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TECHNICAL SPECIFICATION

Distributed energy resources connection with the grid

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IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland
Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

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CONTENTS

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DISTRIBUTED ENERGY RESOURCES CONNECTION WITH THE GRID

FOREWORD

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Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 62786 has been prepared by IEC Technical Committee 8: System aspects for electrical energy supply.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
8/1439/DTS	8/1457/RVDTS

Full information on the voting for the approval of this technical specification can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

DISTRIBUTED ENERGY RESOURCES CONNECTION WITH THE GRID

1 Scope and object

This technical specification provides principles and technical requirements for distributed energy resources (DERs) connected to the distribution network. It applies to the planning, design, operation and connection of DERs to distribution networks. It includes general requirements, connection scheme, choice of switchgear, normal operating range, immunity to disturbances, active power response to frequency deviation, reactive power response to voltage variations and voltage changes, EMC and power quality, interface protection, connection and start to generate electrical power, active power management, monitoring, control and communication, and conformance tests.

This document specifies interface requirements for connection of generating plants with the distribution network operating at a nominal frequency of 50 Hz or 60 Hz.

DERs include distributed generation and permanently connected electrical energy storage in the form of synchronous generators, asynchronous generators, converters, etc., connected to the medium voltage (MV) or low voltage (LV) distribution network.

NOTE Mobile electrical energy storage devices (e.g. electrical vehicles) are under consideration for future editions.

The requirements of this document can be superseded by laws and regulations where applicable.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61000 (all parts), *Electromagnetic compatibility (EMC)*

IEC TS 62749, *Assessment of power quality – Characteristics of electricity supplied by public networks*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
black start
start up of an electric power system from a blackout through internal energy resources

3.2
converter-type generator
generator that produces electrical power and is connected to the distribution network via a converter, including doubly-fed induction machines

3.3
distributed energy resource
DER
generators, including loads having a generating mode (such as electrical energy storage systems) connected to the low or medium voltage distribution network, with their auxiliaries, protection and connection equipment

3.4
distribution network
electric power network for the distribution of electric power from and to network users for which a distribution system operator (DSO) is responsible

3.5
distribution system operator
DSO
party operating a distribution network

Note 1 to entry: In some countries, a DSO is also referred to as DNO (distribution network operator).

[SOURCE: IEC 60050-617:2009, 617-02-10, modified – Note 1 to entry has been added]

3.6
flicker
impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates with time

Note 1 to entry: Flicker can be calculated by short term indicator P_{st} and long term indicator P_{lt}.

[SOURCE: IEC 60050-161:1990, 161-08-13, modified – Note 1 to entry has been added]

3.7
fundamental frequency
frequency of the fundamental component of a periodic quantity

Note 1 to entry: For the purpose of this document, the fundamental frequency is the same as the power supply frequency, e.g. 50 Hz or 60 Hz.

[SOURCE: IEC 60050-103, 103-07-21, modified – Note 1 to entry has been added]

3.8
fundamental component
sinusoidal component of Fourier series of periodic quantity having the frequency of the quantity itself

[SOURCE: IEC 60050-103,103-07-19]

3.9
generating unit
indivisible set of equipment whose primary purpose is to generate electrical power

3.10
generating plant
group of generating units including auxiliaries connected to one POC

3.11
harmonic frequency
frequency of a harmonic component

[SOURCE: IEC 60050-103:2009, 103-07-26]

3.12
harmonic component
sinusoidal component of Fourier series of a periodic quantity, the harmonic order of which is an integer number greater than one

Note 1 to entry: A component of harmonic *n* (with *n*>1) is generally designated n^{th} harmonic. the designation of the fundamental component as "1^{st} harmonic" is not recommended.

[SOURCE: IEC 60050-103:2009, 103-07-25]

3.13
interface protection
combination of protection relay functions which opens the interface switch of a generating unit and prevents its closure, whichever is appropriate, in the case of:

- a fault on the electric power network;
- an unintentional islanding situation;
- voltage and frequency being outside continuously operating ranges

3.14
interharmonic frequency
frequency which is a non-integer multiple of the reference fundamental frequency

Note 1 to entry: By extension from harmonic order, the interharmonic order is the ratio of an interharmonic frequency to the fundamental frequency. This ratio is not an integer (recommended notation: "m").

