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TECHNICAL SPECIFICATION

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Distributed energy resources connection with the grid –
Part 1: General requirements

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Part 1: General requirements

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IEC TS 62786-1 has been prepared by IEC Technical Committee 8: System aspects of electrical energy supply. It is a Technical Specification.

The text of this Technical Specification is based on the following documents:

Draft	Report on voting
8/1656/DTS	8/1677/RVDTS

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Specification is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 62786 series, published under the general title *Distributed energy resources connection with the grid*, can be found on the IEC website.

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DISTRIBUTED ENERGY RESOURCES CONNECTION WITH THE GRID –

Part 1: General requirements

1 Scope and object

This part of IEC 62786, which is a Technical Specification, provides principles and general technical requirements for distributed energy resources (DER) connected to an electric power network (in the following: the "network"). It applies to the planning, design, operation and connection of DER to networks. It includes general requirements, connection scheme, choice of switchgear, normal operating range, immunity to disturbances, active power response to frequency deviations, reactive power response to 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.

It is supplemented by additional parts of IEC 62786 series, covering specific aspects.

This document specifies interface and interoperability requirements for connection of DER to a network operating at a nominal frequency of 50 Hz or 60 Hz. These requirements are intended for application at the point of connection (POC) of the DER to the grid. In some situations, the requirements can be the applied at the AC terminals of the generator. Additional parts of IEC 62786 provide more specific requirements.

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

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 60255-12, *Electrical relays – Part 12: Directional relays and power relays with two input energizing quantities*

IEC 60255-127, *Measuring relays and protection equipment − Part 127: Functional requirements for over/under voltage protection*

IEC 60255-151, *Measuring relays and protection equipment − Part 151: Functional requirements for over/under current protection*

IEC 60255-181, *Measuring relays and protection equipment − Part 181: Functional requirements for frequency protection*

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

IEC 61850 (all parts), *Communication networks and systems for power utility automation*

IEC 62116, *Utility-interconnected photovoltaic inverters – Test procedure of islanding prevention measures*

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

3 Terms, definitions and abbreviated terms

3.1 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

3.1.1
black start
startup of an electric power system from a blackout through internal energy resources

3.1.2
converter-type generator
generator that produces electrical power and is connected to the network via a converter, including doubly fed induction machines

3.1.3
declared supply voltage
U_C
supply voltage agreed by the power system operator and the network user

Note 1 to entry: Generally declared supply voltage U_C is the nominal voltage U_n but it may be different according to the agreement between the DSO and the network user.

3.1.4
distributed energy resource
DER
generators (with their unit auxiliaries, protection and connection equipment), including loads having a generating mode (such as electrical energy storage systems), connected to a low voltage or a medium-voltage network

[SOURCE: IEC 60050-617:2017, 617-04-20, modified – unit has been added.]

3.1.5
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

3.1.6
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.]

3.1.7
electrical proximity
state of two or more pieces of equipment linked to one another by connections the impedances of which are negligible as compared to other impedances involved

3.1.8
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 flicker indicator P_{st} and long-term flicker indicator P_{lt}.

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

3.1.9
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 60050-103:2009, 103-07-21, modified – Note 1 to entry has been added.]

3.1.10
fundamental component
sinusoidal component of the Fourier series of a periodic quantity having the frequency of the quantity itself

[SOURCE: IEC 60050-103:2009, 103-07-19]

3.1.11
generating unit
set of equipment connected together whose primary purpose is to generate electrical power.

3.1.12
generating plant
group of generating units including auxiliaries connected to one POC

3.1.13
harmonic component
sinusoidal component of the 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 the "1^{st} harmonic" is not recommended.

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

3.1.14
interface protection
combination of protection relay functions which open the interface switch of a generating unit and prevents its closure, whichever is appropriate, in the case of:

- a fault in the electric power network;
- an unintentional islanding situation;
- voltage and/or frequency being outside the tolerance of their operating ranges for continuous operation

3.1.15
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 can be used.

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

3.1.16
interharmonic component
sinusoidal component of a periodic quantity having an interharmonic frequency

Note 1 to entry: Its value is normally expressed as an RMS value.

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

3.1.17
interoperability
property permitting diverse systems or components to work together for a specified purpose

[SOURCE: IEC 60050-871:2018, 871-05-06]

3.1.18
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]

3.1.19
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]

3.1.20
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]

3.1.21
point of connection
POC
reference point on the electric power system where the user's electrical facility is connected

Note 1 to entry: See Figure 1.

[SOURCE: IEC 60050-617:2009, 617-04-01]

3.1.22
power converter
electronic equipment that converts

- AC to DC (rectifier)
- DC to AC (inverter)
- DC to DC (DC-to-DC converter)
- AC to AC (AC-to-AC converter)

[SOURCE: IEC TR 61850-90-7:2013, 3.1.16]

3.1.23
port
location giving access to a device or network where electromagnetic energy or signals may be supplied or received or where the device or network variables may be observed or measured

[SOURCE: IEC TR 62109.1:2010, 3.64]

3.1.24
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]

3.1.25
rate of change of frequency
ROCOF
amount of frequency change per unit of time

3.1.26
short-term flicker indicator
a 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]

3.1.27
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 60050-441:1984, 441-17-17]

3.1.28
single fault tolerance
built-in capability of a system to provide continued correct execution of its function in the presence of a single fault

3.1.29
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]

3.1.30
switch
device for changing the electric connections among its terminals

Note 1 to entry: See Figure 1.

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

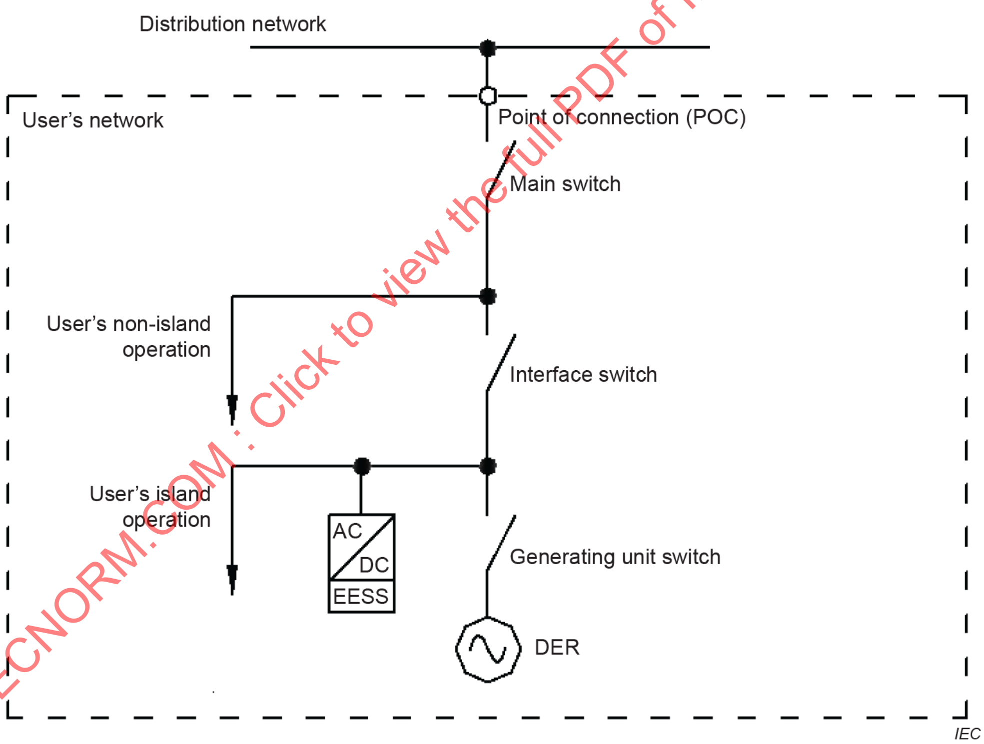


Figure 1 – Example of electricity generating plant connected to a network (schematic view of switches)

3.1.31
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 network

Note 1 to entry: See also Figure 1.

