technically feasible although there is no specified accuracy required.

4.7.2.2 Capabilities

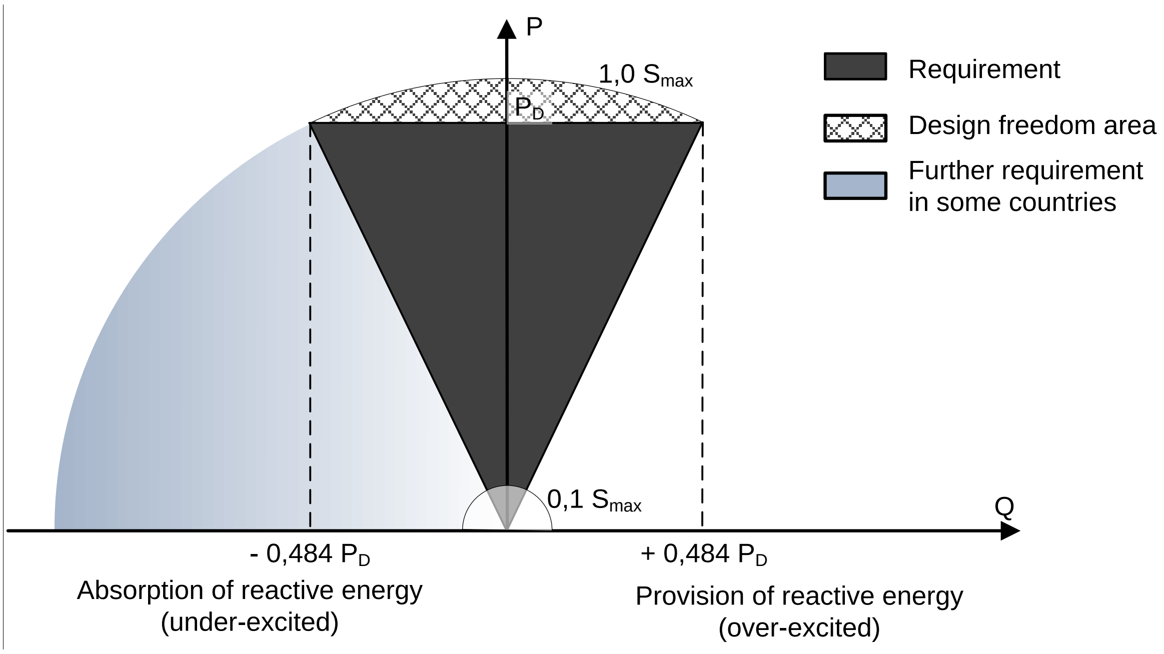

Figure 12 — Reactive power capability at nominal voltage

Figure 12 gives a graphical representation of the minimum and optional capabilities at nominal voltage.

Unless specified differently below, for specific generating technologies, generating plants shall be able to operate with active factors as defined by the DSO and the responsible party from active factor = $0{,}90_{underexcited}$ to active factor= $0{,}90_{overexcited}$ at the terminals of the/each generating unit

CHP generating units with a capacity ≤ 150 kVA shall be able to operate with active factors as defined by the DSO from $\cos \varphi = 0{,}95_{underexcited}$ to $\cos \varphi = 0{,}95_{overexcited}$

Generating units with an induction generator coupled directly to the grid and used in generating plants above micro generating level, shall be able to operate with active factors as defined by the DSO from $\cos \varphi = 0{,}95_{underexcited}$ to $\cos \varphi = 1$ at the terminals of the unit. Deviating from 4.7.2.3 only the cos φ set point mode is required. Deviating from the accuracy requirements below, the accuracy is only required at active power P_D.

Generating units with an induction generator coupled directly to the grid and used in micro generating plants shall operate with an active factor above 0.95 at the terminals of the generating unit. A controlled voltage support by reactive power is not required from this technology.

Generating units with linear generators, coupled directly and synchronously to the grid shall operate with an active factor above 0.95 at the terminals of the generating unit, and therefore a controlled voltage support by reactive power is not required from this technology.

In case of different generating technologies with different requirements in one generating plant, each unit shall provide voltage support by reactive power as required for its specific technology. A compensation of one technology to reach the general plant requirement is not expected.

The DSO and the responsible party may relax the above requirements. This relaxation might be general or specific for a certain generating plant or generating technology.

NOTE 1 The generating unit manufacturer has a certain freedom in the sizing of the output side of the generating unit considering the advantages and drawbacks in the practical use of the generating unit when evaluating the need to reduce active output power (e.g. due to voltage changes or reactive power exchange) in order to respond to the requirements of this European Standard. This is indicated by the Design freedom area in Figure 12.

All involved parties can expect to have access to information documenting the actual choices regarding active power capabilities relative to reactive power requirements and related to the power rating in the operating voltage range (see further in this clause). A P-Q Diagram shall be included in the product documentation of a generating unit.

NOTE 2 For additional network support an optional extended reactive power capability according to Figure 12 might be provided by the generating plant, if agreed on between the DSO and the producer and is generally required in some countries for some technologies by legal regulations.

NOTE 3 Additional requirements (e.g. continuous Var compensation or continuous reactive power operation disregarding the availability of the primary energy) might be provided by the generating plant, if agreed between the DSO and the producer.

NOTE 4 In case of overvoltage, additional reactive power might be exchanged up to the rated current (increasing the apparent power as a consequence), if agreed on between the DSO and the producer.

When operating above the apparent power threshold S_{min} equal to 10 % of the maximum apparent power S_{max} or the minimum regulating level of the generating plant, whichever is the higher value, the reactive power capability shall be provided with an accuracy of ± 2 % S_{max}. Up to this apparent power threshold S_{min}, deviations above 2 % are permissible; nevertheless the accuracy shall always be as good as technically feasible and the exchange of uncontrolled reactive power in this low-power operation mode shall not exceed 10 % of the maximum apparent power S_{max}. At POC loads, if present in the producer’s network might interfere with the response of the generating plant. The effect of loads is not considered for the evaluation of the accuracy, only the behaviour of the generating plant is relevant.

For voltages differing from the nominal voltage but within the continuous operating voltage range (see 4.4.4), the reactive power capability at active power P_D shall be at least according to Figure 13 and where necessary adapted to the general reactive power capability requirement for the specific generating technology.

NOTE 5 Depending on the P-Q characteristic of the generating plant/unit, the reactive power at active powers below P_D might be lower respecting the requirements above. If no or less than 0,484 Q/P_D reactive power is required, the active power might increase above P_D as indicated in Figure 12

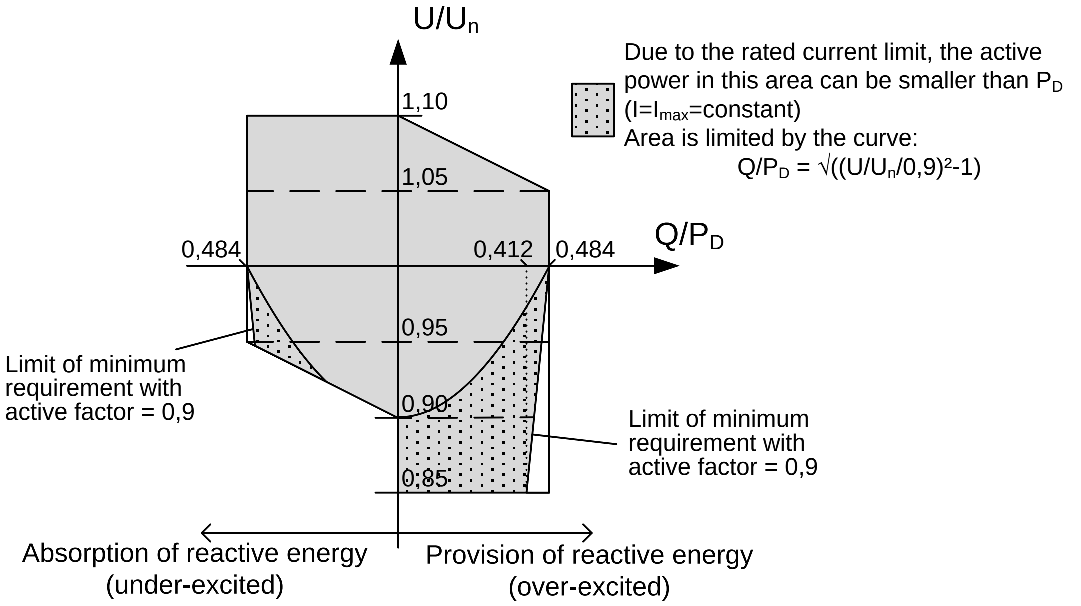

Figure 13 — Reactive power capability at active power P_D in the voltage range (positive sequence component of the fundamental)

For voltages below U_n it is allowed to reduce apparent power according to clause 4.4.4

NOTE 6 Whether there is a priority given to P or Q or the active factor when reaching the maximum apparent power this is not defined in this European Standard. Risks and benefits of different priority approaches are under consideration.

4.7.2.3 Control modes

4.7.2.3.1 General

Where required, the form of the contribution to voltage control shall be specified by the DSO.

The control shall refer to the terminals of the generating units

The generating plant/unit shall be capable of operating in the control modes specified below within the limits specified in 4.7.2.2. The control modes are exclusive; only one mode may be active at a time.

- Q setpoint mode
- Q (U)
- Cos φ setpoint mode
- Cos φ (P)

NOTE For mass market products, it is recommended to implement all control modes. In case of site specific generating plant design, only the control modes required by the DSO need to be implemented.

The configuration, activation and deactivation of the control modes shall be field adjustable. For field adjustable configurations and activation of the active control mode, means shall be provided to protect the settings from unpermitted interference (e.g. password or seal) if required by the DSO.Which control modes are available in a product and how they are configured shall be stated in the product documentation.

4.7.2.3.2 Setpoint control modes

Q setpoint mode and cos φ setpoint mode control the reactive power output and the cos φ of the output respectively, according to a set point set in the control of the generating plant/unit.

In the case of change of the set point local or by remote control the settling time for the new set point shall be less than one minute.

4.7.2.3.3 Voltage related control modes

The voltage related control mode Q (U) controls the reactive power output as a function of the voltage.

There is no preferred state of the art for evaluating the voltage. Therefore it is the responsibility of the generating plant designer to choose a method. One of the following methods should be used:

- the positive sequence component of the fundamental;
- the average of the voltages measured independently for each phase to neutral or phase to phase;
- phase independently the voltage of every phase to determine the reactive power for every phase.

For voltage related control modes, a characteristic with a minimum and maximum value and three connected lines according to Figure 16 shall be configurable.