Note 2 to entry: In the case where m<1, the term subharmonic frequency may be used.

[SOURCE: IEC 60050-551:2001, 551-20-06, modified – Note 1 to entry and Note 2 to entry have been added]

3.15
interharmonic component
sinusoidal component of a periodic quantity having an interharmonic frequency

Note 1 to entry: Its value is normally expressed as an r.m.s. value.

Note 2 to entry: For brevity, such a component may be referred to simply as an "interharmonic".

[SOURCE: IEC 60050-551:2001, 551-20-08, modified – The existing note has been deleted and Note 1 to entry and Note 2 to entry have been added]

3.16
long-term flicker indicator
measure of flicker evaluated over a specified time interval of a relatively long duration, using successive values of the short-term flicker indicator

Note 1 to entry: The duration is typically 2 hours, using 12 successive values of P_{st}, in accordance with IEC 61000-4-15.

[SOURCE: IEC 60050-161:1990, 161-08-19]

3.17
low voltage
LV
set of voltage levels used for the distribution of electricity and whose upper limit is generally accepted to be 1 000 V for alternating current

[SOURCE: IEC 60050-601:1985, 601-01-26]

3.18
medium voltage
MV
any set of voltage levels lying between low and high voltage

Note 1 to entry: The boundaries between medium and high voltage levels that overlap and depend on local circumstances as well as history or common usage. Nevertheless the band 1 kV to 35 kV is considered as the accepted medium voltage boundary.

Note 2 to entry: Because of existing network structures, boundary between MV and HV can be different from country to country.

[SOURCE: IEC 60050-601:1985, 601-01-28, modified – The existing note has been modified and Note 2 to entry has been added]

3.19
point of connection
POC
physical connection point on the distribution network where a generating plant is connected

3.20
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: IEC 60050-131:2002, 131-11-46]

3.21
rapid voltage changes
RVC
quick transition (that may last several cycles) in r.m.s. voltage between two steady-state conditions while the voltage stays within the thresholds defined for voltage swells and dips

Note 1 to entry: RVC is expressed by the relative steady state voltage change or by a maximum r.m.s. voltage change aggregated over several cycles.

3.22
short term flicker indicator
measure of flicker evaluated over a specified time interval of a relatively short duration

Note 1 to entry: The duration is typically 10 minutes, in accordance with IEC 61000-4-15.

[SOURCE: IEC 60050-161:1990, 161-08-18]

3.23
short-time withstand current
the current that a circuit or a switching device in the closed position can carry during a specified short time under prescribed conditions of use and behaviour

[SOURCE: IEC 60050-441:2000, 441-17-17]

3.24
system operator
party responsible for safe and reliable operation of a part of the electric power system in a certain area and for connection to other parts of the electric power system

[SOURCE: IEC 60050-617:2009, 617-02-09]

3.25
switch
device for changing the electric connections among its terminals

[SOURCE: IEC 60050-151:2001, 151-12-22]