3.1.32
unit auxiliaries
any auxiliary equipment specific to the unit and indispensable for its operation

Examples: mills, circulating pumps, induced draught fans.

[SOURCE: IEC 60050-602:1983, 602-02-29]

3.1.33
interface switch
switch (circuit breaker, switch or contactor) installed in the producer's network, for separating the part(s) of the producer's network that contain at least one generation unit from the network

Note 1 to entry: See also Figure 1.

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

3.1.34
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.

3.1.35
voltage deviation
difference between the supply voltage at a given instant and the declared supply voltage

[SOURCE: IEC 60050-614:2016, 614-01-4]

3.1.36
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]

3.1.37
voltage fluctuation
series of voltage changes or a continuous variation of the RMS or peak value of the voltage

Note 1 to entry: Whether the RMS 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.]

3.1.38
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

3.1.39
voltage unbalance
condition in a polyphase system in which the RMS 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.]

3.2 Abbreviated terms

DER	distributed energy resource
DFIG	doubly fed induction generator
DSO	distribution system operator
EHV	extra high voltage
EMC	electromagnetic compatibility
HV	high voltage
OVRT	overvoltage ride through
LV	low voltage
UVRT	undervoltage ride through
MV	medium voltage
POC	point of connection
PV	photovoltaic
ROCOF	rate of change of frequency

4 Requirements for generating plants

4.1 General

When connecting a DER to the network, consideration should be given to all generating units and loads connected or to be connected in the same electrical proximity. The combined effect of DER should be considered when selecting an appropriate POC for the DER concerned.

4.2 Connection scheme

DER shall follow the requirements of the system operator in POC. Different requirements can be subject to agreement between the operator of the DER and the system operator 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.

Switches and their protections shall be suitable for the type of generating units installed. Related applicable standard shall be used.

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

NOTE In some countries, accessibility is also required for DER 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 or an equivalent device may be required by the system operator.

The interface switch can be combined with either the main switch or with the generating unit switch. In case of a combination, the single switch should be compliant with 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 can include electronic switch (gate blocking) in case of converter connection.

4.4 Normal operating range

4.4.1 General

A DER 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

DER with rated power exceeding the power threshold for frequency deviation $P_{\text{th-fd}}$, (see Annex F), as defined by individual countries, shall withstand frequency deviations in accordance with those specified in Table 1.

Table 1 – Operating frequency requirements of DER

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

The recommended range values of f_{min1}, f_{min2}, f_{max1}, f_{max2} and T_{f1} are specified in Annex A.

4.4.3 Operating voltage range

A DER with a rated power exceeding the power threshold for voltage deviation $P_{\text{th-vd}}$ (see Annex F) as defined by individual countries, should provide capability of withstanding voltage deviations at POC, in accordance with those specified in Table 2.

Table 2 – Operating voltage requirements of DER

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

If the voltage drops below U_{min2}, undervoltage ride through limits as specified in 4.5.3 shall apply.

If voltage exceeds U_{max2}, overvoltage ride through limits as specified in 4.5.4 shall apply.

The recommended range values of U_{min1}, U_{min2}, U_{max1}, U_{max2}, T_{u1} and T_{u2} are specified in Annex B.

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 the system operator in individual countries and by subparts of this series of standards. Immunity level of ROCOF may be configured via communication interfaces.

Three examples follow.

Example 1

After a frequency event on the grid and whilst frequency remains within required frequency operation limits, a DER should maintain continuous operation whilst the absolute value of ROCOF does not exceed:

a) a higher threshold $ROCOF_{hi}$ for the first $t_{ROCOFhi}$ seconds, or

b) a lower threshold $ROCOF_{lo}$ for the first $t_{ROCOFlo}$ seconds,

where $ROCOF_{hi} > ROCOF_{lo}$ and $t_{ROCOFhi} < t_{ROCOFlo}$.

$ROCOF_{hi}$ and $ROCOF_{lo}$ are the higher and the lower ROCOF threshold values, respectively. They are expressed in Hz/s and specified by individual countries.

$t_{ROCOFhi}$ is the minimum time during which a DER should withstand violation of $ROCOF_{hi}$.

$t_{ROCOFlo}$ is the minimum time during which a DER should withstand violation of $ROCOF_{lo}$ (unless $ROCOF_{hi}$ is also exceeded, in which case the above requirement applies).

$t_{ROCOFhi}$ and $t_{ROCOFlo}$ are expressed in seconds and specified by individual countries.

Example 2

Figure 2 and/or Figure 3 may be defined by the system operator.

If frequency is within "stay connected" area, a DER shall maintain the connection with the network. If frequency moves outside of “stay connected” area, a DER may disconnect. The system operator should choose appropriate values for f_0, f_1, f_2, t_0, t_1, t_2, t_3. The chosen values shall be coordinated with the operating frequency range (see 4.4.2).

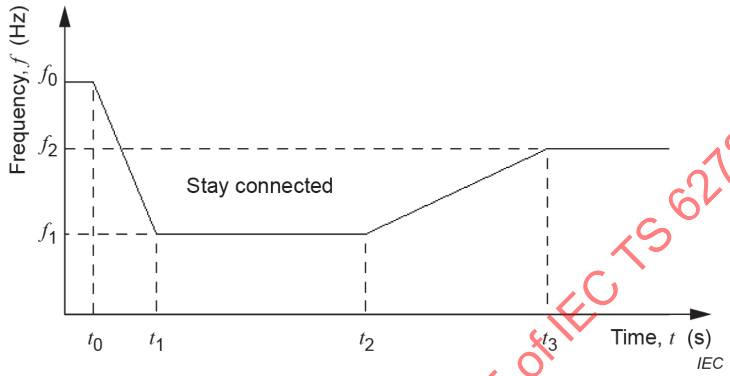


Figure 2 – Underfrequency ride through capability requirements of DER

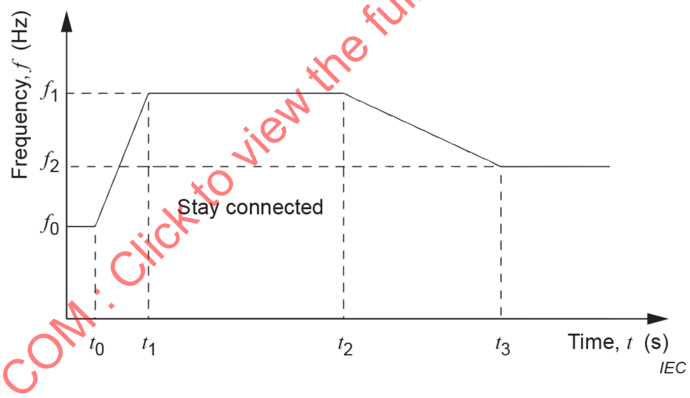


Figure 3 – Overfrequency ride through capability requirements of DER

Example 3

Depending on local system requirements, DER shall be capable of staying connected to the grid during frequency step change caused by autoreclose of transmission line. General requirement of immunity of DER to frequency step change is illustrated in Figure 4.