In addition to the characteristic, further parameters shall be configurable:

- The dynamics of the control shall correspond with a first order filter having a time constant that is configurable in the range of 3 s to 60 s.

NOTE 1 The time to perform 95 % of the changed set point due to a change in voltage will be 3 times the time constant.

NOTE 2 The dynamic response of the generating units to voltage changes is not considered here. The response to disturbances as in clause 4.5 and short circuit current requirements as in 4.7.4 is not included in this clause.

NOTE 3 An intentional delay is under consideration.

To limit the reactive power at low active power two methods shall be configurable:

- a minimal cos φ shall be configurable in the range of 0-0,95;
- two active power levels shall be configurable both at least in the range of 0 % to 100 % of P_D. The lock-in value turns the Q(U) mode on, the lock-out value turns Q(U) off. If lock-in is larger than lock-out a hysteresis is given. See also Figure 14.

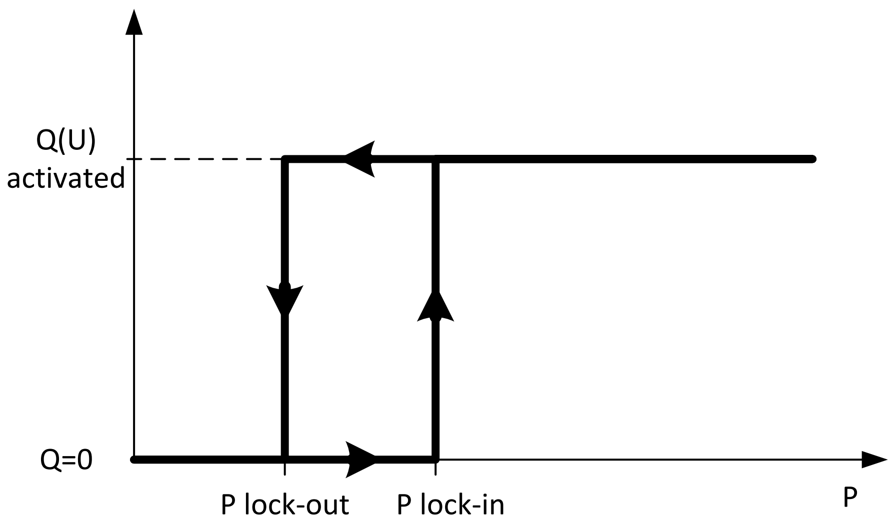

Figure 14 – Example of lock-in and lock-out values for Q(U) mode

The static accuracy shall be in accordance with Figure 4.7.2.2. The dynamic accuracy shall be in accordance with Figure 15 with a maximum tolerance of +/- 5% of P_D plus a time delay of up to 3 seconds deviating from an ideal first order filter response.

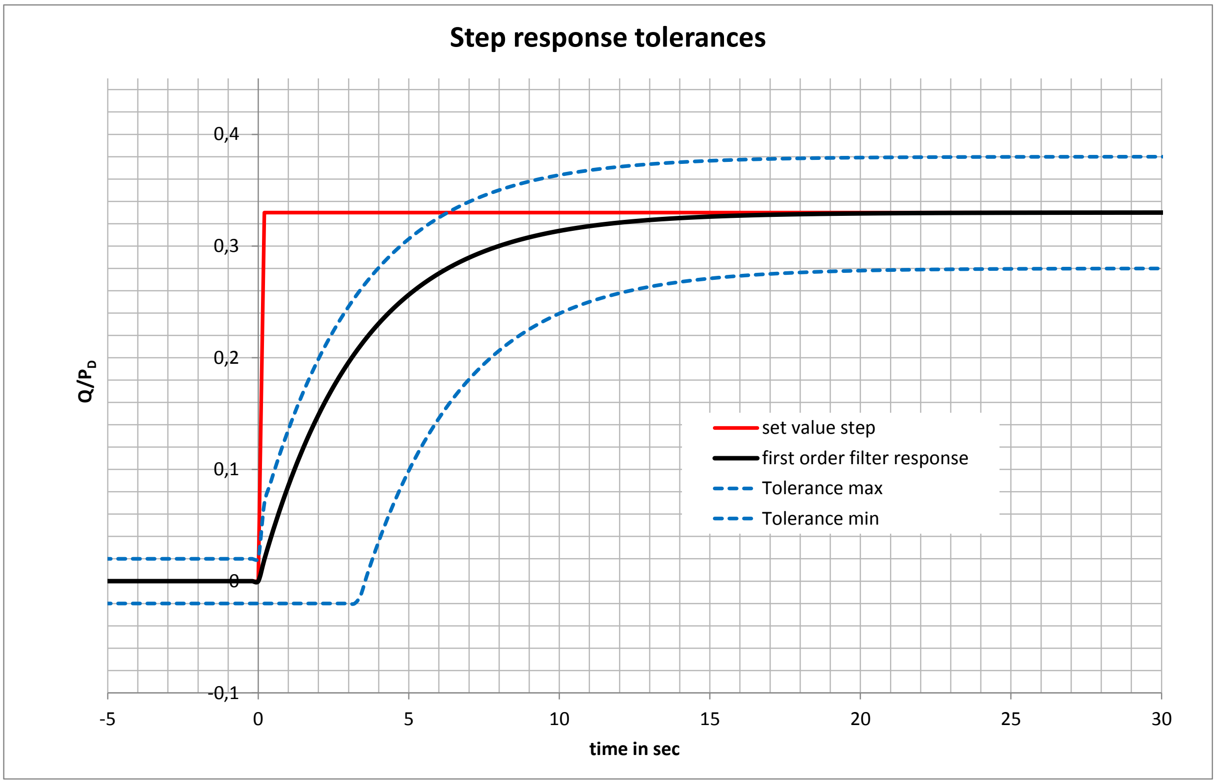

Figure 15 — Example of dynamic control response and tolerance band for a step from Q=0 to Q= 33%P_D with τ=3,33s

4.7.2.3.4 Power related control mode

The power related control mode cos φ (P) controls the cos φ of the output as a function of the active power output.

For power related control modes, a characteristic with a minimum and maximum value and three connected lines shall be configurable in accordance with Figure 16.

Resulting from a change in active power output a new cos φ set point is defined according to the set characteristic. The response to a new Q respectively cos φ set value shall be as fast as technically feasible to allow the change in reactive power to be in synchrony with the change in active power. The new reactive power set value shall be reached at the latest within 10 s after the end value of the active power is reached. The static accuracy of each Q set point and each cos φ set point respectively shall be according to 4.7.2.2.

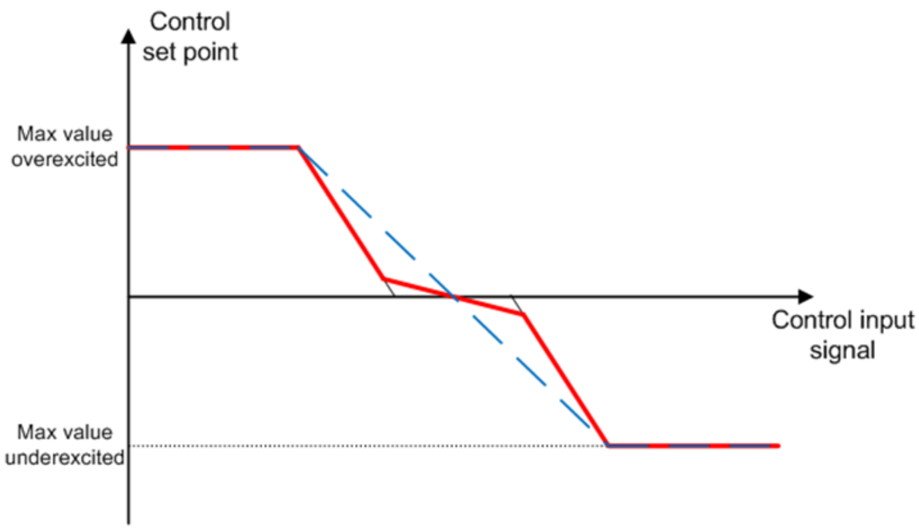

Figure 16 — Example characteristics for Q respectively cos φ control mode

4.7.3 Voltage related active power reduction

In order to avoid disconnection due to overvoltage protection (see 4.9.2.3 and 4.9.2.4), generating plants/units are allowed to reduce active power output as a function of this rising voltage. The final implemented logic can be chosen by the manufacturer. Nevertheless, this logic shall not cause steps or oscillations in the output power. The power reduction caused by such a function may not be faster than an equivalent of a time constant tau = 3 s (= 33%/s at a 100% change). The enabling and disabling of the function shall be field adjustable and means have to be provided to protect the setting from unpermitted interference (e.g. password or seal) if required by the DSO.

4.7.4 Short circuit current requirements on generating plants

4.7.4.1 General

The following clauses describe the required short circuit current contribution for generating plants taking into account the connection technology of the generating modules.

Generating modules classified as type B modules according to COMMISSION REGULATION 2016/631 shall comply with the requirements of 4.7.4.2 and 4.7.4.3. Generating modules classified as type A according to COMMISSION REGULATION 2016/631 should comply with these requirements. The actual behaviour of type A modules shall be specified in the connection agreement.

NOTE Based on the chosen banding threshold it is considered necessary to include generating modules classified as type A if connected to medium voltage distribution grids. Exemption is only acceptable for CHP and generating units based on rotating machinery below 50 kW as EN 50465 for gas appliance requests disconnection in case of under voltage.

4.7.4.2 Generating plant with non-synchronous generating technology

4.7.4.2.1 Voltage support during faults and voltage steps

In general no voltage support during faults and voltage steps is required from generating plants connected in LV distribution networks as the additional reactive current is expected to interfere with grid protection equipment. If the responsible party requires voltage support during faults and voltage steps for generating plants of type B connected to LV distribution grids, the clause 4.7.4 of EN50549-2 applies.

4.7.4.2.2 Zero current mode for converter connected generating technology

If UVRT capability (see 4.5.3) is provided additional to the requirements of 4.5, generating units connected to the grid by a converter shall have the capability to reduce their current as fast as technically feasible down to or below 10 % of the rated current when the voltage is outside of a static voltage range. Generating units based on a doubly fed induction machine can only reduce the positive sequence current below 10 % of the rated current. Negative sequence current shall be tolerated during unbalanced faults. In case this current reduction is not sufficient, the DSO should choose suitable interface protection settings.