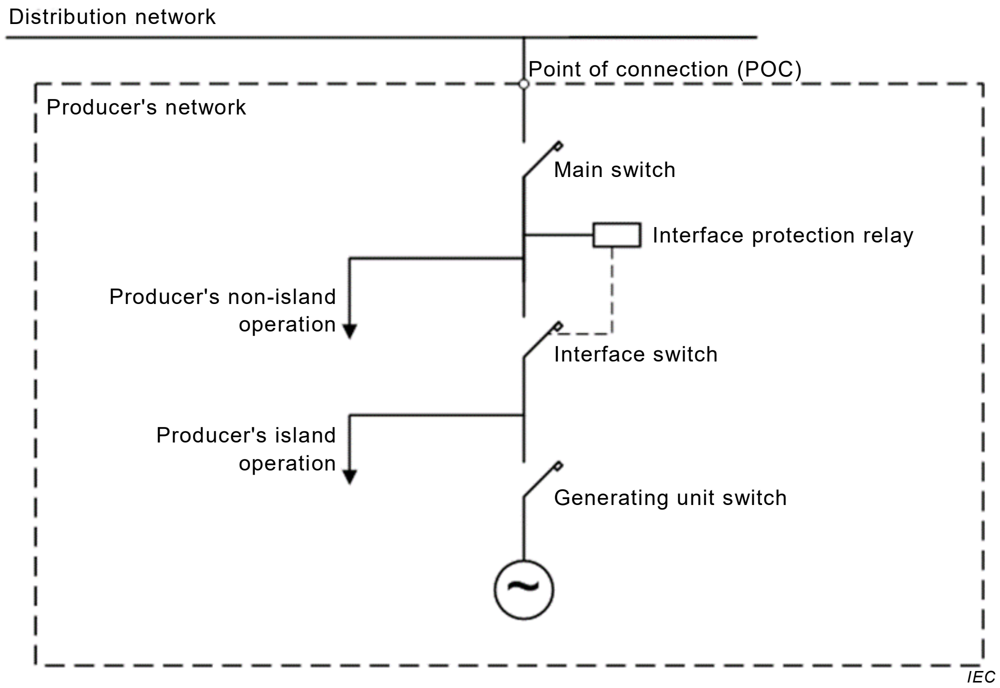


Figure 1 – Electricity generating plant connected to a distribution network (schematic view of switches)

3.26
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 1.

3.27
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 generation unit from the distribution network

Note 1 to entry: See also Figure 1.

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.

3.28
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 1.

3.29
voltage deviation
difference between the supply voltage at a given instant and the declared supply voltage

[SOURCE: IEC 60050-614:2016, 614-01-04]

3.30
voltage dip
sudden voltage reduction at a point in an electric power system, followed by voltage recovery after a short time interval, from a few periods of the sinusoidal wave of the voltage to a few seconds

[SOURCE: IEC 60050-614:2016, 614-01-08]

3.31
voltage fluctuation
series of voltage changes or a continuous variation of the r.m.s. or peak value of the voltage

Note 1 to entry: Whether the r.m.s. or peak value is chosen depends upon the application.

[SOURCE: IEC 60050-161:1990, 161-08-05, modified – Note to entry 1 has been modified]

3.32
voltage swell
sudden increase of voltage at a point in an electrical system followed by voltage reduction after a short period of time from a few cycles to a few seconds

3.33
voltage unbalance
condition in a polyphase system in which the r.m.s. values of the phase element voltages (fundamental component), or the phase angles between consecutive phase element voltages, are not all equal

Note 1 to entry: The degree of the inequality is usually expressed as the ratios of the negative- and zero-sequence component to the positive-sequence component.

Note 2 to entry: In this standard, voltage unbalance is considered in relation to 3-phase systems.

[SOURCE: IEC 60050-614:2016, 614-01-32, modified – Note 1 to entry and Note 2 to entry have been added]

4 Requirements on generating plants

4.1 General

When connecting a DER to the distribution network, consideration should be given to whether there are other power resources connected or to be connected in the same electrical proximity. The combined effect of DERs should be considered when selecting an appropriate POC for the DER concerned.

4.2 Connection scheme

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

4.3 Choice of switchgear

4.3.1 General

Switches shall be chosen based on the characteristics of the electric 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 the contribution of the generating plant.

Depending on local system requirements, generating plant should be equipped at the connection point with isolating devices and visible signs that are easily operated and lockable.

The method of isolating the generating plant connected to a MV network shall be accessible to the DSO at all times, unless the DSO requires or permits using an alternative method.

NOTE In some countries, accessibility is also required for the DERs connected to a LV network.

4.3.2 Interface switch

Interface switches shall have 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 maximum short circuit current at the POC.

In case of loss of auxiliary power supply to the switchgear, the interface switch shall disconnect immediately. An uninterruptible power supply may be required by the DSO.

The interface switch may coincide either with the main switch or with the generating unit switch. In case of a combination, the single switch should be compliant to the requirements of the two separate switches. As a consequence, at least two switches in series should be present between any generating unit and the POC. One of the two switches may include electronic switch (gate blocking) in case of converter connection.

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

DERs with capacity above a certain level, as defined by individual countries, shall provide capability of withstanding frequency deviations in accordance with those specified in Table 1.

Table 1 – Operating frequency requirements of DERs

Frequency	DER actions required
$f < f_{min2}$ $f > f_{max2}$	Instantaneous disconnection permitted
$f_{min2} \le f < f_{min1}$ $f_{max1} < f \le f_{max2}$	Operate for a minimum time T_{f1}
$f_{min1} \le f \le f_{max1}$	Operate continuously

The recommended range values of f_{min1}, f_{min2}, f_{max1}, f_{max2} and T_{f1} under continuous and limited operating frequency range are specified in Table A.1 and Table A.2 of Annex A, respectively.