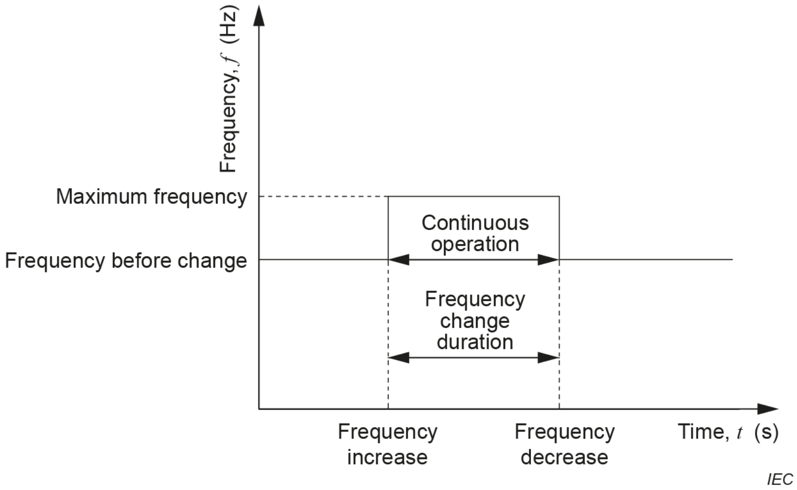


Figure 4 – Instantaneous frequency change ride through requirement of DER

4.5.3 Undervoltage ride through (UVRT) requirements

Depending on local system requirements, DER shall stay connected with the grid for a minimum time during a voltage dip at the POC. General requirements of immunity of DER to voltage dips are illustrated in Figure 5.

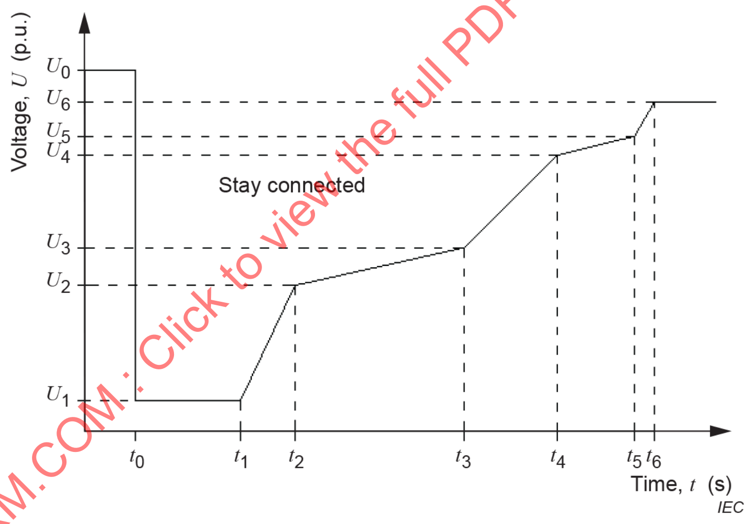


Figure 5 – Undervoltage ride through capability requirements of DER

If the voltage drop at the POC is within "stay connected" area, the DER shall maintain the connection with the network. If the voltage drop at the POC moves out of "stay connected" area, the DER may disconnect.

After the fault is cleared, the DER should recover a specified proportion of its pre-fault output power, S_{rec}, within a specified time, T_{rec}, after stable network conditions are detected as shown in Figure 6.

These requirements apply to all types of short circuit faults. For three phase DER, the lowest phase-to-phase voltage shall be used. Depending on local system requirements, the lowest phase-to-neutral voltage may be used instead.

The recommended value ranges for parameters t_1, t_2, t_3, t_4, t_5, t_6, U_1, U_2, U_3, U_4, U_5, U_6 in Figure 5 are listed in Annex C, Table C.1. The chosen values shall be coordinated with the operating voltage range (see 4.4.3).

If required, a DER connected to MV networks shall participate in dynamic network support (such as fast reactive current injection for inverter based DER), see also 4.7.2 and 4.7.3.

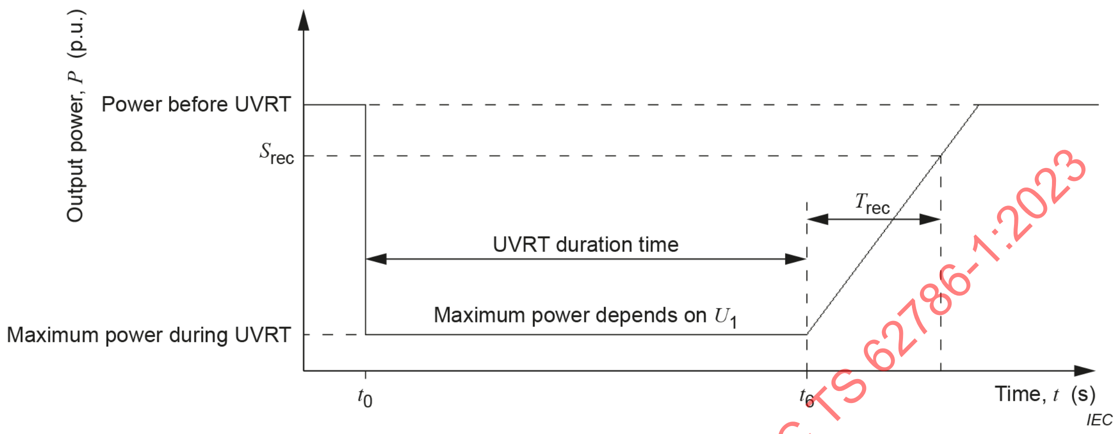


Figure 6 – Power recovering requirements for UVRT operation of DER (example)

4.5.4 Overvoltage ride through (OVRT) requirements

Depending on local system requirements, DER shall stay connected with the grid for a minimum time during a voltage swell at the POC. General requirements of immunity of DER to voltage swell are illustrated in Figure 7.

If the voltage at the POC is within "stay connected" area, DER shall maintain the connection with the network. If the voltage at the POC moves out of "stay connected" area, DER may disconnect.

For three phase DER, the highest phase-to-phase voltage shall be used. Depending on local system requirements, the highest phase-to-neutral voltage may be used instead.

The recommended range values for parameters in Figure 7 are listed in Annex D, Table D.1. The chosen values shall be coordinated with the operating voltage range (see 4.4.3).

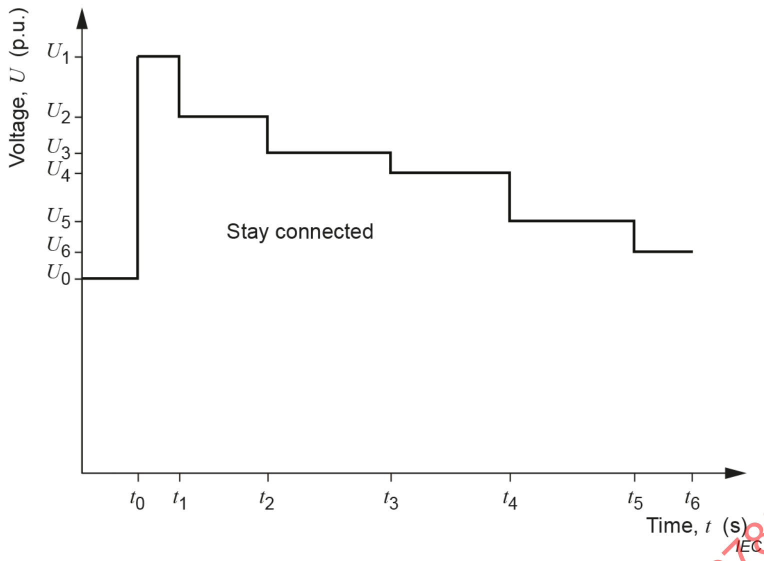


Figure 7 – Overvoltage ride through capability

4.5.5 Rapid phase angle change immunity

Depending on local system requirements, generating units shall be capable of staying connected when the voltage phase angle changes instantaneously.

Recommended immunity thresholds are: 60° (single-phase fault) and 20° (three-phase fault).

NOTE Such a change can happen e.g. during an UVRT or OVRT event.

NOTE Instantaneous phase angle change of voltage vector shape and angle depends on the failure types of line to line or line to neutral short circuit failures and winding connection type of transformer at the substation or distribution line. The winding connection types are expressed in 'delta' and 'star'. The relations of failure types and transformer winding connections are categorized and illustrated in IEC TS 62910. In Figure 8, an example for instantaneous voltage phase angle change during UVRT is illustrated.