The static voltage range shall be adjustable from 20 % to 100 % of U_n for the undervoltage boundary and from 100 % to 130 % of U_n for the overvoltage boundary. The default setting shall be 50% of U_n for the undervoltage boundary and 120% of U_n for the overvoltage boundary. Each phase to neutral voltage or if no neutral is present each phase to phase voltage shall be evaluated. At voltage re-entry into the voltage range, 90% of pre-fault power or available power, whichever is the smallest, shall be resumed as fast as possible, but at the latest according to clauses 4.5.3 and 4.5.4.
All described settings are defined by the DSO and the responsible party. If no settings are provided, the function shall be disabled.
The enabling and disabling and the settings shall be field adjustable and means have to be provided to protect these from unpermitted interference (e.g. password or seal) if required by the DSO.

4.7.4.2.3 Induction generator based units

In general no voltage support during faults and voltage steps is required from generating plants connected in LV distribution networks as the additional reactive current is expected to interfere with grid protection equipment. If the responsible party requires voltage support during faults and voltage steps for generating plants of type B connected to LV distribution grids, the clause 4.7.4 of EN50549-2 applies.

4.7.4.3 Generating plant with synchronous generating technology - Synchronous generator based units

In general no voltage support during faults and voltage steps is required from generating plants connected in LV distribution networks as the additional reactive current is expected to interfere with grid protection equipment. If the responsible party requires voltage support during faults and voltage steps for generating plants of type B connected to LV distribution grids, the clause 4.7.4 of EN50549-2 applies.

4.8 EMC and power quality

Similar to any other apparatus or fixed installation, generating units shall comply with the requirements on electromagnetic compatibility established in Directive 2014/30/EU or 2014/53/EU, whichever applies.

EMC limits and tests, described in EN 61000 series, have been traditionally developed for loads, without taking into account the particularities of generating units, such as their capability to create overvoltages or high frequency disturbances due to the presence of power converters, which were either impossible or less frequent in case of loads.

NOTE 1 Currently, IEC SC 77A are reviewing all their existing standards to include, where necessary, specific requirements for generating units/plants. For dispersed generating units in LV networks, the Technical Report IEC/TR 61000–3-15 is addressing gaps in the existing EMC standards making recommendations on the following aspects:

- Harmonic emissions;
- Flicker and voltage fluctuations;
- DC injection;
- Short and long duration overvoltages emission;
- Switching frequency emission;
- Immunity to voltage dips and short interruptions;
- Immunity to frequency variation;
- Immunity to harmonics and inter-harmonics;
- Unbalance.

As long as specific tests for generating units are not available for immunity and/or emission, generic EMC standards and/or any relevant EU harmonized EMC standard should be applied.

NOTE 2 Besides the compliance with EN61000 Series, in most countries power quality characteristic according to standards such as for example EN 61400–21 or VDE V 0124–100 are required as part of the connection agreement

Additional phenomena need to be addressed specifically to generating plants and their integration in the power system.

- ROCOF: See 4.5.2
- UVRT: See 4.5.3
- OVRT: See 4.5.4
- DC injection: Generating plants shall not inject direct currents.

NOTE 3 The DC injection clause is considered to be passed when for all generating units within the generating plant the measured DC injection of a type-tested unit is below the testing threshold.

Generating plants can also disturb mains signalling (ripple control or power line carrier systems). EMC requirements on inter-harmonics and on conducted disturbances in the frequency range between 2 kHz and 150 kHz are under development. In case of electromagnetic interferences to mains signalling systems due to the connection of a generating plant, mitigation measures should be taken and national requirements may apply.

Generating units are also expected to be compatible with voltage characteristics at the point of connection, as described in EN 50160 or in national regulations; however no compliance test is required due to the scope of EN 50160.

4.9 Interface protection

4.9.1 General

According to HD 60364-5-551:2010, 551.7.4, means of automatic switching shall be provided to disconnect the generating plant from the distribution network in the event of loss of that supply or deviation of the voltage or frequency at the supply terminals from values declared for normal supply.

This automatic means of disconnection has following main objectives:

- prevent the power production of the generating plant to cause an overvoltage situation in the distribution network it is connected to. Such overvoltages could result in damages to the equipment connected to the distribution network as well as the distribution network itself;
- detect unintentional island situations and disconnect the generating plant in this case. This is contributing to prevent damage to other equipment, both in the producers' installations and the distribution network due to out of phase re-closing and to allow for maintenance work after an intentional disconnection of a section of the distribution network;

NOTE 1 It is pointed out that checking the absence of voltage on all the live conductors is anyway mandatory before accessing a site for (maintenance) work.

- assist in bringing the distribution network to a controlled state in case of voltage or frequency deviations beyond corresponding regulation values.

It is not the purpose of the interface protection system to:

- disconnect the generating plant from the distribution network in case of faults internal to the power generating plant. Protection against internal faults (short-circuits) shall be coordinated with network protection, according to DSO protection criteria. Protection against e.g. overload, electric shock and against fire hazards shall be implemented additionally according to HD 60364-1 and local requirements;
- prevent damages to the generating unit due to incidents (e.g. short circuits) on the distribution network

Interface protections may contribute to preventing damage to the generating units due to out-of-phase reclosing of automatic reclosing which may happen after some hundreds of ms. However, in some countries some technologies of generating units are explicitly required to have an appropriate immunity level against the consequences of out-of-phase reclosing.

The type of protection and the sensitivity and operating times depend upon the protection and the characteristics of the distribution network.

A wide variety of approaches to achieve the above mentioned objectives is used throughout Europe. Besides the passive observation of voltage and frequency other active and passive methods are available and used to detect island situations. The requirements given in this clause are intended to provide the necessary functions for all known approaches as well as to give guidance in their use. Which functions are available in a product shall be stated in the product documentation.

The interface protection system shall comply with the requirements of this European Standard, the available functions and configured settings shall comply with the requirements of the DSO and the responsible party. In any case, the settings defined shall be understood as the values for the interface protection system, i.e. where there is a wider technical capability of the generation module, it shall not be withheld by the settings of the protections.

For micro generating plants, the interface protection system and the point of measurement might be integrated into the generating units. For generating plants with nominal current above 16 A the DSO may define a threshold above which the interface protection system shall be realized as a dedicated device and not integrated into the generating units.

NOTE 2 Example thresholds are 11,08 kW per generating plant (Italy), 30 kVA per generating plant (Germany, Austria) and 50 kW per generating unit (GB)

NOTE 3 Integrated interface protection systems might not be possible for two different reasons:

- to place the protection system as close to the point of connection as possible, to avoid tripping due to overvoltages resulting from the voltage rise within the producer’s network;
- to allow for periodic field tests. In some countries periodic field tests are not required if the protection system meets the requirements of single fault safety.

The interface protection relay acts on the interface switch. The DSO may require that the interface protection relay acts additionally on another switch with a proper delay in case the interface switch fails to operate.

In case of failure of the power supply of the interface protection, the interface protection shall trigger the interface switch without delay. An uninterruptible power supply may be required by the DSO, for instance in case of UVRT capability, delay in protection etc.

In case of field adjustable settings of threshold and operation time, means shall be provided to protect the settings from unpermitted interference (e.g. password or seal) if required by the DSO.

4.9.2 Requirements on voltage and frequency protection

4.9.2.1 General

Part or all of the following described functions may be required by the DSO and the responsible party.

NOTE 1 In the following the headings of the clause sections contain ANSI device numbers according to IEEE/ANSI C37.2 in square brackets e.g. [27].

The protection functions shall evaluate at least all phases where generating units, covered by this protection system, are connected to.

In case of three phase generating units/plants and in all cases when the protection system is implemented as an external protection system in a three phase power supply system, all phase to phase voltages and, if a neutral conductor is present, all phase to neutral voltages shall be evaluated.

NOTE 2 It is possible to calculate the phase to phase voltages based on phase-neutral measurements.

The frequency shall be evaluated on at least one of the voltages.

If multiple signals (e.g. 3 phase to phase voltages) are to be evaluated by one protection function, this function shall evaluate all of the signals separately. The output of each evaluation shall be OR connected, so that if one signal passes the threshold of a function, the function shall trip the protection in the specified time.

The minimum required accuracy for protection is:

- for frequency measurement ± 0,05 Hz;
- for voltage measurement ± 1 % of Un.
- The reset time shall be ≤50ms
- The interface protection relay shall not conduct continuous starting and disengaging operations of the interface protection relay. Therefore a reasonable reset ratio shall be implemented which shall not be zero but be below 2% of nominal value for voltage and below 0,2Hz for frequency.

NOTE 3 If the interface protection system is external to the generating unit, it is preferably located as close as possible to the point of connection. The voltage rise between the point of connection and the measurement input of the interface protection system is then kept as small as possible to avoid nuisance tripping of the overvoltage protection.

4.9.2.2 Undervoltage protection [27]

The protection shall comply with EN 60255-127. The evaluation of the r.m.s. or the fundamental value is allowed.

Undervoltage protection may be implemented with two completely independent protection thresholds, each one able to be activated or not. The standard adjustment ranges are as follows.

Undervoltage threshold stage 1 [27 <]:

- Threshold (0,2 – 1) U_n adjustable by steps of 0,01 U_n
- Operate time (0,1 – 100) s adjustable in steps of 0,1 s

Undervoltage threshold stage 2 [27 < <]:

- Threshold (0,2 – 1) U_n adjustable by steps of 0,01 U_n
- Operate time (0,1 – 5) s adjustable in steps of 0,05 s

The undervoltage threshold stage 2 is not applicable for micro-generating plants

4.9.2.3 Overvoltage protection [59]

The protection shall comply with EN 60255-127. The evaluation of the r.m.s. or the fundamental value is allowed.

Overvoltage protection may be implemented with two completely independent protection thresholds, each one able to be activated or not. The standard adjustment ranges are as follows.

Overvoltage threshold stage 1 [59 >]:

- Threshold (1,0 – 1,2) U_n adjustable by steps of 0,01 U_n
- Operate time (0,1 – 100) s adjustable in steps of 0,1 s

Overvoltage threshold stage 2 [59 > >]:

- Threshold (1,0 – 1,30) U_n adjustable by steps of 0,01 U_n
- Operate time (0,1 – 5) s adjustable in steps of 0,05 s

4.9.2.4 Overvoltage 10 min mean protection

The calculation of the 10 min value shall comply with the 10 min aggregation of EN 61000-4-30 Class S, but deviating from EN 61000-4-30 as a moving window is used. Therefore the function shall be based on the calculation of the square root of the arithmetic mean of the squared input values over 10 min. The calculation of a new 10 min value at least every 3 s is sufficient, which is then to be compared with the threshold value.