4.4.3 Operating voltage range

DERs with a capacity above a certain level, as defined by individual countries, shall provide capability of withstanding voltage deviations, in accordance with those specified in Table 2.

Table 2 – Operating voltage requirements of DERs

Voltage at connection point	DER actions required
$U < U_{min2}$ $U > U_{max2}$	Disconnection allowed after time T_{u2}
$U_{min2} \le U < U_{min1}$ $U_{max1} < U \le U_{max2}$	Disconnection allowed after time T_{u1}
$U_{min1} \le U \le U_{max1}$	Operate continuously

The recommended range values of U_{min1}, U_{min2}, U_{max1}, U_{max2}, T_{u1} and T_{u2} under continuous and limited operating voltage range are specified in Table B.1 and Table B.2 of Annex B, respectively.

4.5 Immunity to disturbances

4.5.1 General

The following withstand capabilities shall be fulfilled regardless of the topology and 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 distributed generation, a significant loss of active power can occur.

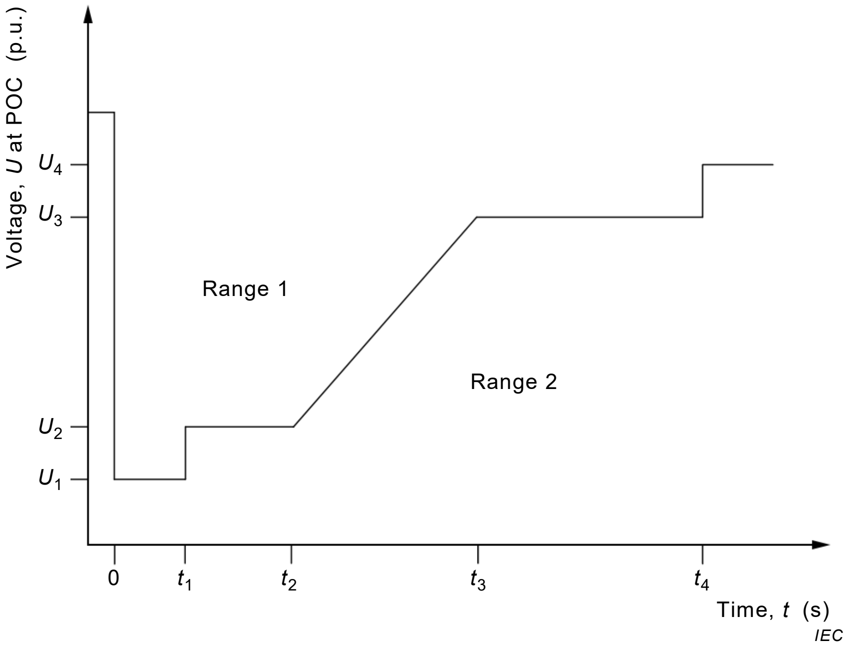
4.5.2 Rate of change of frequency (ROCOF) immunity

Regarding the ROCOF withstand capability, the generating unit shall be able to operate with a ROCOF as specified by individual countries.

NOTE In some countries, 2,5 Hz/s is required for the ROCOF immunity.

4.5.3 Under voltage ride through (UVRT) requirements

Depending on local system requirements, generating units shall be capable to stay connected with the grid for a minimum time during a voltage dip at the POC. General requirements of immunity of DERs to voltage dips are illustrated in Figure 2 below.



NOTE Voltage level before the low voltage event on the left hand side of the diagram can be anywhere within the operating voltage range.

Figure 2 – Under voltage ride through capability requirements of DER

If the voltage drop at the POC is within Range 1, DERs shall maintain connection with the network. If the voltage drop at the POC is within Range 2, DERs may disconnect or block the switching devices.

After the fault is cleared, DERs should recover its output within a certain time. Depending on local system requirements, DERs should not absorb more inductive reactive power than that before the fault.

These requirements apply to all types of short circuit faults. For three phase DERs, the lowest phase-to-phase voltage shall be used.