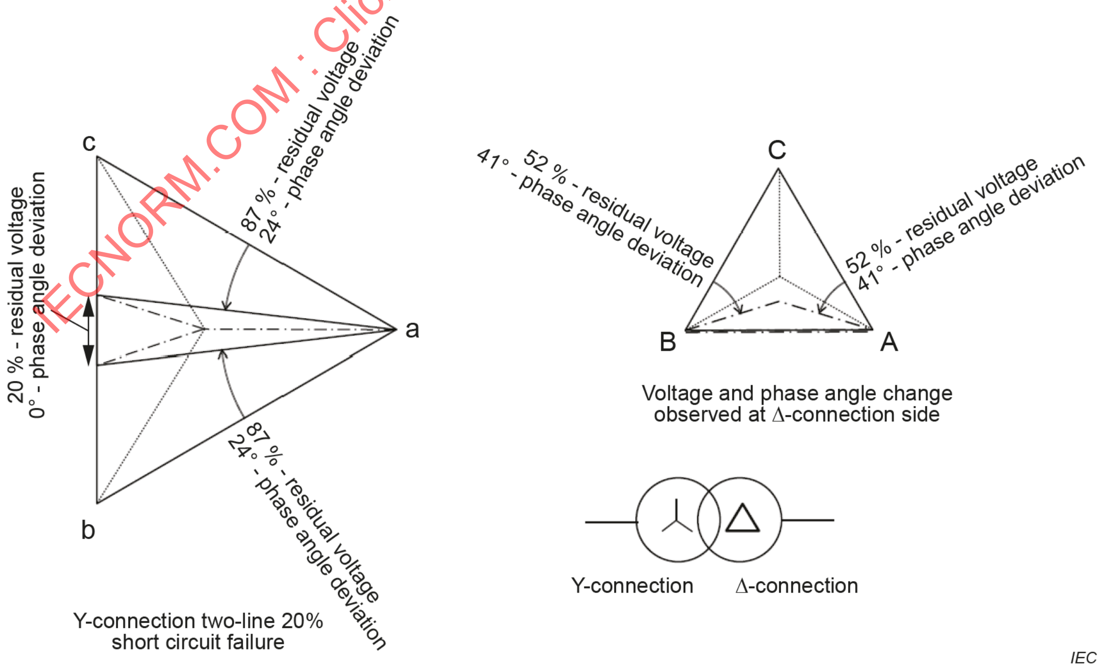


Figure 8 – Example of instantaneous voltage phase angle change during UVRT

4.6 Active power response to frequency deviation

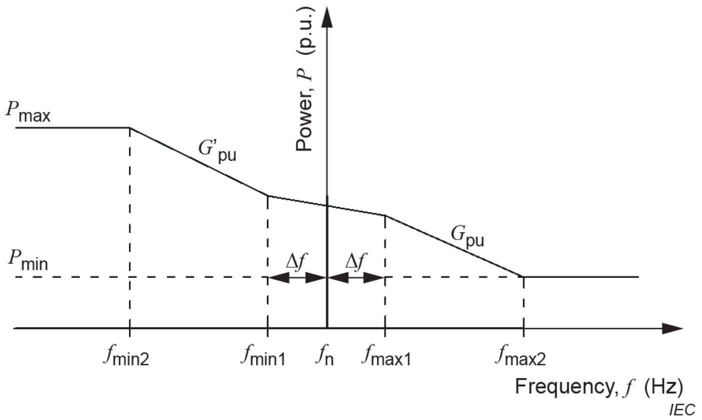


Figure 9 – Typical power-frequency response curve

Depending on local system requirements, all DER connected to MV and those connected to LV network with a rated power exceeding the power threshold for active power control $P_{th\text{-}apc}$, (see Annex F), as defined by individual countries, shall have active power control capability. They shall adjust their active power output in response to frequency deviation (power-frequency response), ensuring the secure operation of the network.

Figure 9 shows a typical power-frequency response curve, as well as the main parameters that specify it.

When network frequency exceeds nominal value (f_n) by more than Δf, DER should reduce their active power output with a gradient G_{pu}. Δf shall be expressed in Hz based on national requirements. G_{pu} shall be expressed as per-unit of DER active power per Hz. Values of Δf and G_{pu} shall be specified by individual countries.

When the network frequency is below nominal value (f_n) by more than $\Delta f'$ and if active power increase is possible, DER should increase their active power output with a gradient G'_{pu}. $\Delta f'$ shall be expressed in Hz based on national requirements. G'_{pu} shall be expressed as per-unit of DER active power per Hz. Values of $\Delta f'$ and G'_{pu} shall be specified by individual countries.

4.7 Power response to voltage changes

4.7.1 General

When the contribution to voltage support is required by the system operator, the generating plant shall manage reactive power generation according to the requirements of 4.7. Priority between functions for voltage support services should be considered on the basis of mutual agreement between the system operator and the DER operator.

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

4.7.2 Voltage support by reactive power

DER connected to MV network, as well as those connected to LV network with a rated power exceeding the power threshold for reactive power $P_{th\text{-}rp}$ (see Annex F), as defined by individual countries, should participate in steady state voltage regulation in response to network voltage conditions or system operator instructions. Such DER should therefore have reactive power capability and be able to maintain a given power factor at POC.

4.7.3 Reactive power control modes

DER required to participate in steady state voltage regulation as per 4.7.2 should provide the following capabilities as required by the system operator.

- $Q = f(U)$ (refer to 4.7.5),
- cos (phi) = $f(U)$ (depending on local system requirements),
- $Q = f(P)$,
- cos (phi) = $f(P)$,
- Q = constant (imposed by DSOs),
- cos (phi) = constant (imposed by DSOs),
- Q = commands from remote controller,
- cos (phi) = commands from remote controller.

Where appropriate, the system operator should give settings concerning the gradient of the characteristic curve.

DER should be able to adjust reactive power output within their reactive power capability range.

NOTE Further information is given in Annex E.

4.7.4 Voltage related active power control

DER connected to MV network and those connected to LV network with a rated power exceeding the power threshold for volt-watt mode $P_{th\text{-}vwm}$, (see Annex F), as defined by individual countries, should have the capability to reduce the power output in response to a rise in voltage (volt-watt response mode). Table 3 provides examples of setting ranges for parameters involved. Figure 10 provides an example of reduction in active power in response to an increase of voltage above U_{max1}. Values and the ranges for MV and LV can be different p.u. values depending on local system operator requirements. The DER is only requested to reduce the power as low as the minimum active power output at stable operation.

Table 3 – Volt watt mode parameters (example)

Reference	Voltage reference values Default (range)	Default values for active power (p.u. of rated power P_{nom})	Range for active power (p.u. of rated power P_{nom})
U_{min2}	0,9 U_{nom} (0,8 to 1)	1,05 P_{nom}	1 to 1,2 or maximum power
U_{min1}	0,95 U_{nom} (0,8 to 1)	P_{nom}	1
U_{max1}	1,05 U_{nom} (1 to 1,2)	P_{nom}	1
U_{max2}	1,1 U_{nom} (1 to 1,2)	0,9 P_{nom}	0 to 1

