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Wind energy generation systems – Part 21-2: Measurement and assessment of electrical characteristics – Wind power plants

Systèmes de génération d'énergie éolienne – Partie 21-2: Mesurage et évaluation des caractéristiques électriques – Centrales éoliennes



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WIND ENERGY GENERATION SYSTEMS –

Part 21-2: Measurement and assessment of electrical characteristics – Wind power plants

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INTRODUCTION

This part of IEC 61400 defines a uniform method that will ensure the measurement, testing and assessment of the electrical characteristics of grid connected wind power plants. These characteristics include: power quality aspects, control characteristics such as power control, reactive power control, voltage control, frequency control, fault ride-through behaviour, as well as grid protection testing.

The measurements and assessment refer to the point of connection (POC) of the power plant. The procedure describes standardized methods, which will allow the developer as well as system operators (e.g. transmission system operators (TSOs) and distribution system operators (DSOs)) to analyze the fulfilment of the grid connection rules with respect to the above-mentioned characteristics.

This document includes the following aspects:

– definition and specification of the quantities to be determined for characterizing the electrical characteristics of grid connected power plants;
– measurement and test procedures for quantifying the electrical characteristics of a power plant;
– measurement and test procedures of the power plant controller;
– procedures and methods for the estimation of electrical capabilities, using results from each of the wind turbine measurements to assess compliance with electrical connection requirements on power plant level;
– test and measurement procedures that can be used as a reference, for example commissioning tests for existing or newly connected power plants;
– procedures for measurement and fault recording for the validation and verification of wind power plant simulation models as described in IEC 61400-27-1 and IEC 61400-27-2.

These measurement procedures are valid for power plants, including the power plant controller (PPC) and other connected equipment necessary for the operation of the power plant. The measurement procedures are valid for any size of power plant connected to the POC with a single interface.

The results of the measurements and assessment of the power plant’s electrical characteristics can be used as input for the verification of the electrical simulation models for wind power plants as described in IEC 61400-27-2.

Any aspects described in this document can be tested and reported individually, and it is not mandatory to perform all of the described tests and measurements.

The validation of control functions on the power plant is a combination of the performance of the individual power generation units (PGUs), any additional plant components, the communication system and the PPC.

The control performance of the power plant can be proved by a combination of performance tests on site and functionality tests carried out on a hardware-in-the-loop (HIL) setup.

The validation tests for the control performance are therefore divided into two parts:

1) performance tests
2) functionality tests

Functionality tests can be carried out either on a specific test setup (HIL test) or on site.

Performance tests, which are site-dependent, are done at each specific site under the specific site conditions and provide together with the functionality tests the complete control performance of the power plant.

Additional tests and measurements may be carried out and reported on for more detailed assessment of simulation models and compliance with specific grid code requirements.

As the described tests can be used for the validation of other renewable power plants, this document uses the following generic abbreviations:

- PGU: power generation unit as an abbreviated term for a wind turbine
- PP: power plant as the abbreviated term for wind power plant

WIND ENERGY GENERATION SYSTEMS –

Part 21-2: Measurement and assessment of electrical characteristics – Wind power plants

1 Scope

This part of IEC 61400 defines and specifies the quantities that are determined to characterize the electrical characteristics of grid-connected power plants (PPs).

This document defines the measurement and test procedures for quantifying the electrical characteristics as basis for the verification of compliance of PPs, including:

- power quality aspects,
- steady state operation,
- dynamic response (undervoltage and overvoltage fault ride-through),
- disconnection from grid (grid protection),
- control performance.

This document defines a uniform functionality test and measurement procedure for the power plant controller (PPC), as a basis for the unit test of the power plant controller.

This document defines the procedures for assessing compliance with electrical connection requirements, including the aggregation methods for power quality aspects such as voltage variations, flicker, harmonics and interharmonics.

This document defines the procedures for measurement and fault recording, for example for the verification of power plant electrical simulation models in relation to undervoltage and overvoltage ride-through events.