- Threshold (1,0 – 1,15) U_n adjustable by steps of 0,01 U_n
- Start time ≤ 3s not adjustable
- Time delay setting = 0 ms

NOTE 1 This function evaluates the r.m.s value.

NOTE 2 More information can be found in EN 50160.

4.9.2.5 Underfrequency protection [81 <]

Underfrequency protection may be implemented with two completely independent protection thresholds, each one able to be activated or not. The standard adjustment ranges are as follows.

Underfrequency threshold stage 1 [81 <]:

- Threshold (47,0 – 50,0) Hz adjustment by steps of 0,1 Hz
- Operate time (0,1 – 100) s adjustable in steps of 0,1 s

Underfrequency threshold stage 2 [81 < <]:

- Threshold (47,0 – 50,0) Hz adjustment by steps of 0,1 Hz
- Operate time (0,1 – 5) s adjustable in steps of 0,05 s

In order to use narrow frequency thresholds for islanding detection (see 4.9.3.3) it may be required to have the ability to activate and deactivate a stage by:

- an external signal .

The frequency protection shall function correctly in the input voltage range between 20 % U_n and 120 % U_n and shall be inhibited for input voltages of less than 20 % U_n.

NOTE Under 0,2 Un the frequency protection is inhibited. Disconnection may only happen based on undervoltage protection.

4.9.2.6 Overfrequency protection [81 >]

Overfrequency protection may be implemented with two completely independent protection thresholds, each one able to be activated or not. The standard adjustment ranges are as follows.

Overfrequency threshold stage 1 [81 >]:

- Threshold (50,0 - 52,0) Hz adjustment by steps of 0,1 Hz
- Operate time (0,1 – 100) s adjustable in steps of 0,1 s

Overfrequency threshold stage 2 [81 > >]:

- Threshold (50,0 - 52,0) Hz adjustment by steps of 0,1 Hz
- Operate time (0,1 - 5) s adjustable in steps of 0,05 s

In order to use narrow frequency thresholds for islanding detection (see 4.9.3.3) it may be required to have the ability to activate and deactivate a stage by:

- an external signal .

The frequency protection shall function correctly in the input voltage range between 20 % U_n and 120 % U_n and shall be inhibited for input voltages of less than 20 % U_n.

4.9.3 Means to detect island situation

4.9.3.1 General

Besides the passive observation of voltage and frequency further means to detect an island may be required by the DSO. Detecting islanding situations shall not be contradictory to the immunity requirements of REF _Ref493838645 \r \h 4.5.

Commonly used functions include:

- Active methods tested with a resonant circuit;
- ROCOF tripping;

- Switch to narrow frequency band;
- Vector shift
- Transfer trip.

Only some of the methods above rely on standards. Namely for ROCOF tripping and for the detection of a vector shift, also called a vector jump, currently no European Standard is available.

4.9.3.2 Active methods tested with a resonant circuit

These are methods which pass the resonant circuit test for PV inverters according to EN 62116.

4.9.3.3 Switch to narrow frequency band (see Annex E and Annex F)

In case of local phenomena (e.g. a fault or the opening of circuit breaker along the line) the DSO in coordination with the responsible party may require a switch to a narrow frequency band to increase the interface protection relay sensitivity. In the event of a local fault it is possible to enable activation of the restrictive frequency window (using the two underfrequency/overfrequency thresholds described in REF _Ref493837775 \r \h 4.9.2.5 and REF _Ref493837782 \r \h 4.9.2.6) correlating its activation with another additional protection function.

If required by the DSO, a digital input according to 4.9.4 shall be available to allow the DSO the activation of a restrictive frequency window by communication.

NOTE An additional gateway to ensure communication with the DSO communication system might be required.

4.9.4 Digital input to the interface protection

If required by the DSO, the interface protection shall have at least two configurable digital inputs. These inputs can for example be used to allow transfer trip or the switching to the narrow frequency band.

4.10 Connection and starting to generate electrical power

4.10.1 General

Connection and starting to generate electrical power is only allowed after voltage and frequency are within the allowed voltage and frequency ranges for at least the specified observation time. It shall not be possible to overrule these conditions.

Within these voltage and frequency ranges, the generating plant shall be capable of connecting and starting to generate electrical power.

The setting of the conditions depends on whether the connection is due to a normal operational start-up or an automatic reconnection after tripping of the interface protection. In case the settings for automatic reconnection after tripping and starting to generate power are not distinct in a generating plant, the tighter range and the start-up gradient shall be used.

The frequency range, the voltage range, the observation time and the power gradient shall be field adjustable.

For field adjustable settings, means shall be provided to protect the settings from unpermitted interference (e.g. password or seal) if required by the DSO.

4.10.2 Automatic reconnection after tripping

The frequency range, the voltage range, the observation time shall be adjustable in the range according to Table 3 column 2. If no settings are specified by the DSO and the responsible party, the default settings for the reconnection after tripping of the interface protection are according to Table 3 column 3.

Table 3 — Automatic reconnection after tripping

Parameter	Range	Default setting
Lower frequency	47,0Hz – 50,0Hz	49,5Hz

Upper frequency	50,0Hz – 52,0Hz	50,2Hz
Lower voltage	50% – 100%U_n	85 % U_n
Upper voltage	100% – 120% U_n	110 % U_n
Observation time	10s – 600s	60s
Active power increase gradient	6% – 3000%/min	10%/min

After reconnection, the active power generated by the generating plant shall not exceed a specified gradient expressed as a percentage of the active nominal power of the unit per minute. If no gradient is specified by the DSO and the responsible party, the default setting is 10 % P_n/min. Generating modules for which it is technically not feasible to increase the power respecting the specified gradient over the full power range may connect after 1 min to 10 min (randomized value, uniformly distributed) or later.

4.10.3 Starting to generate electrical power

The frequency range, the voltage range, the observation time shall be adjustable in the range according to Table 4 column 2. If no settings are specified by the DSO and the responsible party, the default settings for connection or starting to generate electrical power due to normal operational start-up or activity are according to Table 4 column 3.

Table 4 — Starting to generate electrical power

Parameter	Range	Default setting
Lower frequency	47,0Hz – 50,0Hz	49,5Hz
Upper frequency	50,0Hz – 52,0Hz	50,1Hz
Lower voltage	50% – 100%U_n	85 % U_n
Upper voltage	100% – 120% U_n	110 % U_n
Observation time	10s – 600s	60s
Active power increase gradient	6% – 3000%/min	disabled

If applicable, the power gradient shall not exceed the maximum gradient specified by the DSO and the responsible party. Heat driven CHP generating units do not need to keep a maximum gradient, since the start up is randomized by the nature of the heat demand.

For manual operations performed on site (e.g. for the purpose of initial start-up or maintenance) it is permitted to deviate from the observation time and ramp rate.

4.10.4 Synchronization

Synchronizing a generating plant/unit with the distribution network shall be fully automatic i.e. it shall not be possible to manually close the switch between the two systems to carry out synchronization.

4.11 Ceasing and reduction of active power on set point

4.11.1 Ceasing active power

Generating plants with a maximum capacity of 0,8 kW or more shall be equipped with a logic interface (input port) in order to cease active power output within five seconds following an instruction being received at the input port. If required by the DSO and the responsible party, this includes remote operation.

4.11.2 Reduction of active power on set point

For generating modules of type B, a generating plant shall be capable of reducing its active power to a limit value provided remotely by the DSO. The limit value shall be adjustable in the complete operating range from the maximum active power to minimum regulating level.
The adjustment of the limit value shall be possible with a maximum increment of 10% of nominal power
A generation unit/plant shall be capable of carrying out the power output reduction to the respective limit within an envelope of not faster than 0,66 % P_n/ s and not slower than 0,33 % P_n/ s with an accuracy of 5 % of nominal power. Generating plants are permitted to disconnect from the network at a limit value below it minimum regulating level.

NOTE Besides the requirements of this clause there might be other systems in place to control active power for reasons of market participation or local optimisation.

4.12 Remote information exchange

Generating plants whose power is above a threshold to be determined by the DSO and the responsible party shall have the capacity to be monitored by the DSO or TSO control centre or control centres as well as receive operation parameter settings for the functions specified in this European Standard from the DSO or TSO control centre or control centres.

This information exchange is aimed at allowing the DSO and/or the TSO to improve, optimize and make safer the operation of their respective networks.

The remote monitoring and operation parameter settings system that may be used by the DSO is not aimed at replacing the manual and automatic control means implemented by the generating plant operator to control the operation of the generating plant. It should not interact directly with the power generation equipment and the switching devices of the generating plant. It should interact with the operation and control system of the generating plant.

In principle, standardized communication should be used. It is recommended that in case of using protocols for signal transmission used between the DSO or TSO control centre or control centres and the generating plant, relevant technical standards (e.g. EN 60870-5-101, EN 60870-5-104, EN 61850 and in particular EN 61850-7-4, EN 61850-7-420, IEC/TR 61850-90-7, as well as EN 61400-25 for wind turbines and relevant parts of IEC 62351 for relevant security measures) are recognized.

Alternative protocols can be agreed between the DSO and the producer. These protocols include hardwired digital input/output and analogue input/output provided locally by DSO. The information needed for remote monitoring and the setting of configurable parameters are specific to each distribution network and to the way it is operated.

Signal transmission times between the DSO and/or the TSO control centre and the generating plant will depend on the means of transmission used between the DSO and/or TSO control centre and the generating plant.

Informative Annex B of EN50549-2 can be used as guidance regarding the monitoring information and the remote operation parameter setting.

4.13 Requirements regarding single fault tolerance of interface protection system and interface switch

If required in 4.3.2, the interface protection system and the interface switch shall meet the requirements of single fault tolerance.

A single fault shall not lead to a loss of the safety functions. Faults of common cause shall be taken into account if the probability for the occurrence of such a fault is significant. Whenever reasonably practical, the individual fault shall be displayed and lead to the disconnection of the power generating unit or system.

NOTE This requirement for the detection of individual faults does not mean that all faults are detected. Accumulation of undetected faults can therefore lead to an unintentional output signal and result in a hazardous condition.

Series-connected switches shall each have a independent breaking capacity corresponding to the rated current of the generating unit and corresponding to the short circuit contribution of the generating unit.

The short-time withstand current of the switching devices shall be coordinated with maximum short circuit power at the connection point.

At least one of the switches shall be a switch-disconnector suitable for overvoltage category 2. For single-phase generating units, the switch shall have one contact of this overvoltage category for both the neutral conductor and the line conductor. For poly-phase generating units, it is required to have one contact of this overvoltage category for all active conductors. The second switch may be formed of electronic switching components from an inverter bridge or another circuit provided that the electronic switching components can be switched off by control signals and that it is ensured that a failure is detected and leads to prevention of the operation at the latest at the next reconnection.