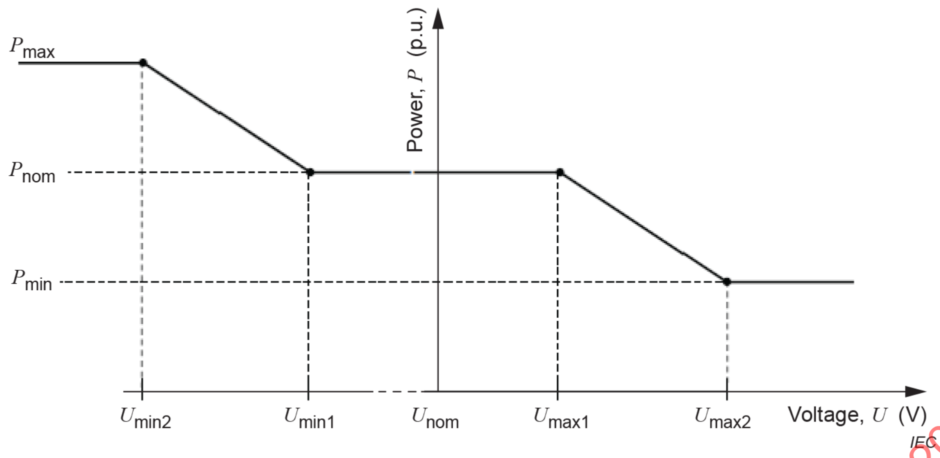


Figure 10 – Typical volt-watt response curve

4.7.5 Voltage related reactive power response

The voltage related reactive power response (volt-var response mode) varies the reactive power output of the generating unit in response to the voltage at its terminals connected to the network. DER connected to a MV network and DER connected to a LV network with a rated power exceeding the power threshold for volt-var response $P_{h\text{-}vvr}$ (see Annex F), as defined by individual countries, should have volt-var response capability. If both volt-watt response mode and volt-var response mode are used, volt-var response mode should be used first.

An example of response curve required for the volt-var response is defined by the voltage reference values specified and corresponding var levels listed in Table 4 and shown in Figure 11.

Table 4 – volt-var response set-point values for reference voltages (example)

Reference	Voltage reference values default (range)	Default values for var level (% rated VA)	Range %
U_{min2}	0,9 U_{nom} (0,8 to 1)	30 overexcited	0 to 60 overexcited
U_{min1}	0,95 U_{nom} (0,8 to 1)	0	0
U_{max1}	1,05 U_{nom} (1 to 1,2)	0	0
U_{max2}	1,1 U_{nom} (1 to 1,2)	30 underexcited	0 to 60 underexcited

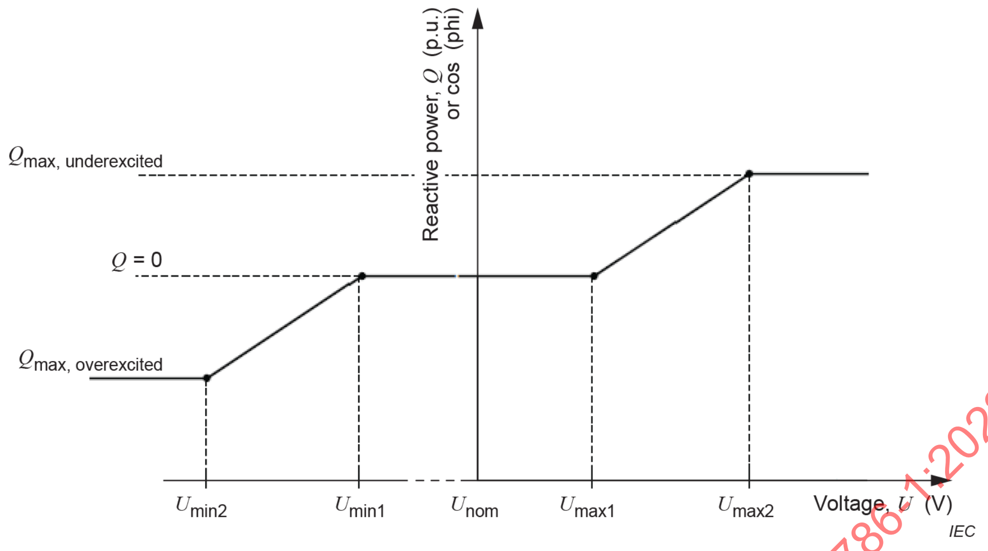


Figure 11 – Typical volt-var response curve

4.7.6 Additional reactive current requirements on generating plants

4.7.6.1 General

In case of faults in the network, depending on local system requirements, three-phase generating plants should have the capability to provide additional reactive current.

The additional reactive current shall be provided when a voltage change occurs. The requirements apply to voltage steps of the positive and the negative sequence component of the fundamental voltage. Voltage steps in the positive sequence result in additional reactive current in the positive sequence; voltage steps in the negative sequence result in additional reactive current in the negative sequence.

NOTE 1 The requirements below describe the general behaviour of the plant. Any implementation is acceptable, provided the generating plant meets the requirements.

The generating plant shall be capable of providing additional reactive current if at least one of the following conditions occurs:

– one or more phase to phase voltages are outside the static voltage range;

– a sudden change in voltage occurs.

The generating plant should cease providing additional reactive current when one of the following occurs:

– all the phase to phase voltages are back into the static voltage range, or

– 5 s if the sudden voltage change did not result in any voltage exceeding the static voltage range.

The static voltage range shall be adjustable from 80 % to 100 % of U_C for the undervoltage boundary and from 100 % to 120 % of U_C for the overvoltage boundary. The default setting shall be the continuous operating voltage range according to 4.4.3. Each phase to phase voltage shall be evaluated.

For the positive sequence, a sudden voltage jump is defined by Formula (1).

$$\Delta U_{1\_Nper} = (U_1 - U_{1\_Nper})/U_C \quad (1)$$

where

ΔU_{1_Nper} is the absolute value of the sudden voltage jump (positive sequence);

U_1 is the actual value of the positive sequence voltage;

U_{1_Nper} is the average, calculated on a number of periods equal to N_{per}, of the positive sequence voltage (recommended value: N_{per} = 50);

U_C is the declared supply voltage.

For the negative sequence, a sudden voltage jump is defined by Formula (2).

$$\Delta U_{2\_Nper} = (U_2 - U_{2\_Nper}) / U_C \tag{2}$$

where

ΔU_{2_Nper} is the absolute value of the sudden voltage jump (negative sequence);

U_2 is the actual value of the negative sequence voltage;

U_{2_Nper} is the average, calculated on a number of periods equal to N_{per}, of the negative sequence voltage;

U_C is the declared supply voltage.

For ΔU_{Nper}, a deadband may be configurable based on local requirements. A recommended range is 0 % to 15 %.

Within the deadband, an additional dynamic reactive current may be required by the DSO, provided it does not cause any network distortions.

The additional reactive current in the positive sequence ΔI_{Q1} is set by the gradient k_1 as per Formulae (3) and (4).

$$\Delta I_{Q1} = k_1 \, \Delta U_1 \tag{3}$$

$$\Delta U_1 = (U_1 - U_{1\_Nmin}) / U_C \tag{4}$$

where

U_1 is the actual voltage of the positive sequence;

U_{1_Nmin} is the average, calculated on N_{min} minutes, of the pre-fault voltage of the positive sequence (recommended value: N_{min} = 1).

NOTE 2 In normal operation, the positive sequence voltage is almost identical to the RMS value.

The gradient k_1 shall be configurable in the range 2 to 6 with a minimum step size of 0,5.

The additional reactive current in the negative sequence ΔI_{Q2} is set by the gradient k_2 as per Formulae (5) and (6):

$$\Delta I_{Q2} = k_2 \, \Delta U_2 \tag{5}$$

$$\Delta U_2 = (U_2 - U_{2\_1min}) \, / \, U_C \tag{6}$$

where

U_2 is the actual voltage of the negative sequence;

U_{2_1min} is the 1 min average of the pre-fault voltage of the negative sequence.

NOTE 3 In normal operation, the negative sequence voltage is ~0.

The gradient k_2 shall be configurable in the range of 2 to 6 with a minimum step size of 0,5.

If the negative sequence voltage is near zero, the phase angle is not detectable. Therefore, if the deadband is configured near zero, for negative sequence voltage jumps, additional reactive current is only required if the negative sequence voltage is large enough for reliable phase angle detection.