These measurement procedures are valid for power plants, including the power plant controller and other connected equipment, necessary for the operation of the power plant. The measurement procedures are valid for any size of power plant connected to the point of connection (POC) at one connection point.

The procedures for assessing and verifying the compliance with grid connection requirements are valid for power plants in power systems with fixed frequency and a sufficient short-circuit power.

Out of the scope of this document are:

– evaluation of several power plants, i.e. the control by a cluster management of several power plants (PPs) or evaluation where the power plant is connected to several connection points;
– compliance test and performance requirements, including pass or fail criteria;
– specific component test and validation of the PP equipment (switchgear, cables, transformers, etc.), which are covered by other IEC standards;
– wind power plant model validation, as defined in IEC 61400-27-2;
– load flow calculation methods and load flow study guidelines;
– test and measurement of the communication interface and system of the PP as defined in the IEC 61400-25 series.

NOTE For the purposes of this document, the following terms for system voltage apply, based on IEC 60038:

– low voltage (LV) refers to 100 V < U_n ≤ 1 kV;

– medium voltage (MV) refers to 1 kV < U_n ≤ 35 kV;

– high voltage (HV) refers to 35 kV < U_n ≤ 230 kV;

– extra high voltage (EHV) refers to U_n > 230 kV.

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 60038, *IEC standard voltages*

IEC 60255-121:2014, *Measuring relays and protection equipment – Part 121: Functional requirements for distance protection*

IEC 60255-127:2010, *Measuring relays and protection equipment – Part 127: Functional requirements for over/under voltage protection*

IEC 60255-151:2009, *Measuring relays and protection equipment – Part 151: Functional requirements for over/under current protection*

IEC 60255-181:2019, *Measuring relays and protection equipment – Part 181: Functional requirements for frequency protection*

IEC TR 61000-3-6, *Electromagnetic compatibility (EMC) – Part 3-6: Limits – Assessment of emission limits for the connection of distorting installations to MV, HV and EHV power systems*

IEC 61000-4-15, *Electromagnetic compatibility (EMC) – Part 4-15: Testing and measurement techniques –Flickermeter – Functional and design specifications*

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

IEC 61400-21-1:2019, *Wind energy generation systems – Part 21-1: Measurement and assessment of electrical characteristics – Wind turbines*

IEC 61400-27-1, *Wind energy generation systems – Part 27-1: Electrical simulation models – Generic models*

IEC 61400-27-2, *Wind energy generation systems – Part 27-2: Electrical simulation models – Model validation*

IEC 61869-2, *Instrument transformers – Part 2: Additional requirements for current transformers*

IEC 61869-3, *Instrument transformers – Part 3: Additional requirements for inductive voltage transformers*

IEC/IEEE 61850-9-3, *Communication networks and systems for power utility automation – Part 9-3: Precision time protocol profile for power utility automation*

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
additional plant components, pl.
additional equipment necessary for the operation and grid compliance performance of the power generation unit or power plant

EXAMPLE: Capacitor banks, reactive power compensation devices, shunt reactors, static var compensations (SVCs), storage systems, etc.

3.2
available active power
predicted instantaneous active power from the PP, taking into account the available power of each of the PGUs, additional storage equipment, power losses in the collector grid, etc.

Note 1 to entry: The available active power at the PCC is typically provided from the SCADA system.

3.3
available reactive power
predicted instantaneous reactive power from the PP, taking into account the PGUs' capability, compensation equipment, transformers, etc.

Note 1 to entry: The available reactive power at the PCC is typically provided from the SCADA system.

3.4
compliance test
procedure to verify if a characteristic or a property complies with the stated requirements

[SOURCE: IEC 60050-192:2015, 192-09-02]

3.5
component
smallest unit where all necessary functions are available in the unit and which cannot be divided into smaller parts without losing the primary function

Note 1 to entry: Examples for wind turbine components: generators, transformers, switchgear, gearboxes and converters.

3.6
component test
test on a single component, whose necessary functions and required behaviour are not dependent on other components or systems (e.g. the protection device, if this is an independent unit)

Note 1 to entry: A test done on component level shall be valid for all turbine variants where the same component is applied.