For PV-inverters without simple separation between the network and the PV generating unit (e.g. PV-Inverter without transformer) both switches mentioned in the paragraph above shall be switch-disconnectors with the requirements described therein, although one switching device is permitted to be located between PV array and PV inverter.

Annex A
(informative)

Interconnection guidance

A.1 General

This clause provides guidance on the criteria for the connection of generating plants to a distribution network and provides guidance for the selection of connection schemes and for the co-ordination of electric protection functions.

Generating plants (whether equipped with rotating, reciprocating or static generating technology) may be operated in parallel with a distribution network, subject to compliance with the requirements below. As this annex is informative, the requirements below are not part of this EN, but are requirements typically found in national grid connection rules.

A.2 Network integration

All generating plants should meet the following connection requirements:

- maximum active and apparent power should be according to the operating criteria agreed with the DSO;
- the connection of the generating plant should not cause a voltage rise exceeding the voltage limits at any point within the network;
- the connection of the generating plant should not cause the harmonic distortion of the voltage exceeding its limits at any point within the network;
- the connection of the generating plant should not cause flicker exceeding limits at any point within the network;
- the connection of the generating plant should not cause the short circuit current to exceed the breaking and making current of circuit breakers and, in general, the withstand current of network components;
- the protection schemes and settings for internal faults should be designed not to jeopardize the performance of the generating plant and its generating units and should ensure reliable operation at all times;
- the settings applied to the interface protection system should be selected to ensure correct tripping of the generating plant under conditions described in 4.9;
- where the generating plant is connected to a public distribution network that is fitted with fast automatic switching devices (e.g. auto-reclose circuit breaker), the opening times of the interface switches should be such that the risk of out of phase reclosure is negligible. To allow a sufficient time for the self-extinction of the fault, the maximum opening time of the interface-protection should be lower than the auto-reclosure-time. However, arrangements should be provided, if appropriate, under the producer’s responsibility, in agreement with the DSO to prevent damage to the generating unit and to find the best solution for both, operation and preservation of the generating unit. Especially on feeders feeding generating units with directly coupled generating technology and DFIG, the automatic reclosing action and the disconnection of the generating plant should be coordinated; the generating unit should be disconnected before any reclosing action.

A connection agreement should be reached between the DSO and the producer, prior to connection. The connection agreement should include, but should not be limited to, the following issues:

- maximum active and apparent power to be installed in the generating plant and if applicable the maximum active and apparent power to be exported and imported by the generating plant;
- connection voltage at POC;
- contribution of the generating plant to short circuit current;
- if appropriate, active factor or reactive power control at POC respectively at the generating unit terminals;
- operation and settings of automatic voltage controller, active factor controller and power frequency controller where present;
- single line diagram of installation, showing the point of connection, the installation boundary, the metering point, all switching devices, the protection devices, the inverter (if any), etc.;
- earthing arrangement of the generating plant (in compliance with national legislation, standards and regulations);
- connection requirements;
- settings applied to the interface protection;
- a list of measurement and control signals to be exchanged between the DSO/TSO and generating plant.

A.3 Clusters of single-phase generating units

When a generating plant is composed of clusters of single-phase generating units, the imbalance of current should not exceed 16 A for the sum of generating units connected to low voltage DSO network, unless the unbalance is generated to counteract voltage unbalance at the point of connection, in agreement with the DSO.

NOTE 1 Communication links between the single-phase units may be used to ensure this requirement.

NOTE 2 Higher values than 16 A may be defined by national legislation or the DSO, up to the maximum contractual power of single phase connection contract for consumers with no generation.

NOTE 3 This clause can be taken to apply to any imbalance caused by asymmetric phase loading, whether caused by single-, two-, or three-phase generating units.

Annex B
(informative)

void

Annex C
(informative)

Parameter Table

This annex provides an overview over all parameters used in this European Standard, the value range and the default values provided in this European Standard as well as a column for specific values as required by one DSO and the responsible party. The Column Ref specifies if a parameter is relevant for COMMISSION REGULATION 2016/631 and for what Type of generating module the parameter is relevant. If n.a. is set, this parameter is: not applicable for 2016/631, but is introduce into EN50549-1 for local DSO network management reasons and is not considered as cross border issues

Table 5 — Parameter table

<table>
<tr><th>Clause(s) / subclause(s)
of this EN</th><th>Ref</th><th>Parameter</th><th>Typical value range</th><th colspan="2">Value default</th><th>DSO Requir e-ment</th></tr>
<tr><td>4.3.2 Interface switch</td><td>n.a.</td><td>Single fault tolerance for interface switch required</td><td>yes | no</td><td colspan="2">no</td><td></td></tr>
<tr><td rowspan="6">4.4.2 Operating frequency range</td><td>A</td><td>47,0 – 47,5 Hz Duration</td><td>0 – 20 s</td><td colspan="2">0s</td><td></td></tr>
<tr><td>A</td><td>47,5 – 48,5 Hz Duration</td><td>30 – 90 min</td><td colspan="2">30 min</td><td></td></tr>
<tr><td>A</td><td>48,5 – 49,0 Hz Duration</td><td>30 – 90 min</td><td colspan="2">30 min</td><td></td></tr>
<tr><td>A</td><td>49,0 – 51,0 Hz Duration</td><td>not configurable</td><td colspan="2">unlimited</td><td></td></tr>
<tr><td>A</td><td>51,0 – 51,5 Hz Duration</td><td>30 – 90 min</td><td colspan="2">30 min</td><td></td></tr>
<tr><td>A</td><td>51, 5 – 52 Hz Duration</td><td>0 – 15 min</td><td colspan="2">0 s</td><td></td></tr>
<tr><td rowspan="2">4.4.3 Minimal requirement for active power delivery at underfrequency</td><td>A</td><td>Reduction threshold</td><td>49 Hz – 49,5 Hz</td><td colspan="2">49,5 Hz</td><td></td></tr>
<tr><td>A</td><td>Reduction rate</td><td>2 – 10 % P_M/Hz</td><td colspan="2">10 % P_M/ Hz</td><td></td></tr>
<tr><td rowspan="2">4.4.4 Continuous operating voltage range</td><td>n.a.</td><td>Upper limit</td><td>not configurable</td><td colspan="2">110% U_n</td><td></td></tr>
<tr><td>n.a.</td><td>Lower limit</td><td>not configurable</td><td colspan="2">85% U_n</td><td></td></tr>
<tr><td>4.5.2 Rate of change of frequency (ROCOF) immunity</td><td>A</td><td>ROCOF withstand capability (defined with a sliding measurement window of 500 ms)
non-synchronous generating technology:
synchronous generating technology:</td><td>not defined</td><td colspan="2">

2 Hz/s
1 Hz/s</td><td></td></tr>
<tr><td rowspan="5">4.5.3.2 Generating plant with non-synchronous generating technology</td><td>B</td><td>Maximum power resumption time</td><td>not defined</td><td colspan="2">1 s</td><td></td></tr>
<tr><td rowspan="4">B</td><td rowspan="4">Voltage-Time-Diagram</td><td rowspan="4">see Figure 6</td><td>Time [s]</td><td>U [p.u.]</td><td rowspan="4"></td></tr>
<tr><td>0,0</td><td>0,2</td></tr>
<tr><td>0,15</td><td>0,2</td></tr>
<tr><td>1,5</td><td>0,85</td></tr>
<tr><td rowspan="2">4.5.3.3 Generating plant with synchronous</td><td>B</td><td>Maximum power resumption time</td><td>not defined</td><td colspan="2">3 s</td><td></td></tr>
<tr><td>B</td><td>Voltage-Time-Diagram</td><td>see Figure 7</td><td>Time [s]</td><td>U [p.u.]</td><td></td></tr>
</table>

Clause(s) / subclause(s) of this EN	Ref	Parameter	Typical value range	Value default		DSO Requir e-ment
generating technology				0,0	0,3	
				0,15	0,3	
				0,15	0,7	
				0,7	0,7	
				1,5	0,85	
4.5.4 Over-voltage ride through (OVRT)	n.a.	Voltage-Time-Diagram	not configurable	Time [s]	U [p.u.]	
				0,0	1,25	
				0,1	1,25	
				0,1	1,20	
				5,0	1,20	
				5,0	1,15	
				60	1,15	
				60	1,10	
4.6.1 Power response to overfrequency	A	Threshold frequency f_1	50,2 Hz – 52 Hz	50,2 Hz		
	A	Droop	2 % – 12 %	5 %		
	A	Power reference	P_M | P_{max}	P_M		
	A	Intentional delay	0 – 2 s	0s		
	A	Deactivation threshold f_{stop}	50,0 Hz – f_1	deactivated		
	A	Deactivation time t_{stop}	0 – 600 s	-		
	A	Acceptance of staged disconnection	yes | no	yes		
4.6.2 Power response to underfrequency	n.a.	Threshold frequency f_1	49,8 Hz – 46 Hz	49,8 Hz		
	n.a.	Droop	2 – 12 %	5 %		
	n.a.	Power reference	P_M | P_{max}	P_{max}		
	n.a.	Intentional delay	0 – 2 s	0 s		
4.7.2.2 Capabilities	B	Active factor range overexcited	0,9 – 1	0,9		
		Active factor range underexcited	0,9 – 1	0,9		
4.7.2.3 Control modes	n.a.	Enabled control mode	Q setp. Q(U) cos φ setp. cos φ (P)	Q setpoint		
4.7.2.3.2 Setpoint control modes	n.a.	Q setpoint and excitation	0 – 48 % P_D	0		
	n.a.	cos φ setpoint and excitation	1 – 0,9	1		
4.7.2.3.3 Voltage related control modes	n.a.	Characteristic curve	-	-		
	n.a.	Time constant	3 s – 60 s	10 s		
	n.a.	Min cos φ	0,0 – 1	0,9		
	n.a.	Lock in power	0 % – 20 %	deactivated		
	n.a.	Lock out power	0 % – 20 %	deactivated		
4.7.2.3.4 Power related control mode	n.a.	Characteristic curve	-	-		