The recommended range values of parameters in Figure 2 are given in for synchronous and non-synchronous generators are given in Table C.1 and Table C.2 of Annex C, respectively.

If required, DERs connected to MV networks shall participate in dynamic network support (such as fast reactive current injection), see also 4.7.3.

4.5.4 Over voltage ride through (OVRT) requirements

Depending on local system requirements, generating units shall be capable of staying connected to the grid for at least T_{ov}, if the voltage at the POC exceeds the upper limit of the continuous operating voltage U_{max1} as defined in 4.4.3. The largest phase-to-phase voltage shall be used.

Recommended range values for parameters T_{ov} and U are given in Table D.1 of Annex D.

4.6 Active power response to frequency deviation

Depending on local system requirements, all DERs connected to MV and those connected to LV network with a capacity above a certain level shall have active power control capability. They should be able to adjust its active power output in response to frequency change ensuring the secure operation of the network.

When network frequency exceeds nominal value (f_n) by more than Δf, DERs should reduce their active power output with a gradient of G %. Δf shall be expressed in Hz based on national requirements. G % may be expressed as a percentage of DER active power per Hz. Values of Δf and G shall be specified by the individual country concerned. When the network frequency is below nominal value (f_n) by more than $\Delta f'$ and if active power increase is possible, DERs should increase their active power output with a gradient of G' %. $\Delta f'$ shall be expressed in Hz based on national requirements. G' % may be expressed as a percentage of DER active power per Hz. Values of $\Delta f'$ and G' shall be specified by the individual country concerned.

4.7 Reactive power response to voltage variations and voltage changes

4.7.1 General

When the contribution to voltage support is required by the DSO, the generating plant shall be designed to have the capability of managing reactive power generation according to the requirements of 4.7.

NOTE A mutual agreement between the DSO and the DER operator can be the basis for enhanced voltage support services.

4.7.2 Reactive power control

DERs connected to MV network and those connected to LV network with a capacity above a certain level should have reactive power capability and maintain the power factor at POC as per national requirements.

DERs should be able to adjust reactive power output within its reactive power capability range and participate in steady state voltage regulation in response to network voltage conditions or network operator or system operator instructions.

In case of reactive power control in response to voltage change, the distribution system operator should give settings concerning the gradient of the characteristic curve and the input filter's time constant (first order low pass).

4.7.3 Dynamic reactive power support capabilities

Depending on local system requirements, when the POC voltage drops due to a network fault, converter-based DERs connected to MV should inject dynamic reactive current into the network that meets the following requirements:

– From the moment of voltage drop at the POC, the step response time of dynamic reactive current injection should be less than T_{in} (injection time).
– DERs should inject dynamic reactive current into the network until the voltage is restored to normal range.

The value of T_{in} should be determined by local requirements. The recommended value is 30 ms.

NOTE 1 Depending on local system requirements, dynamic voltage current injection may not be required or explicitly forbidden for DERs.

NOTE 2 Synchronous generators are assumed to be intrinsically compliant with this requirement.

4.8 EMC and power quality

4.8.1 General

Generating plants shall meet the basic electromagnetic compatibility (EMC) requirements as stipulated in IEC 61000 series and shall also meet the local requirements for power quality at the POC.

Generating units are also expected to be compatible with voltage characteristics at the POC, as described in IEC TS 62749.

NOTE Currently, IEC SC 77A is reviewing all its existing standards to include, where necessary, specific requirements for generating units/plants. For distributed generation 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;
– flickers and voltage fluctuations;
– DC injection;
– short and long duration overvoltage excursion;
– switching frequency emission;
– immunity to voltage dips and short interruptions;
– immunity to frequency variation;
– immunity to harmonics and inter-harmonics;
– unbalance.

4.8.2 Direct current (DC) injection

Generating plants shall not inject direct current into the network.

NOTE The DC injection clause is considered to be passed for DERs with converter type generators where the measured DC injection of type tested unit is below the testing threshold.

4.9 Interface protection

DERs should have protection devices installed to ensure the safe and secure operation of the distribution network. The configuration and selection of protection devices should meet the requirements specified by the local network operator concerned. In converter type generators, the interface protection may be integrated inside the converter.

The interface protection system has the following main objectives:

– to prevent the generating plant causing an over-voltage situation in the distribution network, and
– to detect unintentional islanding situations and where required, disconnect the generating plant in those cases.