3.7
continuous operation
normal operation of the power plant excluding start-up and shut-down of the complete power plant

3.8
disconnection time
time duration from exceeding a predefined disconnection level until the physical disconnection of the power generation unit (PGU) or power plant (PP) from the grid

3.9
droop
ratio of the per-unit change in frequency to the per-unit change in nominal active power

$$droop = \frac{\Delta f / f_{\mathrm{g}}}{\Delta P / P_{\mathrm{n}}} \tag{1}$$

[SOURCE: IEC 60050-603:1986, 603-04-08, modified – used “droop” instead of “droop of a set” in the term, and formula changed.]

3.10
fault ride-through
FRT
ability of a power generation unit or power plant to stay connected during faults in the grid

3.11
flicker coefficient for continuous operation
normalized measure of the flicker emission during continuous operation of the power generation unit or power plant

$$c(\psi_{\mathrm{k}}) = P_{\mathrm{st,fic}} \times \frac{S_{\mathrm{k,fic}}}{S_{\mathrm{n}}} \tag{2}$$

where

$P_{\mathrm{st,fic}}$ is the short-term flicker severity from the PGU or PP on the fictitious grid

S_{n} is the nominal apparent power of the PGU or PP

$S_{\mathrm{k,fic}}$ is the short-circuit apparent power of the fictitious grid

3.12
flicker step factor
normalized measure of the flicker emission due to a single switching operation of the PGU

$$k_{\mathrm{f}}(\psi_{\mathrm{k}}) = \frac{1}{130} \times \frac{S_{\mathrm{k,fic}}}{S_{\mathrm{n}}} \times P_{\mathrm{st,fic}} \times T_{\mathrm{p}}^{0,31} \tag{3}$$

where

T_{p} is the measurement period, which is long enough to ensure that the transient of the switching operation has abated, though limited to exclude possible power fluctuations due to turbulence

$P_{\mathrm{st,fic}}$ is the short-term flicker severity from the PGU on the fictitious grid

S_{n} is the nominal apparent power of the PGU

$S_{\mathrm{k,fic}}$ is the short-circuit apparent power of the fictitious grid

Note 1 to entry: The short-term flicker severity $P_{st,fic}$ is calculated over the time period T_p.

3.13
functionality
ability to perform a specified operation performed by a component or subsystem and a software program

Note 1 to entry: The activity of performing a function normally employs a system of displays, controls and instrumentation.

3.14
functionality test
measurement or test carried out to determine the functionality of the component or system against selected parameters as defined in this document

3.15
hardware-in-the-loop-simulation
HIL
simulation method that allows a hardware under test to interact in a closed loop with a real-time simulation model

Note 1 to entry: In this document the simulation includes electrical emulation of sensors, control signals and actuators, where the electrical emulations act as the interface between the embedded hardware of the power plant controller and the power plant is simulated under the tests.

3.16
installed capacity
sum of the declared ratings for the installed PGUs in the PP

3.17
maximum voltage change
d_{max}
maximum absolute voltage change during an observation period.

Note 1 to entry: For detailed information about the calculation of d_{max}, see IEC 61000-4-15.

3.18
negative sequence component of the fundamental
<for a three-phase system with phases L1, L2 and L3> one of the three symmetrical sequence components which exists only in an unsymmetrical three-phase system of sinusoidal quantities and which is defined by the following complex mathematical expression::

$$\underline{X}_2 = \frac{1}{3}\left(\underline{X}_{L1} + \underline{a}^2\,\underline{X}_{L2} + \underline{a}\,\underline{X}_{L3}\right) \quad (4)$$

where $a = e^{j2\pi/3}$ is the 120° operator, and X_{L1}, X_{L2} and X_{L3} are the complex expressions of the fundamental frequency phase quantities concerned, i.e. current or voltage phasors

Note 1 to entry: Negative sequence voltage or current components can be significant only when the voltages or currents, respectively, are unbalanced. For example, if phase voltage phasors are symmetrical $U_{L1} = Ue^{j\theta}$, $U_{L2} = Ue^{j(\theta+4\pi/3)}$ and $U_{L3} = Ue^{j(\theta+2\pi/3)}$ then $U_2 = (Ue^{j\theta} + e^{j4\pi/3}\,Ue^{j(\theta+4\pi/3)} + e^{j2\pi/3}\,Ue^{j(\theta+2\pi/3)})/3 = Ue^{j\theta}\,(1 + e^{j2\pi/3} + e^{j4\pi/3})/3 = 0$

[SOURCE: IEC 60050-448:1995, 448-11-28, modified – clarified the a operator and note added.]