Clause(s) / subclause(s) of this EN	Ref	Parameter	Typical value range	Value default	DSO Requir e-ment
4.7.4.2.2 Zero current mode for converter connected generating technology	n.a.	Enabling	enable | disable	disable	
	n.a	Static voltage range overvoltage	100 % U_n – 120 % U_n	120 % U_n	
	n.a	Static voltage range undervoltage	20 % U_n – 100 % U_n	50 % U_n	
4.9.2 Requirements on voltage and frequency protection	n.a.	Threshold for protection as dedicated device [in A or kW, kVA]	16 A – 250 kVA	-	
	B	Undervoltage threshold stage 1	0,2 U_n – 1 U_n	-	
	B	Undervoltage operate time stage 1	0,1 s – 100 s	-	
	B	Undervoltage threshold stage 2	0,2 U_n – 1 U_n	-	
	B	Undervoltage operate time stage 2	0,1 s – 5 s	-	
	B	Overvoltage threshold stage 1	1,0 U_n – 1,2 U_n	-	
	B	Overvoltage operate time stage 1	0,1 s – 100 s	-	
	B	Overvoltage threshold stage 2	1,0 U_n – 1,3 U_n	-	
	B	Overvoltage operate time stage 2	0,1 s – 5 s	-	
	B	Overvoltage threshold 10 min mean protection	1,0 U_n – 1,15 U_n	-	
	B	Underfrequency threshold stage 1	47,0 Hz– 50,0 Hz	-	
	B	Underfrequency operate time stage 1	0,1 s – 100 s	-	
	B	Underfrequency threshold stage 2	47,0 Hz – 50,0 Hz	-	
	B	Underfrequency operate time stage 2	0,1 s – 5 s	-	
	B	Overfrequency threshold stage 1	50,0 Hz – 52,0 Hz	-	
	B	Overfrequency operate time stage 1	0,1 s – 100 s	-	
	B	Overfrequency threshold stage 2	50,0 Hz – 52,0 Hz	-	
	B	Overfrequency operate time stage 2	0,1 s – 5 s	-	
4.10.2 Automatic reconnection after tripping		Lower frequency	47,0 Hz – 50,0 Hz	49,5 Hz	
		Upper frequency	50,0 Hz – 52,0 Hz	50,2 Hz	
		Lower voltage	50 % – 100 % U_n	85 % U_n	
		Upper voltage	100 % – 120 % U_n	110 % U_n	
		Observation time	10 s – 600 s	60 s	
		Active power increase gradient	6 % – 3000%/min	10 % /min	
4.10.3 Starting to generate electrical		Lower frequency	47,0 Hz – 50,0 Hz	49,5 Hz	

Clause(s) / subclause(s) of this EN	**Ref**	**Parameter**	**Typical value range**	**Value default**	**DSO Requir e-ment**
power		Upper frequency	50,0 Hz – 52,0 Hz	50,1 Hz	
		Lower voltage	50 % – 100 % U_n	85 % U_n	
		Upper voltage	100 % – 120 % U_n	110 % U_n	
		Observation time	10 s – 600 s	60 s	
		Active power increase gradient	6 % – 3000 %/min	disabled	
4.11 Ceasing and reduction of active power on set point	A	Active power controllability required NOTE: If yes further definition is provided by the DSO	yes | no	No	
4.12 Remote information exchange	B	Remote information exchange required NOTE: If yes further definition is provided by the DSO	yes | no	No	

Annex D
(informative)

List of national requirements applicable for generating plants

This annex provides an overview of further national requirements and recommendations applicable for generating plants. Generating plants are expected to be required to comply with these national requirements.

This list is informative only is not complete and might be outdated. It is the responsibility of the producer to ensure that all applicable requirements are complied with.

Additional information might also be found at the network code implementation monitoring page of ENTSO-E http://www.entso-e.eu -> PROJECTS-> Connection Code – Active Library

Or https://docs.entsoe.eu/cnc-al/

Note: the web address might change

Table 6 — List of national requirements applicable for generating plants

Country	Applicable Documents
Austria	TOR D4 Technical and organisational rules by e-control Part D: Special technical rules Section D4: Operation of generating stations in parallel with distribution networks
Belgium	C10/11 Specifieke technische aansluitingsvoorschriften voor gedecentraliseerde productie-installaties die in parallel werken met het distributienet. Prescriptions techniques spécifiques de raccordement d'installations de production décentralisée fonctionnant en parallèle sur le réseau de distribution
France	Under consideration
Germany	VDE-AR-N 4100 Technische Regeln für den Anschluss von Kundenanlagen an das Niederspannungsnetz und deren Betrieb VDE-AR-N 4105 Erzeugungsanlagen am Niederspannungsnetz VDE-AR-N 4110 Technische Regeln für den Anschluss von Kundenanlagen an das Mittelspannungsnetz und deren Betrieb
Great Britain	ER G59 ER G83 ER G99 (post May 2019) ER G98 (post May 2019)
Italy	CEI 0-16 CEI 0-21
Latvia	Sabiedrisko pakalpojumu regulēšanas komisijas padomes noteikumi "Sistēmas pieslēguma noteikumi elektroenerģijas ražotājiem" (Regulations for a system connection for electricity producers, issued by national Public utilities commission)
Romania	ANRE Order no. 30/2013 – Technical Norm – Technical Requirements for connecting photovoltaic power plants to public electrical network; ANRE Order no. 51/2009 - Technical Norm – Technical Requirements

	for connecting wind power plants to public electrical network; ANRE Order no. 29/2013 – Technical Norm – Addendum to Technical Requirements for connecting wind power plants to public electrical network
Slovenia	SONDO and SONDSEE (Slovenian national rules for connection and operation of generators in the distribution network)
Switzerland	NE/EEA-CH, Country Settings Switzerland

Annex E
(informative)

Loss of Mains and overall power system security

Loss of Mains detection and overall power system security entail conflicting requirements.

On the one hand, frequency is a common characteristic within an interconnected synchronous area. As it affects all connected generating plants at the same time, frequency related requirements aim to ensure overall power system security. Considering the share of distributed generation in the overall production, these generating plants are expected to have the capability to operate in a wide frequency range for a definite duration in order to avoid a massive disconnection. They are as well capable of participating actively in load frequency control due to a chosen response to frequency changes.

On the other hand, frequency dependant characteristics can be used to detect unintentional island situations in order to disconnect the generating units (see 4.9 and more specific 4.9.3). This is essential to limit the risk of damages to equipment (in the producer's installations as well as in the distribution network) due to:

- (automatic) reclosing cycles 'causing' to out of phase re-closing;
- non-compliance with EN 50160.

Additionally frequency dependant characteristics allow for maintenance work after an intentional disconnection of a section of the distribution network.

If implemented without any precaution, the wide operating frequency range and the active response to frequency deviations will have a negative impact on the detection of unintentional islands using frequency-dependant characteristics. At present, reported islanding situations occur in moments where load and generation are sufficiently balanced, which limits the probability of this kind of events. The use of active power response to frequency deviations in combination with a wider operating frequency range (and wide protection settings) will make a load-generation balance more likely. As a consequence, a stable unintentional island may occur, especially in situations with production exceeding consumption.

This European Standard identifies some approaches to combine the interests of overall power system security and the detection of unintentional islanding:

- an intentional delay in the activation of the response to frequency deviation with the time needed for the island detection to operate (see 4.6.1 and 4.6.2);
- the possible activation of a narrow frequency window (e.g. 49,8 Hz – 50,2 Hz) in the interface protection in case of a local event (and not an overall power system event) (see 4.9.3.3);

and, as an option for all generating units,

- the immunity to out of phase re-closing (see 4.8 and 4.9) or similar solutions.

Other possibilities to combine both interests and to partially counteract the negative impact on the detection of unintentional islanding and its consequences exist. Nevertheless, they all have their limitations and drawbacks and cannot be implemented in a general way due to different constraints (technical, timing, economical, etc). Among other possibilities, some are listed here:

- other methods of islanding detection not based on frequency including transfer trip;
- voltage supervised reclosing;
- remote control of generating plants or loads, e.g. during maintenance works;

- multiphase earthing of the island.

Annex F
(informative)

Examples of protection strategies

F.1 Introduction

F.1.1 General

When looking at protection strategies applied in distribution networks, the handling of possible islanding situations is a main topic. Some general aspects are highlighted first as introduction to the example strategies applied in two different countries.

F.1.2 Generalities

Island operation as such is not an unwanted operational event. In particular, islanding situations due to scenarios such as a major disturbance, or intended islanding during maintenance works and the restoration of network operation after a wide blackout are part of the normal operational conditions even though this islanding is temporary.

Unlike the above mentioned island situations, unwanted islands can be characterized by one or more of the following:

- No monitoring of the network parameters within the disconnected network section;
- Impossibility to detect that a disconnection section of the network is under voltage;
- Generating units performing non-supervised voltage and frequency regulation;
- Malfunction of the coordinated protection system.

Whether an island is wanted or not it therefore has to be determined for various configurations in advance. In most cases, islands in medium and low voltage networks are considered as unwanted.

F.1.3 Detection of unwanted islands

It is difficult to identify reliably unwanted islanding situations from the viewpoint of the generating unit (both MV and LV):

- Network impedance will have to be measured accurately in low voltage parts of the grid to achieve a reliable reading which can be used to identify an impedance shift, phase shift etc. and thus an islanding event. Furthermore, differentiating between islanding and switching of the network (for instance reverse supply) is a problem.
- Voltage and frequency can be held in the island within normal operating ranges by methods of frequency control needed to optimize the interconnection in disturbed state and voltage support by use of reactive and active power.
- Strategies adopted in some countries, that use the measurement of positive, negative and zero sequence components of the fundamental voltages to differentiate between local faults in MV networks and external perturbations coming from voltage levels above ($U_n \geq 110$ kV), can cause a quick disintegration of unwanted islands in most cases (see Example strategy 1). Nevertheless, there are situations where even this method can lead to a sustained islanding due to e.g. switching off a MV feeder for maintenance work (in absence of a fault). For such cases the potential of a stable island (or the existence of an island during several minutes) should still be considered.

NOTE 1 The risk for nuisance tripping should be considered together with the efficiency of the detection of island situations.

F.1.4 Problems with uncontrolled islanding in MV networks

F.1.4.1 Safety

When performing maintenance work it should not be assumed that the disconnected network area is indeed without voltage. The five safety rules shall be strictly observed to avoid major accidents, especially testing whether a power system is ‘live’ before earthing and short circuiting.

- Disconnect mains;
- Prevent reconnection;
- Test for all phases for absence of harmful voltages;
- Earth and short circuit; and
- Cover or close nearby live parts.

F.1.4.2 Grid parameters

In island situations they will remain within the permissible range due to the existing protection devices of the generating units as far as network frequency and voltage supply is concerned. A deviation with regard to the angle between phases (120°), flicker and harmonics levels is not tested. The latter may cause overcurrents, especially in the case of directly connected three-phase electrical machines. Possible damage can occur due to higher current drain.