The additional reactive current according to Figure 12 shall be provided up to the current limit of the generating plant, at least up to the rated current while considering that both positive and negative sequence reactive current affect the individual phase currents simultaneously. The highest phase current is relevant for the limitation.

During the provision of additional reactive current, it is acceptable to reduce the active current component to maximize reactive current within the apparent current limits of the generating unit. However, the reduction of active current shall be as small as possible.

For voltages below 15 % U_C, no current supply is required.

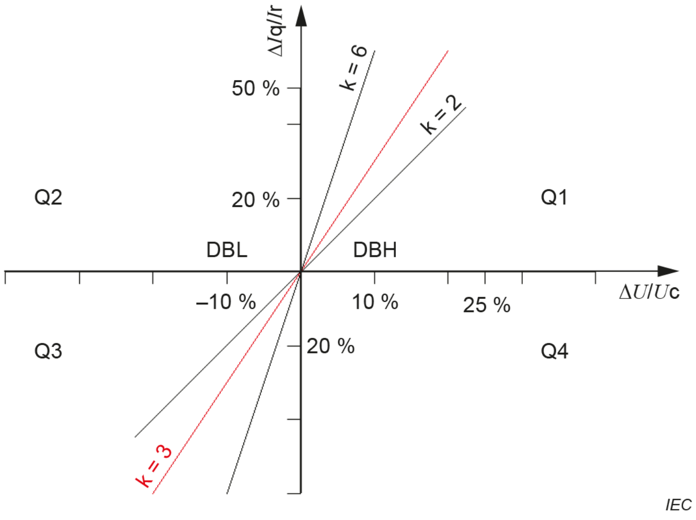


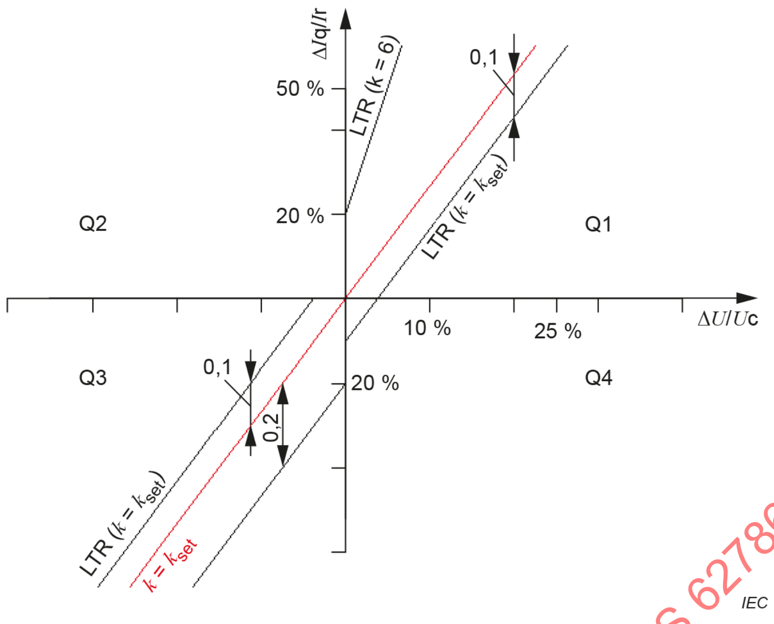
Figure 12 – Principle of voltage support during faults and voltage steps (DBL: lower deadband limit; DBH: higher deadband limit)

The additional reactive current step response time should be no greater than $T_{\text{rc-step}}$ as defined by individual countries (recommended value: $T_{\text{rc-step}}$ = 30 ms). The settling time shall be no greater than $T_{\text{rc-set}}$ as defined by individual countries (recommended value: $T_{\text{rc-set}}$ = 60 ms). This applies for the inception of the fault as well as the fault clearance or any voltage step in the duration of the fault.

This short circuit current requirement may either be implemented in the generating units or in additional equipment in the generating plant. Due to the high dynamic of the requirement, the accuracy of injected current and the response and settling time is evaluated at the clamps of the generating unit or if applicable at the clamps of the additional equipment providing the short circuit current.

The tolerance is defined as in Figure 13.

The lower tolerance in quadrant 1 and 3 is −10 %, the higher tolerance in quadrant 3 is +20 %, the higher tolerance in quadrant 1 has a starting value of +20 % but is increasing with k = 6 independent of the set k factor. Furthermore, in quadrant 1 it is accepted to limit the apparent power to P_{max}.



Key

LTR limit of tolerance range

k shall be assumed to be equal to k_1 in positive sequence and to k_2 in negative sequence.

Figure 13 – Accuracy requirement for additional reactive current in positive and negative sequence

All described settings are defined by the system operator. If no settings are provided, the function shall be disabled.

The enabling and disabling and the settings shall be field adjustable; if required by the system operator, means shall be provided to protect these from unpermitted interference (e.g. password or seal).

4.7.6.2 Optional modes

If required by the system operator, generating plants shall provide one or more of the following optional modes, in addition to the requirements in 4.7.6.1.

Active power priority: The generating plant shall be able to give priority to active current injection. In this case, the generating unit shall deliver maximum available active current, limited only by the current limit of the generating unit. If the resulting active current is lower than the current limit threshold of the generating unit, additional reactive current shall be provided.

Reactive current limitation: the generating plant shall be able to limit the reactive current to a value specified by the system operator. This limitation applies to the absolute reactive current, namely to the sum of the pre-fault reactive current and the additional reactive current. The reactive current limit shall be configurable in the range of 0 % to 100 % of rated current.

Zero current threshold: the generating plant shall have the capability to reduce the current as fast as technically feasible down to or below 10 % of its rated current when the voltage drops below a set zero current threshold. As long as the voltage remains above or once it recovers above this threshold, voltage support during faults and voltage steps is provided. The zero current threshold is defined by the system operator. The smallest phase to neutral voltage or, if no neutral is present, the smallest phase to phase voltage shall be evaluated.

NOTE 1 Active current priority might be necessary in small synchronous zones where the loss of active power generation during a fault might result in frequency deviations.

NOTE 2 For specific technologies, further requirements can be included in relevant parts of the IEC 62786 series.

4.8 EMC and power quality

4.8.1 General

Generating plants shall meet the basic electromagnetic compatibility (EMC) requirements as stipulated in the IEC 61000 series.

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, IEC TR 61000-3-15 is addressing gaps in the existing EMC standards making recommendations, i.e., 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 changes;
– immunity to harmonics and interharmonics components;
– Immunity to voltage unbalance.

4.8.2 Direct current (DC) injection

Generating plants shall not inject direct current into the network in excess of a given threshold, as defined by individual countries (e.g.,0,5 % of nominal current).

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

4.9 Interface protection

4.9.1 General

DER should have protection devices installed to ensure the safe and secure operation of the network. The configuration and selection of protection devices should meet the requirements specified by the local network operator concerned.

The interface protection system has the following main objectives:

– to limit the duration of fault current supplied to the network by the DER, and
– to prevent the DER causing an overvoltage situation or contribute to overfrequency in the network, and
– to detect unintentional islanding situations and where required, disconnect the generating plant in those cases.

The generating plant shall assure the following:

– faults and malfunctions occurring within the generating plant shall not impair the normal functioning of the network;
– the interface switch should be operated in co-ordination with the generating unit switch, the main switch and switches in the network, for faults or malfunctions occurring within the generating plant or the system operator network during operation in parallel with the network;
– the earthing and wiring schemes of generating plants shall be consistent with that of the network.

NOTE 1 If the generating plant is designed for self-consumption only, i.e. no export to the 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 network in case of faults internal to the power generating plant;

NOTE 1 Protection against internal faults (e.g. short-circuits) is coordinated with network protection, according to system operator protection criteria. In addition, protection against overload, electric shock, fire hazards, etc. is implemented according to local requirements.

NOTE 2 For specific technologies, further requirements can be included in relevant parts of the IEC 62786 series.