3.19
network impedance phase angle
phase angle of the network short-circuit impedance:

$$\psi_{\mathrm{k}} = \arctan\left(X_{\mathrm{k}} / R_{\mathrm{k}}\right) \tag{5}$$

where

X_{k} is the network short-circuit reactance

R_{k} is the network short-circuit resistance

3.20
nominal apparent power
apparent power from the power plant while operating at nominal current and nominal voltage and frequency:

$$S_{\mathrm{n}} = \sqrt{3} U_{\mathrm{n}} I_{\mathrm{n}} \text{ at } Q = 0 \tag{6}$$

where

U_{n} is the nominal voltage at the POC of the PP

I_{n} is the nominal current at the POC of the PP

3.21
nominal current
nominal value I_{n} of the power plant current, which is calculated from the nominal active power P_{n} and the nominal voltage U_{n} according to $I_{\mathrm{n}} = \frac{P_{\mathrm{n}}}{\sqrt{3} U_{\mathrm{n}}}$

Note 1 to entry: I_{n} is mainly used for the normalization of the results and the p.u. calculations.

3.22
nominal active power
P_{n}
nominal value of the power plant active power agreed between the grid operator and the plant owner

Note 1 to entry: P_{n} is typically used for the normalization of the results and as the base value for the p.u. calculations (active, reactive, apparent power etc.).

3.23
normal operation
fault free operation as defined by the power plant specification

3.24
operational mode
settable mode of operation, for example voltage control mode, frequency control mode, reactive power control mode, active power control mode, etc.

3.25
overshoot
difference between the maximum measured value of the response and the steady state final value

Note 1 to entry: See Figure 1.

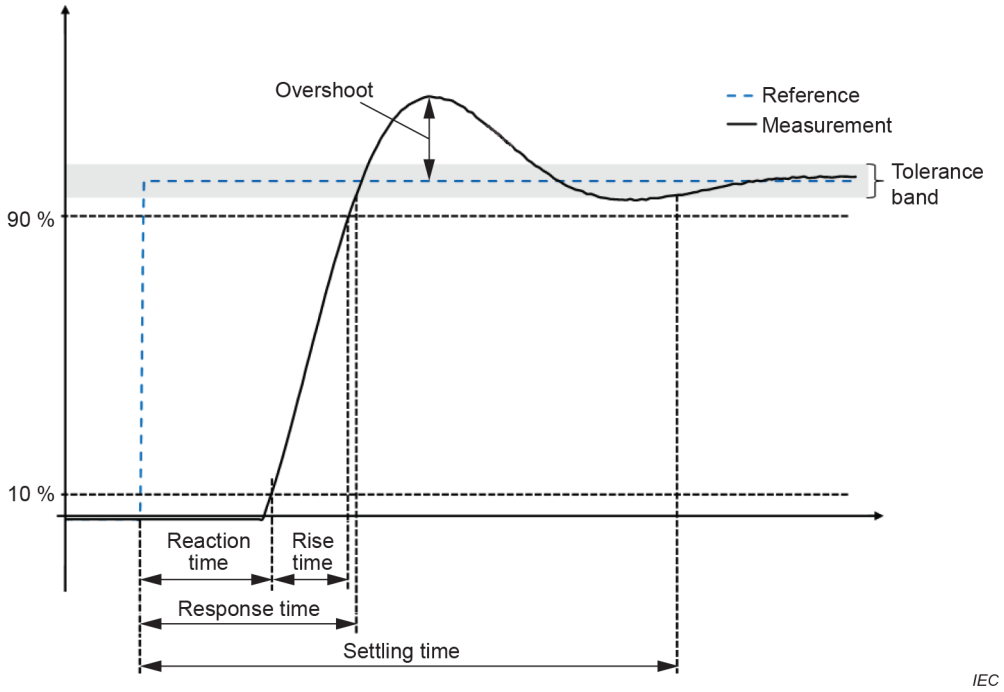


Figure 1 – Example of step response

3.26
overvoltage ride-through
OVRT
ability of a PGU or PP to stay connected during voltage swells