F.1.4.3 Reclosing operations

The voltage phasor in the island is not synchronized with the main grid. This may cause high transient currents, voltage and phase shifts when an undetected island is reconnected automatically, on remote control or manually. This is a risk to electrical machinery, including the switch which performs the reconnection, and attached drivetrains of machines or prime movers of generating units. As there is no central frequency and voltage control in the island and no measuring of voltage along the circuit breaker (= coupling switch) in unwanted islands, no correct in phase re-synchronization can be achieved.

F.1.4.4 Protection of islands against overcurrents

When the power supply in the islanding network is primarily realized via converter based energy sources there will be a lack of sufficiently large short circuit current to trigger the existing protection devices on LV and MV level (distance and over current protection) in case of faults. Prior to islanding, short circuit power was supplied via a power transformer by the high voltage network. Therefore, it may happen that the island is only dysfunctionally protected against network faults. In the case of a short circuit, continuous operation cannot be expected because of the unbalanced power supply. Locating the fault is made more difficult, because no (selective) tripping of power system protection devices takes place.

F.1.4.5 Protection against phase to earth faults

When an electrical island exists in a medium voltage network, the earthing conditions change significantly, as measures for treating the neutral point (Petersen-coil, low-resistance earthing, etc.) are in general implemented in the transformer substation. If there is no galvanic connection between the fault and the neutral point at the substation in an islanding situation, this can lead to a continuous operation with an earth fault, causing risks to human life by step and touch voltages.

Therefore, network islands without controlled, preferably automatic network control and monitoring, should generally be avoided.

F.2 Example strategy 1

In Italy, automatic reclosing on MV feeders is generally applied. Moreover, a complete MV network automation acting for any kind of fault (3 ph, 2 ph, 1 ph to earth and cross country faults) is also present. The automation scheme is based only on local automata and measurements. With the wide frequency window set on interface protection relays, combined with generating plant’s UVRT and OVRT capabilities and the frequency sensitive mode, uncontrolled island operation is highly possible. Supported from both MV and LV connected generating plants, an island may sustain after faults and switching operation without fault (operation needs). In these situations a reclosing action can be triggered automatically or by remote control. On asynchronous networks e.g. in counterphase, or with an angle between voltage phasors of two network parts exceeding 45° a reclosing may cause damages both to customer and DSO assets. In addition, the islanding part of network is not controlled and protected against any fault.

Two solutions have been defined, depending on the availability of a proper communication network:

a) In absence of communication network:

   1) If the local setting is set to LOW (0), the wide frequency window is enabled except in case of a fault detection at MV level. Then, the narrow frequency window is activated by the voltmetric unlock function (see Figure 17). In this latter situation a temporary increase of interface protection relays sensitivity of all the generating plants connected to a single HV/MV transformer is foreseen. This solution may not avoid completely islanding in case of intentional switching operations without faults.

   2) If the local setting is set to HIGH (1), wide frequency window is always enabled, independent of the output of the voltmetric unlock function (ANSI CODE 81V).

b) In presence of communication network:

   1) Local setting has to be set to LOW (0);

   2) Interface protection relay tripping is obtained through transfer trip, if communication network operates correctly. During a communication malfunction the narrow frequency window of the interface protection relay will be activated by voltmetric unlock function (ANSI CODE 81V), in case of a fault detection at MV level, as described in the situation 1.a. above.

NOTE 2 The ANSI CODE refers to standard device numbers according to IEEE C37.2.

In case of MV connected generating plants the voltmetric unlock function may be embedded in the interface protection relay or realized through a separate device. In case of LV connected interface protection relay, the voltmetric unlock function shall be realized through a separate device installed by the DSO on MV side of MV/LV distribution transformer and the narrow frequency window enabling signal will be transmitted to LV connected generating plants through a proper communication network (for instance through power line carrier in the frequency band (3 kHz - 95 kHz).

Typical arrangements of protection functions inside the interface protection relay are shown in the scheme of Figure 17, while corresponding typical settings are indicated in Table 7.

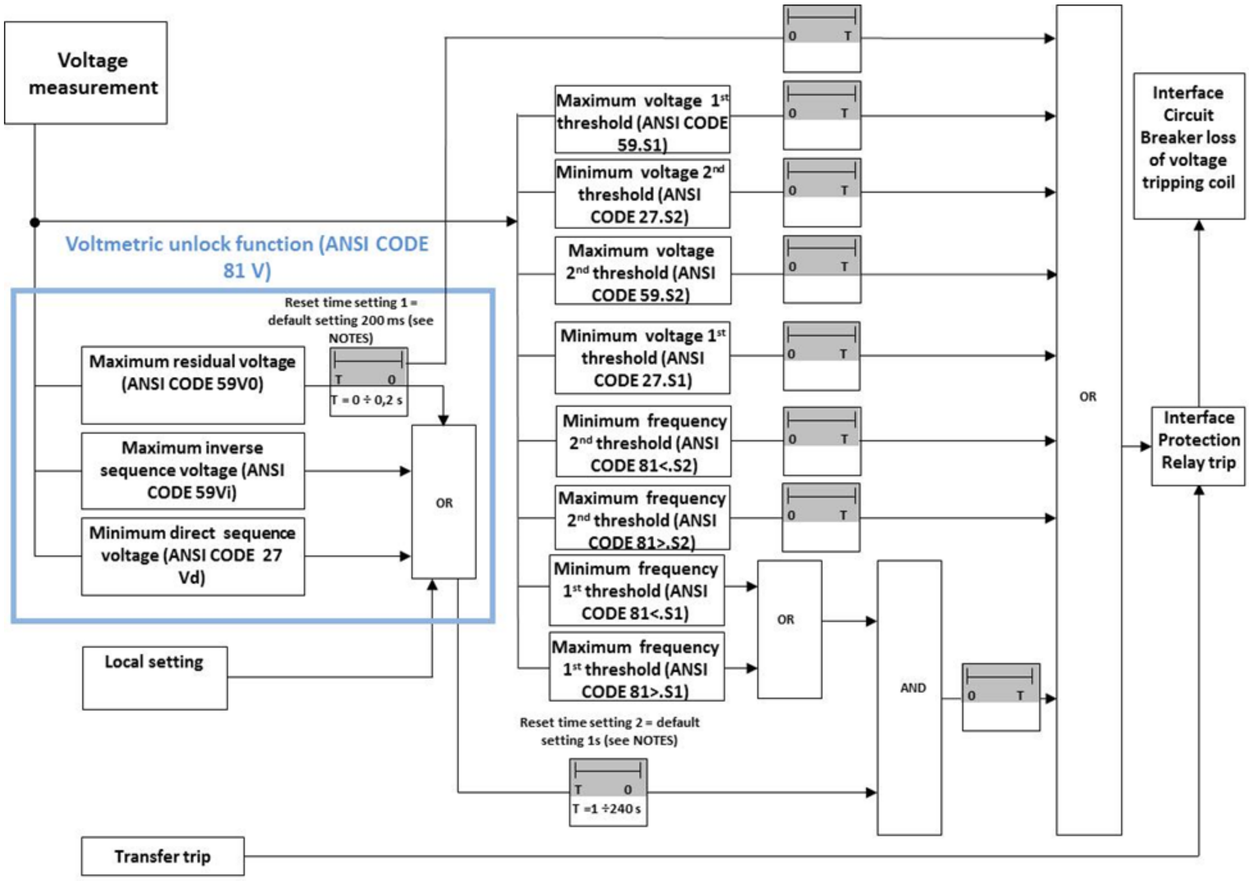

Figure 17 — Typical scheme of interface protection relay in the Italian solution

NOTE 3 Reset time 1 is needed to avoid start and reset in case of arcing faults.

Reset time 2 is related to DSO reclosing/automation cycle and related timing.

Table 7 — Typical protection functions and related regulations on interface protection relays in the Italian solution

Protection function	Default threshold value	Default relay operate time	Maximum opening time of the output-break circuit (interface CB with tripping command operated from a voltage absence coil)
Maximum voltage U>.S1 (ANSI CODE 59.S1), 10 minutes mean function (according to EN 61000-4-30, Class S, but adopting a moving window with refresh time ≤ 3 s)	1,10 Vn	Start time ≤ 3 s, not adjustable. Delay time setting = 0 ms Depending on voltage values during the moving window. Maximum value 603 s.	Depending on voltage values during the moving window. Maximum 603,70 s.
Maximum voltage U>.S2 (ANSI CODE 59.S2)	1,20 Vn	200 ms	270 ms
Minimum voltage U<.S1 (ANSI CODE 27.S1) (1)	0,85 Vn	1500 ms	1570 ms
Minimum voltage U<.S2 (ANSI CODE 27.S2) (1)	0,4 Vn	200 ms	270 ms
Maximum frequency f>.S2 (ANSI CODE 81.S2) (2)	50,2 Hz	150 ms	170 ms
Minimum frequency f<.S2 (ANSI CODE 81.S2) (2)	49,8Hz	150 ms	170 ms
Maximum frequency f>.S1 (ANSI CODE 81.S1) (2)	51,5 Hz	1,0 s	1,07 s
Minimum frequency f<.S1 (ANSI CODE 81.S1) (2)	47,5 Hz	4,0 s	4,07 s
Maximum residual voltage U0> (ANSI CODE 59V0) (3)	5 % Vrn (4)	For protection use: 25 s For voltmetric unlock use (ANSI CODE 81V): 0 ms (equal to start time: 70 ms)	For protection use: 25,07 s For voltmetric unlock use: equal to start time (1)
Maximum inverse sequence voltage Ui> (ANSI CODE 59 Vi) (1)	15% Vn/En (5) (indicative, depending on the network)	For voltmetric unlock use (ANSI CODE 81V): 0 ms (equal to start time: 70 ms)	Equal to start time
Minimum direct sequence voltage Ud< (ANSI CODE 27 Vd) (1)	70% Vn/En (5) (indicative, depending on the network)	For voltmetric unlock use (ANSI CODE 81V): 0 ms (equal to start time: 70 ms)	Equal to start time
Transfer trip		<150 ms	<220 ms

(1) Threshold active only for inverters and rotating generators connected to distribution network with AC/AC converters. For rotating generators directly connected U<.S2: operate time 70 ms, threshold value 70%, U<.S1: excluded.

(2) For voltage values below 0,2 Vn, f>.S1, f>.S2 & f<.S1, f<.S2 protections shall be disabled.