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

The interface protection relay acts on the interface switch. The system operator 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 5.

Table 5 – Interface protection functions

<table>
<tr><th>Type</th><th>Function</th><th>Normative reference</th></tr>
<tr><td rowspan="17">Passive</td><td>Phase undervoltage protection</td><td rowspan="5">IEC 60255-127</td></tr>
<tr><td>Positive sequence undervoltage protection</td></tr>
<tr><td>Phase overvoltage protection</td></tr>
<tr><td>Residual/zero-sequence overvoltage protection</td></tr>
<tr><td>Negative sequence/unbalance overvoltage protection</td></tr>
<tr><td>Underfrequency protection</td><td rowspan="3">IEC 60255-181</td></tr>
<tr><td>Overfrequency protection</td></tr>
<tr><td>Rate of change of frequency protection</td></tr>
<tr><td>Instantaneous phase overcurrent protection</td><td rowspan="7">IEC 60255-151</td></tr>
<tr><td>Time delayed phase overcurrent protection</td></tr>
<tr><td>Instantaneous earth fault protection</td></tr>
<tr><td>Time delayed earth fault protection</td></tr>
<tr><td>Negative sequence overcurrent or current unbalance protection</td></tr>
<tr><td>Phase undercurrent protection</td></tr>
<tr><td>Voltage-dependent overcurrent protection</td></tr>
<tr><td>Directional current protection</td><td>IEC 60255-12</td></tr>
<tr><td>Vector shift protection</td><td>N/A</td></tr>
<tr><td>Active</td><td>Anti-islanding detection</td><td>IEC 62116</td></tr>
</table>

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

NOTE 4 Vector shift protection can trigger inadvertent tripping of generating plans from the network.

NOTE 5 Further technology-specific requirements are included in other parts of the 62786 series.

NOTE 6 Besides observation of voltage and frequency, other methods are available to detect islanding situations.

4.9.2 Requirements on voltage and frequency protection

The following parameters shall be defined to specify the performance of protection function:

a) measured signals,
b) energizing quantity,
c) set value of energizing quantity,
d) operate time,
e) reset time,
f) time delay,
g) disengaging time.

The further required parameters are specified with each normative reference.

The following two output signals should be provided to operate protection relays:

a) start signal,
b) operate (trip) signal.

The further required signals are specified with each normative reference.

Figure 14 shows the simplified common operations of protection functions.

Energizing quantities are obtained from measured signals. Type of energizing quantities shall be declared for each protection functions.

Figure 14 shows an operational example of protection relay with reset timing characteristics.

If the energizing quantity crosses the set value of protection level, the start signal is given, and delay counter starts. When the energizing quantity falls below the set value, the protection relay returns to its reset state after reset time setting, t_r. During t_r, the counter value is retained.

If the energizing quantity crosses the set value during the reset time period, the delay counter starts to count.

If a cumulative counter value crosses the time delay counter, the operate signal is given to operate the protection relay.

After the energizing quantity falls below the set value, the protection relay returns to its reset state.

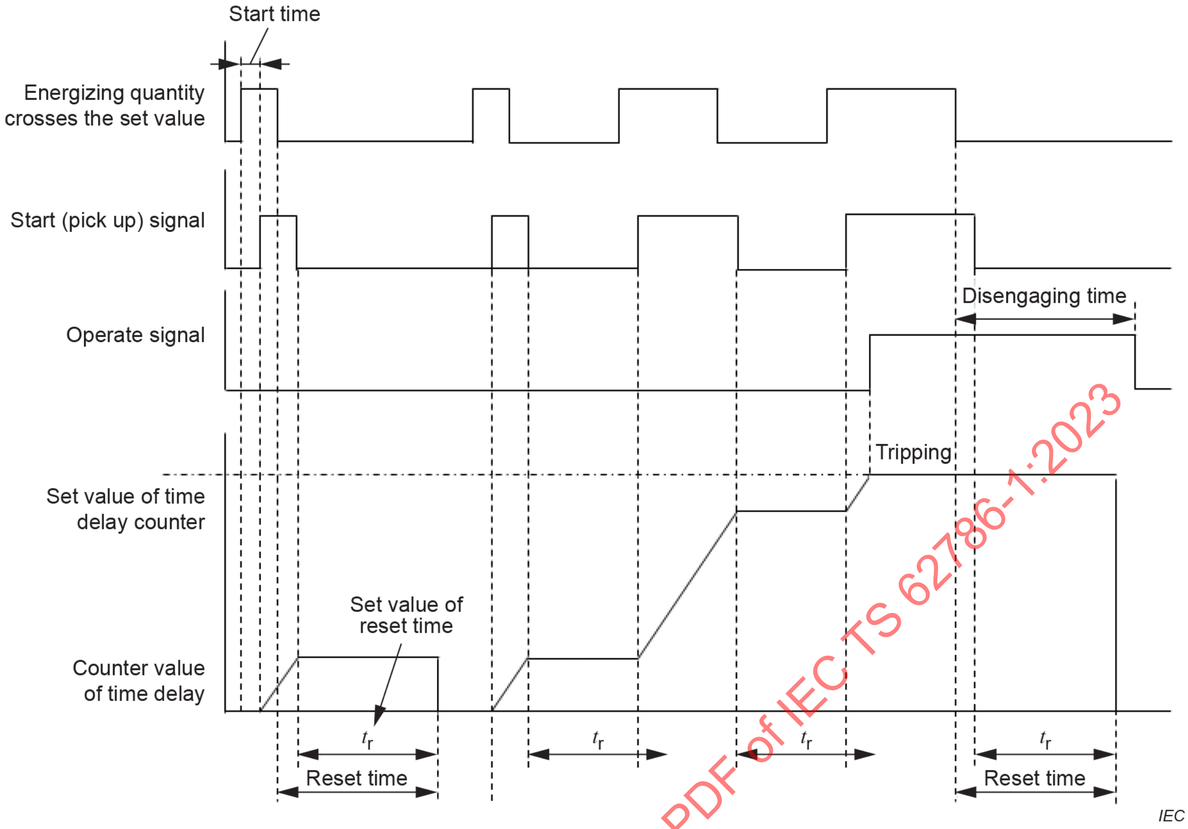


Figure 14 – Operation of protection functions

Detailed requirements of operation of each protection functions are specified in each normative reference.

DER shall include overvoltage and undervoltage protection equipment which shall be consistent with IEC 60255-127. The specification of the function and the performance specification shall be verified on the basis of functional test methodology defined in IEC 60255-127.

DER shall include overfrequency, underfrequency and ROCOF protection equipment which shall be consistent with IEC 60255-181. The specification of the function and the performance specification shall be verified on the basis of functional test methodology defined in IEC 60255-181.

4.9.3 Means to detect islanding situation

In grid-connected operation mode, a DER should have the ability to detect unintentional islanding situations. The unintentional islanding detection and protection time (if any) should not exceed T_{id}.

The anti-islanding protection scheme should also be coordinated with the grid-side line protection and the subsequent reclosing cycle.

The following methods of unintentional islanding prevention methods are commonly used:

a) Passive methods:
   - voltage phase jump detection,
   - voltage harmonic component sudden increase detection,
   - frequency change rate (df/dt) detection,
   - switching to narrow frequency band.

b) Active methods:
   - frequency bias swing with frequency change detection,
   - slip mode frequency shift characteristic with frequency change detection,
   - output active power swing with constant rate with voltage change detection,
   - output reactive power swing with constant rate with voltage phase change detection,
   - load switching with constant rate with current balance detection,
   - output frequency shift characteristic with step reactive power injection by frequency change detection,
   - inter-harmonic current injection with harmonic component detection.

NOTE 1 Depending on local system requirements, a passive method and an active method combination or just one method is used to avoid islanding detection holes on residual P-Q plane before utility open.