3.27
percentile
value of a variable below which a certain percentage of observations fall

3.28
performance
steady state and dynamic fulfilment according to the specification of the complete system in relation to the defined parameters

3.29
performance test
measurements and tests carried out to determine the performance of the power plant at a given site against selected parameters as defined in this document to archive an intended function

3.30
plant owner
natural or legal entity owning a power plant and responsible for the connection agreement with the regulatory authority/system operator

3.31
point of connection
POC
agreed point in the electric power system where the power plant is connected and is obliged to fulfil the requirements

3.32
positive sequence component of the fundamental
<for a three-phase system with phases L1, L2 and L3> one of the three symmetrical sequence components which exists in symmetrical and unsymmetrical three-phase system(s) of sinusoidal quantities and which is defined by the following complex mathematical expression:

$$\underline{X}_1 = \frac{1}{3}\left(\underline{X}_{L1} + \underline{a}\underline{X}_{L2} + \underline{a}^2\underline{X}_{L3}\right) \quad (7)$$

where $a = e^{j2\pi/3}$ is the 120° operator, and $\underline{X}_{L1}$, $\underline{X}_{L2}$ and $\underline{X}_{L3}$ are the complex expressions of the fundamental frequency phase quantities concerned, i.e. current or voltage phasors

Note 1 to entry: In a balanced harmonic-free system, only a positive sequence component of the fundamental exists. For example, if phase voltage phasors are symmetrical $U_{L1} = Ue^{j\theta}$, $U_{L2} = Ue^{j(\theta+4\pi/3)}$ and $U_{L3} = Ue^{j(\theta+2\pi/3)}$ then $U_1 = (Ue^{j\theta} + e^{j2\pi/3}\, Ue^{j(\theta+4\pi/3)} + e^{j4\pi/3}\, Ue^{j(\theta+2\pi/3)})/3 = (Ue^{j\theta} + Ue^{\theta} + Ue^{j\theta})/3 = Ue^{j\theta}$

[SOURCE: IEC 60050-448:1995, 448-11-27, modified – clarified the a operator and note added.]

3.33
power bin
consecutive, non-overlapping intervals of the power plant active power measured at the power plant terminals

Note 1 to entry: The bins (intervals) are of equal size from 0 %, 10 %, 20 %, ... , 100 % of P_n. 0 %, 10 %, 20 %, ..., 100 % are the bin midpoints.

3.34
power collection system
electrical system that collects the power from power generation units and feeds it into an electrical supply network

[SOURCE: IEC 60050-415:1999, 415-04-06, modified – “wind turbine generator system” replaced with “power generation units”.]

3.35
power generation unit
PGU
smallest set of equipment that can generate electrical energy and feed the electricity into an electric power network

EXAMPLE: Wind turbines, which use wind energy as the primary source of energy and convert this into electrical energy.

3.36
power plant
PP
power station comprising one or more power generating units, additional plant components, tap changers, plant control, etc.

3.37
power plant controller
PPC
device that includes all the control functions necessary for the operation of the power plant

3.38
Q **capability**
reactive power capability of a power plant, including the collector grid and contribution of reactive power compensation devices, etc., up to the POC

Note 1 to entry: Q capability can vary depending on the output power of the PP and the voltage at the POC.

3.39
ramp-down time
time taken for the measured value to decrease from 90 % to 10 % of the step change

3.40
reaction time
elapsed time from the setpoint step change to when the measured value reaches 10 % of the step change

Note 1 to entry: See Figure 1.