The generating plant shall assure the following:

a) faults and malfunctions occurring within the generating plant shall not impair the normal functioning of the distribution network;
b) the interface switch should be operated in co-ordination with the generating unit switch, the main switch and switches in the distribution network, for faults or malfunctions occurring within the generating plant or the DSO network during operation in parallel with the distribution network;
c) the earthing scheme of generating plants shall be consistent with that of the network.

NOTE 1 In the case that the generating plant is designed for self-consumption only, i.e. no export to the distribution network is allowed, and depending on local system requirements, some kind of additional reverse charge protection might be necessary.

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;

NOTE 2 Protection against internal faults (e.g. short-circuits) is coordinated with network protection, according to DSO protection criteria. In addition, protection against overload, electric shock, fire hazards, etc. is implemented according to local requirements.

– prevent damages to the generating unit due to incidents on the distribution network (e.g. short circuits) or reclosing operations (especially fast automatic ones, which may happen after some hundreds of milliseconds). Therefore, the generating unit shall have an appropriate immunity level.

Besides the observation of voltage and frequency, other methods are available and used to detect islanding situations.

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

Possible types of interface protection functions and relays are shown in Table 3.

Table 3 – Interface protection functions

Type	Function
Passive functions	Over voltage relay Under voltage relay Zero sequence over voltage relay Negative sequence over voltage relay Ground fault over-voltage relay Over frequency relay Under frequency relay Rate of change of frequency relay Vector jump relay Directional short circuit relay
Active function	Measurement of network impedance Transfer trips

NOTE 3 IEC 62116 provides a test specification to verify the islanding protection for PV-Inverters.

NOTE 4 ROCOF and vector jump relays can cause unintentional tripping.

4.10 Connection and start to generate electrical power

4.10.1 General

After a system disturbance, DERs shall not connect to the network before voltage and frequency are restored to continuous steady state values, and shall only do so after an appropriate period of time. This time shall be decided by the DSO.

4.10.2 Connection of synchronous generators

Synchronous-machine-type DERs should be equipped with an automatic synchronization device. The values for $\Delta\varphi$, Δf and ΔU should be considered. Where $\Delta\varphi$, Δf and ΔU are angle difference, frequency difference and voltage difference, respectively, across the circuit breaker which connects the DER at the POC.

4.10.3 Auto reclose of distribution lines

When the distribution line has a delayed automatic reclosing (DAR) device installed, the generating plant shall disconnect from the distribution network within the DAR time to avoid unnecessary damage to the generating plant. As an alternative, the generating plant may have the capability to withstand out of phase reconnections after auto reclosing of the relevant distribution line.

4.11 Active power management

Generating plant connected to a MV network and those connected to a LV network with a capacity above a certain level shall have the capability to be disconnected or curtailed for instance when the distribution line or a distribution transformer, etc., becomes overloaded. This shall be initiated by the relevant DSO; for communications, refer to 4.12. The maximum active power output and the rate of active power change should not exceed the value determined by the DSO.

4.12 Monitoring, control and communication

4.12.1 Monitoring and control

DERs connected to MV and those connected to LV network with a capacity above a certain level shall be capable of exchanging information with the DSO, and upon mutual agreement, shall be able to be monitored and controlled by the DSO. To ensure the secure operation of network and DERs, DERs should meet the following requirements:

– Required parameters to be sent from DERs to the system operation center shall be stipulated in each country.
– Depending on local system requirements, DERs should accept the control and regulation instruction sent by the DSO.

The information provided by DERs to the DSO may include the following:

– DER connection status, active and reactive power, and generated electrical energy;
– bus voltage and frequency at the POC;
– status of breakers at the POC.

4.12.2 Communication

Secure communication channels between DERs and the DSO should be provided.

Communication channels should be selected in accordance with the DSO requirements, taking into consideration the status of the local network communications.

The communication system should be compatible with the IEC 61850 series.

NOTE Nevertheless there are other legacy communication systems in operation.

When public communication is used as an information exchange between DERs and the DSO, physical security and cyber security measures should be considered. For those DERs with designated black start capability, communication between DERs and the DSO shall be possible even in the case of power failure.

5 Conformance tests

If applicable product standards exist or become available for specific technologies, they should be used.