NOTE 2 The active method detection is designed, considering that when the residual rotating generator capacity in the system is large, islanding detection time tends to be long.

4.9.4 Digital input to the interface protection

If required by the system operator, the interface protection should have at least two configurable digital input ports. These input ports 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

After a system disturbance that has caused a DER to disconnect, that DER shall not connect to the network unless voltage and frequency are within normal operating ranges and shall only do so after a period of time T_{connect} to be decided by the system operator.

4.10.2 Connection of synchronous-type generators

A synchronous-type DER should be equipped with an automatic synchronization device. $\Delta\varphi$, Δf, ΔU and phase sequence should be considered. $\Delta\varphi$, Δf and ΔU are angle difference, frequency difference and voltage difference, respectively, across the circuit breaker which connects the DER to the POC.

4.10.3 Autoreclose of distribution lines

When the distribution line has an automatic reclosing relay installed, the DER shall disconnect from the network within the autoreclose open time to avoid damage. As an alternative, if allowed by the system operator, the DER may have the capability to withstand out of phase reconnections after autoreclose of the relevant distribution line.

4.11 Ceasing and reduction of active power on set point

Generating plants connected to a MV network and those connected to a LV network with a rated power exceeding the power threshold for disconnection $P_{\text{th-dis}}$ (see Annex F), as defined by individual countries, shall have the capability to be disconnected or curtailed, locally or remotely. The maximum active power output and the rate of active power change should not exceed the value determined by the system operator.

4.12 Remote information exchange

4.12.1 General

Three levels of information exchange with communications shall be constructed as follows:

(Level1) Autonomous DER behaviour responding to local conditions with controllers focused on direct and rapid monitoring and control of the DER.

(Level 2) Management system interaction with multiple DER in which the management system has a more global vision of all DER under its control.

(Level 3) Broadcast/multicast consists essentially of one-way notifications without one-to-one communications with large numbers of DER.

4.12.2 Monitoring and control

DER connected to MV and those connected to LV network with a rated power exceeding the power threshold for information exchange $P_{\text{th-inf}}$, (see Annex F), as defined by individual countries, should be capable of exchanging information with the system operator, and upon mutual agreement, shall be able to be monitored and controlled by the system operator. To ensure the secure operation of network and DER, DER should meet the following requirements:

– Required parameters to be sent from the DER to the system operation centre shall be stipulated in each country.

– Depending on local system requirements, the DER should accept the control and regulation instruction sent by the system operator.

The information provided by the DER to the system operator 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.

4.12.3 Communication

Secure communication channels between a DER and the system operator should be provided.

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

When one is required, the communication system shall be compatible with the IEC 61850 series unless otherwise specified by the system operator.

NOTE 1 Other legacy communication systems are presently in operation.

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

Depending on local system requirements, the following functions should be adjustable through communications interface:

a) ROCOF values (refer to 4.5.2);

b) UVRT settings (refer to 4.5.3);

c) OVRT settings (refer to 4.5.4);

d) Frequency – watt settings (refer to 4.6);

e) Volt-var settings;

f) Volt-watt settings.

NOTE 2 More functions are listed in IEC 61850-7-420 as power control functions of converter-based DER. Detailed configuration of parameters are specified in other parts of the 62786 series.

Before modifying ROCOF, UVRT or OVRT settings, it should be verified that the generating plant has the technical capability to withstand the new settings. The new settings should be agreed upon by all relevant parties.

NOTE 3 The applicability of the new settings can be verified by the system operator or by the DER control system. Agreement on the new settings can be verified by information exchange between DER and system operators.

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

If required by the system operator, 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 safety functions. Faults with a 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 should be displayed and lead to the disconnection of the DER.

5 Conformance tests

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

For electrical safety requirements of installations, refer to appropriate regulation for installation safety of each country.

For commissioning tests, refer to appropriate documents in each country or system commissioning documents in IECRE as appropriate.

For type tests, refer to appropriate IEC standards for each equipment or product.

For details of information exchange, refer to IEC 61850-7-4.

For responsibilities as to compliance and for compliance verification, refer to the appropriate certification authentication schemes.

Annex A
(normative)

Operating frequency range

This annex specifies continuous and limited operating frequency ranges under which all DER with rated power exceeding P_{th-f}, as defined by individual countries, should withstand frequency deviations (see Table A.1 and Table A.2)

Table A.1 – Continuous operating frequency range

Frequency of power system Hz	f_{min1} Hz	f_{max1} Hz
50	48,50 to 49,85	50,15 to 51,00
60	58,00 to 59,90	60,2 to 61,5
NOTE Some countries do 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} Hz
50	47,00 to 49,80	50,20 to 52,00	2 s to 90 min
60	56,50 to 59,80	60,30 to 62,50	2 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 POC voltage ranges under which all DER with a rated power exceeding $P_{th\text{-}vd}$, as defined by individual countries, should withstand voltage deviations (see Table B.1 and Table B.2).

Table B.1 – Continuous operating POC 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
0,85 to 0,9	1,1 to 1,2	10,0 to 180,0	0,0

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

Annex C
(normative)

Undervoltage ride through capability of DER

This annex specifies undervoltage ride through capability of generating units during a voltage dip at the POC (see Table C.1 and Table C.2).

Table C.1 – UVRT capability of DER 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	0,05 to 0,70	0,00 to 0,25
U_2, t_2	0,30 to 0,85	0,00 to 0,30
U_3, t_3	0,70 to 0,85	0,00 to 10,00
U_4, t_4	0,85 to 0,90	0,00 to 10,00
U_5, t_5	0,85 to 0,90	0,00 to 180,00
U_6, t_6	0,85 to 0,90	0,00 to 180,00
NOTE 1 $t_1 \leq t_2 \leq t_3 \leq t_4 \leq t_5 \leq t_6$, $U_1 \leq U_2 \leq U_3 \leq U_4 \leq U_5 \leq U_6$. NOTE 2 By appropriately choosing values for U_i and t_i, two or more points can be made coincident. This makes the curve flexible enough as to fit virtually any local UVRT curve in use in individual countries.		

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

Parameters	Residual voltage in per unit	Ride through time in seconds
U_1, t_1	0,05 to 0,70	0,00 to 0,25
U_2, t_2	0,05 to 0,85	0,00 to 2,00
U_3, t_3	0,70 to 0,85	0,00 to 10,00
U_4, t_4	0,85 to 0,90	0,00 to 10,00
U_5, t_5	0,85 to 0,90	0,00 to 180,00
U_6, t_6	0,85 to 0,90	0,00 to 180,00
NOTE 1 $t_1 \leq t_2 \leq t_3 \leq t_4 \leq t_5 \leq t_6$, $U_1 \leq U_2 \leq U_3 \leq U_4 \leq U_5 \leq U_6$. NOTE 2 By appropriately choosing values for U_i and t_i, two or more points can be made coincident. This makes the curve flexible enough as to fit virtually any local UVRT curve in use in individual countries.		

Annex D
(normative)

Overvoltage ride through parameters

This annex specifies overvoltage ride through capability of generating units during a voltage rise at the POC (see Table D.1).

Table D.1 – OVRT capability of DER

Parameters	Voltage in per unit	Ride through time in seconds
U_1, t_1	1,25 to 1,32	0,00 to 0,10
U_2, t_2	1,20 to 1,30	0,00 to 2,00
U_3, t_3	1,15 to 1,25	0,00 to 5,00
U_4, t_4	1,10 to 1,20	0,00 to 10,00
U_5, t_5	1,10 to 1,15	0,00 to 180
U_6, t_6	1,10 to 1,15	0,00 to 180
NOTE $t_1 \leq t_2 \leq t_3 \leq t_4 \leq t_5 \leq t_6$, $U_1 \geq U_2 \geq U_3 \geq U_4 \geq U_5 \geq U_6$.		