3.41
recovery time
elapsed time between the end of the inertia event and the point in time when the active power enters the predefined tolerance band around the pre-event active power value for the last time

3.42
response time
elapsed time from the start of a step change or start of event until the measured value first enters the predefined tolerance band of the target value

Note 1 to entry: See Figure 1.

Note 2 to entry: If the target value is not provided during events, the steady state value can be used.

3.43
rise time
elapsed time from when the measured value reaches 10 % of the step change until the measured value reaches 90 % of the step change

Note 1 to entry: See Figure 1.

3.44
settling time
elapsed time from the start of the step change or start of event until the observed value enters the predefined tolerance band of the target value for the last time

Note 1 to entry: See Figure 1.

Note 2 to entry: If the target value is not provided during events, the steady state value can be used instead.

3.45
short-circuit apparent power
product of the current in the short circuit at a point of a system and a conventional voltage, generally the operating voltage

[SOURCE: IEC 60050-601:1985: 601-01-14]

3.46
short-circuit ratio
SCR
ratio of the short-circuit apparent power S_k to the nominal power S_n

$$SCR = \frac{S_k}{S_n} \tag{8}$$

3.47
start of event
instant of time where the stimulus value deviates outside its defined stimulus tolerance band for the first time

Note 1 to entry: The stimulus can be a reference signal or a disturbance.

Note 2 to entry: The default stimulus tolerance band is defined to be ±10 % of the stimulus increment and centered on the value the stimulus had before the event.

3.48
static error
deviation between the obtained values (observed or measured) and a requested reference value (or setpoint value)

EXAMPLE 1: If the measured value is greater than the setpoint value, the static error or deviation shall have a positive value.

EXAMPLE 2: If the measured value is less than the setpoint value, the static error or deviation shall have a negative value.

3.49
steady state
system state obtained when the settling time has expired

3.50
substation
part of an electrical system confined to a given area, mainly including terminations of transmission or distribution lines, electrical switchgear, protection, control and SCADA equipment, buildings and transformers

Note 1 to entry: The substation can be qualified according to the designation of the system of which it forms a part, for example switching station (transmission system), distribution substation, 400 kV or 20 kV substation.

[SOURCE: IEC 60050-601:1985, 601-03-02, modified – “protection, control and SCADA equipment” has been added and the second part of the definition has been removed.]

3.51
sub-system
system which consists of several components or elements, which are directly related to each other

3.52
sub-system test
test on a sub-system, whose necessary functions and required behaviour are not dependent on other components or systems.

Note 1 to entry: Tests done on a sub-system are valid for all turbine variants, where the same sub-system is applied.

3.53
synthetic inertia
response of a power generating unit or power plant active power production as a function of time after a sudden change in the grid frequency

Note 1 to entry: The expression "synthetic inertia" is in some publications also defined as "virtual inertia", "fast frequency response" or "inertia control". In this document, the term "synthetic inertia" is used for this functionality.

3.54
time-series
record consisting of the numerical values of a time-varying signal's equidistant samples

Note 1 to entry: Samples can represent a measured signal or data processed from the measured values.

3.55
tolerance band
acceptable deviation range of the measured signal from the defined target value

Note 1 to entry: The steady state target value is usually defined as equal to the observed signal's reference value or the value towards which the observed signal is converging after the event.

Note 2 to entry: The default tolerance band is defined to be ±10 % of the nominal value if nothing else is stated.

3.56
unbalance factor
in a three-phase system, the degree of unbalance expressed by the ratio $\left|\underline{X}_2/\underline{X}_1\right|$ (in percent) between the values of the negative sequence component X_2 and the positive sequence component X_1 of voltage or current

[SOURCE: IEC 60050-614:2016, 614-01-33, modified – operator X added and RMS values removed.]

3.57
undervoltage ride-through
UVRT
ability of a power generating unit or power plant to stay connected during voltage dips

3.58
validation
confirmation, through the provision of objective evidence, that the requirements for a specific intended use or application have been fulfilled

Note 1 to entry: In relation to this document, the defined test & measurement procedures are validation procedures as the validation is based on experimental data in relation to an intended use.