(3) Function used both for tripping and for voltmetric unlock function.

(4) Regulation in % of nominal residual voltage Vrn in case of a phase to earth fault with 0 Ω fault resistance derived directly from an open delta winding or calculated internally the IPR from phase to earth voltages derived from non iron core voltage transducers.

(5) Regulation in % of nominal phase to earth or phase to phase voltage, according to voltage measurements methods.

F.3 Example strategy 2

The following example is applicable to a rural MV feeder with overhead lines and an open ring topology. The grade of network automation is low, using only auto-reclosure breakers at the substation.

a) Detection: Before measures coping with unwanted island operation can be taken, the existence of such an island shall be detected.

1) Recognizing network islands

To avoid above all an to out of phase re-closing (see F.1.4), the voltages have to be measured on both sides of the switch (e.g. the breaker at the substation). If the switch is open and there are voltages on both sides, automatic reclosure after a short interruption has to be blocked. Furthermore, a “switch-closing-warning” has to be sent to the control centre. A re-connection can occur only after this warning has been acknowledged. A manual closing for example needs to be done if a meshed operation shall be carried out.

This systematic approach can be implemented with a logical interconnection of the usually available voltage measurements on the 20-kV-busbar, the switch position (On/Off) and a voltage recording on the feeders, e.g. capacitive voltage sensors of the protection equipment.

The requirements on voltage recording at the feeders are minimal. No phase or measurement accuracy is expected. The logical statement “Power ON” or “Power OFF” is sufficient. Hereby threshold values should be selected, so that false positive and false negative measurement errors are avoided and are adjusted to the switch-off limit of the low and medium voltage protection. In Germany, the values are U < 80 % U_n according to VDE-AR-N 4105 and the medium voltage guideline U < < 45 % U_n. In the following example, a threshold of 40 % U_n has been chosen for the determination if voltage is present or not.

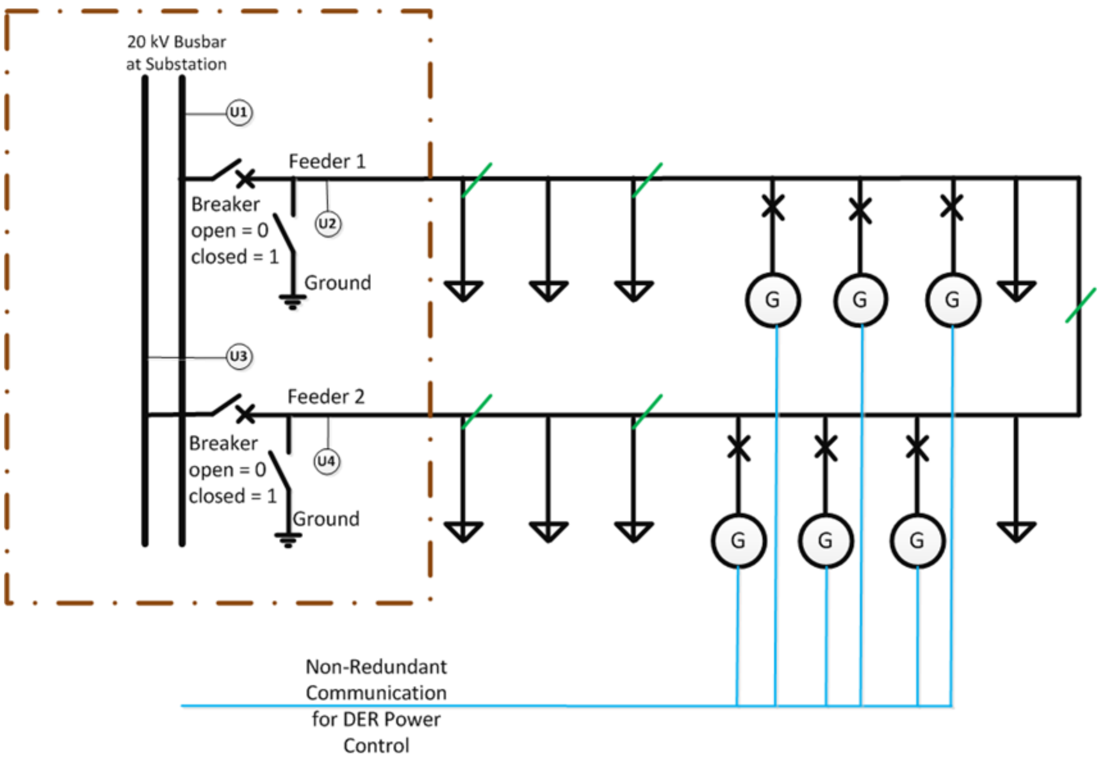

Figure 18

Table 8 — Binary state tree of breaker status and voltage measurements upstream and downstream of the breaker, resulting in an islanding

	Breaker ON (closed)		Breaker OFF (open)	
	U2 ≤ 40 %	U2 > 40 %	U2 ≤ 40 %	U2 > 40 %
U1 ≤ 40 %	ok	Measurement Error	ok	Island warning / manual re-connection only
U1 > 40 %	Measurement Error	ok	ok	Island warning / manual re-connection only

b) There are three basic options how to terminate an island situation:

1) A balance of active and reactive power is necessary for the islanding condition. This changes with user behaviour and the availability of primary energy sources. Basically, it is possible to wait until this balance no longer exists (calm wind, sunset, etc.) and the island disintegrates by itself. However, the power system operator carries the risk that the islanded sub-network is temporarily operated unprotected. Compliance to EN 50160 with regards to harmonics, flicker and negative sequence cannot be ensured.

2) If island operation shall stop quickly, then the active power balance can be disturbed by power system operator intervention. In Germany, feed-in management according to Renewable Energy Sources Act (EEG §11) can be applied to reduce the supply of active power, which causes the disintegration of the island. Alternatively, mechanical switches within the islanding network may be opened and thereby divide the island into smaller parts. Thus, maintaining a power balance is made more difficult.

3) A three-phase-ground-fault can also be provoked in the island when it is not possible to initiate the measures above, e.g. because safety reasons demand a fast reaction. It is best to simply close the earthing-switch at the feeder. This switch is not dimensioned for short circuit currents; however short circuit power in the islanding network should not be significantly higher than the cumulative feed-in power. Most distributed generating units connected to MV and LV networks use inverters for feed-in, which usually do not contribute a short circuit current significantly higher than I_n. There is still a remaining risk that the earthing-switch will be destroyed but in the first instance and before any protection of property, human safety has to be ensured.

Annex G
(normative)

Abbreviations

CHP	combined heat and power
DFIG	doubly fed induction generator
DSO	distribution system operator
EHV	extra high voltage
EMC	electromagnetic compatibility
HV	high voltage
OVRT	over voltage ride through
IEV	International Electrotechnical Vocabulary (IEC 60050)
LV	low voltage
UVRT	under voltage ride through
MV	medium voltage
POC	point of connection
PV	photovoltaic
ROCOF	rate of change of frequency
THD	total harmonic distortion

Annex H
(informative)

Relationship between this European standard and the COMMISSION REGULATION (EU) 2016/631

Generating plants compliant with the clauses of this European Standard are considered to be compliant with the relevant Article of COMMISSION REGULATION (EU) 2016/631, provided, that all settings as provided by the DSO and the responsible party are complied with.

Table 9 – Correspondence between this European standard and the COMMISSION REGULATION (EU) 2016/631

Article	Clause(s) / subclause(s) of this EN
13.1(a)	4.4.2 Operating frequency range
13.1(b)	4.5.2 Rate of change of frequency (ROCOF) immunity
13.2	4.6.1 Power response to overfrequency
13.3	4.4.3 Minimal requirement for active power delivery at underfrequency
13.4	4.4.3 Minimal requirement for active power delivery at underfrequency
13.5	4.4.3 Minimal requirement for active power delivery at underfrequency
13.6	4.11.1 Ceasing active power
13.7	4.10 Connection and starting to generate electrical power
14.1	4.4.2, 4.5.2, 4.6.1, 4.4.3, 4.11.1 and 4.10
14.2(a)	4.11.2 Reduction of active power on set point
14.2(b)	4.12 Remote information exchange
14.3	4.5.3 Under-voltage ride through (UVRT)
14.4.	4.10 Connection and starting to generate electrical power
14.5(a)	4.6, 4.7, 4.9, 4.10, 4.11, 4.12
14.5(b)	4.9 Interface protection,
14.5(c)	4.1 General
14.5(d)	4.12 Remote information exchange
17.1	4. as applicable above
17.2	4.7.2 Voltage support by reactive power
17.3	4.5.3 Under-voltage ride through (UVRT)
20.1	4. as applicable above
20.2 (a)	4.7.2 Voltage support by reactive power
20.2 (b) (c)	4.7.4.2 Short circuit current requirements on generating plants
20.3	4.5.3 Under-voltage ride through (UVRT)

Bibliography

EN 50160, Voltage characteristics of electricity supplied by public electricity networks

EN 61000-2-2, Electromagnetic compatibility (EMC) — Part 2-2: Environment — Compatibility levels for low-frequency conducted disturbances and signalling in public low-voltage power supply systems (IEC 61000-2-2)

EN 61000-3-11, Electromagnetic compatibility (EMC) — Part 3-11: Limits — Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems — Equipment with rated current ≤ 75 A and subject to conditional connection (IEC 61000-3-11)

EN 61000-3-12, Electromagnetic compatibility (EMC) — Part 3-12: Limits — Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current > 16 A and ≤ 75 A per phase (IEC 61000-3-12

IEC/TR 61000-3-15, Electromagnetic compatibility (EMC) — Part 3-15: Limits — Assessment of low frequency electromagnetic immunity and emission requirements for dispersed generation systems in LV network

EN 61000-6-1, Electromagnetic compatibility (EMC) — Part 6-1: Generic standards — Immunity for residential, commercial and light-industrial environments (IEC 61000-6-1)

EN 61000-6-2, Electromagnetic compatibility (EMC) — Part 6-2: Generic standards — Immunity for industrial environments (IEC 61000-6-2)

EN 61000-6-3, Electromagnetic compatibility (EMC) — Part 6-3: Generic standards — Emission standard for residential, commercial and light-industrial environments (IEC 61000-6-3)

EN 61000-6-4, Electromagnetic compatibility (EMC) — Part 6-4: Generic standards — Emission standard for industrial environments (IEC 61000-6-4)

EN 61850-7-420, Communication networks and systems for power utility automation — Part 7-420: Basic communication structure — Distributed energy resources logical nodes (IEC 61850-7-420)

IEC 60050, International Electrotechnical Vocabulary