Annex A
(normative)

Operating frequency range

This annex specifies continuous and limited operating frequency ranges under which DERs with capacity above a certain level, as defined by individual countries, shall provide capability of withstanding frequency deviations.

Table A.1 – Continuous operating frequency range

Frequency of power system Hz	f_{min1} Hz	f_{max1} Hz
50	47,0 to 49,5	50,5 to 52,0
60	57,0 to 59,5	60,5 to 61,8
NOTE Some countries may not specify f_{min1}, f_{max1} value.		

Table A.2 – Limited operating frequency range

Frequency of power system Hz	f_{min2} Hz	f_{max2} Hz	T_{f1}
50	45,0 to 49,5	50,5 to 57,0	0,5 s to 90 min
60	57,0 to 59,5	60,5 to 61,8	0,5 s to 90 min
NOTE $f_{min2} \leq f_{min1}$ and $f_{max1} \leq f_{max2}$			

Annex B
(normative)

Operating voltage range

This annex specifies continuous and limited operating voltage ranges under which DERs with a capacity above a certain level, as defined by individual countries, shall provide capability of withstanding voltage deviations.

Table B.1 – Continuous operating voltage range

U_{min1} in per unit	U_{max1} in per unit
0,9	1,1
NOTE It is possible that some countries do not specify U_{min1} and U_{max1} values.	

Table B.2 – Limited operating voltage range

U_{min2} in per unit	U_{max2} in per unit	T_{u1} in seconds	T_{u2} in seconds
0,5 to 0,9	1,1 to 1,25	0,5 to 2,0	0,0 to 0,3

NOTE 1 For Table B.1 and Table B.2, $U_{min2} \leq U_{min1} < U_{max1} \leq U_{max2}$.

The values chosen for T_{u1} and T_{u2} should be coordinated with under fault ride through times in 4.5.3 and 4.5.4.

Annex C
(normative)

Under voltage ride through capability of DERs

This annex specifies under voltage ride through capability of generating units during a voltage dip at the POC.

Table C.1 – UVRT capability of DERs with an interface to the grid based on a synchronous generator

Parameters	Residual voltage in per unit	Ride through time in seconds
U_1, t_1	0,30 to 0,70	0,0 to 0,15
U_2, t_2	0,70 to 0,85	0,0 to 0,70
U_3, t_3	0,70 to 0,85	0,0 to 1,50
U_4, t_4	U_{min2}	0,0 to 180,0
NOTE 1 $t_1 \le t_2 \le t_3 \le t_4$, $U_1 \le U_2 \le U_3 \le U_4$. NOTE 2 By choosing the same values for (U_1,t_1) and (U_2,t_2), the second data point disappears, which allows the use of the same diagram and methodology in describing the LVRT capability for both classes of generating unit.		

Table C.2 – UVRT capability of DERs with an interface to the grid based on non-synchronous generators (eg. converters, DFIG, etc.)

Parameters	Residual voltage in per unit	Ride through time in seconds
U_1, t_1	0,00 to 0,30	0,0 to 1,0
U_2, t_2	0,00 to 0,30	0,0 to 1,0
U_3, t_3	0,05 to 0,90	0,0 to 2,0
U_4, t_4	U_{min2}	0,0 to 180,0
NOTE 1 $t_1 \le t_2 \le t_3 \le t_4$, $U_1 \le U_2 \le U_3 \le U_4$. NOTE 2 By choosing the same values for (U_1,t_1) and (U_2,t_2), the second data point disappears, which allows the use of the same diagram and methodology in describing the LVRT capability for both classes of generating units.		

Annex D
(normative)

Over voltage ride through parameters

This annex specifies over voltage ride through capability of generating units connected to medium voltage during a voltage rise at the POC.

Table D.1 – Medium voltage OVRT requirements

Voltage in per unit	Minimum ride through time T_{ov} in seconds
1,0 to 1,1	Unlimited
1,1 to 1,2	1,0
1,2 to 1,25	0,2/0,167 (for 50 Hz/60 Hz)
> 1,25	0,0

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

3, rue de Varembé
PO Box 131
CH-1211 Geneva 20
Switzerland

Tel: + 41 22 919 02 11
Fax: + 41 22 919 03 00
info@iec.ch
www.iec.ch