Note 2 to entry: In this document the defined tests procedures etc. are validation tests, as the IS does not verify that specific requirements are meet.

[SOURCE: IEC 60050-192:2015,192-01-18, modified – the notes have been removed and new notes added.]

3.59

verification
confirmation, through the provision of objective evidence, that specified (system) requirements have been fulfilled

Note 1 to entry: In relation to this document the measurement results can be used to assess conformity of the PP to a specified requirement, for example to verify that the PP fulfils for example specific grid code requirements.

3.60
voltage change
d_c
maximum steady state voltage change during an observation period

Note 1 to entry: For detailed information about the calculation of d_c, see IEC 61000-4-15.

3.61
voltage change factor
normalized measure of the voltage change due to a switching operation of the power generating unit:

$$k_u(\psi_k) = \sqrt{3} \times \frac{U_{fic,max} - U_{fic,min}}{U_n} \times \frac{S_{k,fic}}{S_n} \quad (9)$$

where

$U_{fic,min}$ and $U_{fic,max}$	are the minimum and maximum one-period RMS value of the phase-to-neutral voltage on the fictitious grid during the switching operation
U_n	is the nominal phase-to-phase voltage at the PGU terminals
S_n	is the nominal apparent power of the PGU
$S_{k,fic}$	is the short-circuit apparent power of the fictitious grid

Note 1 to entry: The voltage change factor k_u is similar to k_i which is the ratio between the maximum inrush current and the nominal current, though k_u is a function of the network impedance phase angle. The highest value of k_u will be numerically close to k_i.

3.62
voltage dip
limited duration non-periodic sudden decrease of the power supply network's voltage amplitude and associated phase changes

3.63
voltage swell
limited duration non-periodic sudden increase of the power supply network's voltage amplitude above its nominal value and associated phase changes

3.64
wind turbine
WT
system which converts kinetic wind energy into electrical energy

[SOURCE: IEC 60050-415:1999, 415-01-01, modified – "into another form of energy" replaced with "electrical energy".]

3.65
zero sequence component of the fundamental
<for a three-phase system with phases L1, L2 and L3> one of the three symmetrical sequence components which exists only in an unsymmetrical three-phase system of sinusoidal quantities and which is defined by the following complex mathematical expression:

$$\underline{X}_0 = \frac{1}{3}\left(\underline{X}_{L1} + \underline{X}_{L2} + \underline{X}_{L3}\right) \quad (10)$$

where X_{L1}, X_{L2} and X_{L3} are the complex expressions of the fundamental frequency phase quantities concerned, i.e. current or voltage phasors

[SOURCE: IEC 60050-448:1995, 448-11-29]

4 Symbols and abbreviated terms

For the purposes of this document, the following symbols and abbreviated terms are used.

4.1 Symbols

$\frac{\Delta U_{dyn}}{U_n}$	maximum permitted voltage change (%)
ψ_k	network impedance phase angle (°)
$\alpha_m(t)$	electrical angle of the fundamental of the measured voltage (°)
β	exponent associated with summation of harmonics
$c(\psi_k)$	flicker coefficient for continuous operation
d	relative voltage change (%)
d_c	steady state voltage change
d_{max}	maximum voltage change
E_{Plti}	long-term flicker emission limit
E_{Psti}	short-term flicker emission limit
f_g	nominal grid frequency (50 Hz or 60 Hz)
$f_{inertia,\ recovery}$	frequency threshold where the turbine shall stop boosting active power (Hz)
$f_{inertia,\ trigger}$	frequency threshold where the turbine shall start boosting active power (Hz)
f_{over}	overfrequency protection / control activation level (Hz)
f_{under}	underfrequency protection / control activation level (Hz)
h	harmonic order
$I_{h,i}$	h'th order harmonic current distortion of i'th wind turbine (A)
$i_m(t)$	measured instantaneous current (A)
I_n	nominal current (A)
IUF	current unbalance factor
$k_f(\psi_k)$	flicker step factor