IEC/TR 61000-3-15

Edition 1.0 2011-09

TECHNICAL REPORT

colour inside

Electromagnetic compatibility (EMC) – Part 3-15: Limits – Assessment of low frequency electromagnetic immunity and emission requirements for dispersed generation systems in LV network

IEC/TR 61000-3-15:2011(E)

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

PRICE CODE X

ICS 33.100.10

ISBN 978-2-88912-636-1

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 3-15: Limits – Assessment of low frequency electromagnetic immunity and emission requirements for dispersed generation systems in LV network

FOREWORD

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IEC 61000-3-15, which is a technical report, has been prepared by subcommittee 77A: Low frequency phenomena, of IEC technical committee 77: Electromagnetic compatibility.

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

Enquiry draft	Report on voting
77A/744/DTR	77A/759/RVC

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

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

A list of all the parts in the IEC 61000 series, published under the general title *Electromagnetic compatibility* can be found on the IEC website.

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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

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

INTRODUCTION

IEC 61000 is published in separate parts according to the following structure:

Part 1: General

General considerations (introduction, fundamental principles)

Definitions, terminology

Part 2: Environment

Description of the environment

Classification of the environment

Compatibility levels

Part 3: Limits

Emission limits

Immunity limits (in so far as they do not fall under the responsibility of product committees)

Part 4: Testing and measurement techniques

Measurement techniques

Testing techniques

Part 5: Installation and mitigation guidelines

Installation guidelines

Mitigation methods and devices

Part 6: Generic standards

Part 9: Miscellaneous

Each part is further subdivided into several parts published either as International Standards or as technical specifications or technical reports, some of which have already been published as sections. Others are published with the part number followed by a dash and a second number identifying the subdivision (example: IEC 61000-6-1).

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 3-15: Limits – Assessment of low frequency electromagnetic immunity and emission requirements for dispersed generation systems in LV network

1 Scope

This part of IEC 61000 is concerned with the critical assessment of existing and emerging national and international standards for single and multi-phase dispersed generation systems up to 75 A per phase, particularly converters connected to the public supply low voltage network, to serve as a starting point and to ultimately pave the way for the definition of appropriate EMC requirements and test conditions. This Technical Report is limited to EMC issues (immunity and emission) up to 9 kHz and does not include other aspects of connection of generators to the grid.

2 Terms and definitions

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

2.1
electromagnetic compatibility
EMC
ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment

[IEC 60050-161:1990, 161-01-07]

2.2
distributed generation, embedded generation, dispersed generation
DG
generation of electric energy by multiple sources which are connected to the power distribution system

[IEC 60050-617:2009, 617-04-09]

2.3
current source inverter
stiff current source inverter (inverter operating as an impressed current source)

2.4
voltage source inverter
stiff voltage source inverter with current control (inverter operating as an impressed voltage source)

2.5
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 a.c.

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

2.6
(electromagnetic) emission
phenomenon by which electromagnetic energy emanates from a source

[IEC 60050-161:1990, 161-01-08]

NOTE For the purpose of this report, emission refers to phenomena such as conducted electromagnetic disturbances that can cause distortions, fluctuations or unbalance on the supply voltage.

2.7
emission level (of a disturbing source)
level of a given electromagnetic disturbance emitted from a particular device, equipment, system or disturbing installation as a whole, assessed and measured in a specified manner

2.8
power quality
characteristics of the electric current, voltage and frequencies at a given point in an electric power system, evaluated against a set of reference technical parameters

NOTE These parameters might, in some cases, relate to the compatibility between electricity supplied in an electric power system and the loads connected to that electric power system.

[IEC 60050-617:2009, 617-01-05]

2.9
point of common coupling
PCC
point of a power supply network, electrically nearest to a particular load, at which other loads are, or may be, connected

NOTE 1 These loads can be either devices, equipment or systems, or distinct customer's installations.

NOTE 2 In some applications, the term “point of common coupling” is restricted to public networks.

2.10
emission limit (allowed from a disturbing source)
specified maximum emission level of a source of electromagnetic disturbance (e.g. device, equipment, system or disturbing installation as a whole)

2.11
immunity (to a disturbance)
ability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance

[IEC 60050-161:1990, 161-01-20]

2.12
immunity level
maximum level of a given electromagnetic disturbance on a particular device, equipment or system for which it remains capable of operating with a declared degree of performance

2.13
fundamental component
sinusoidal component of the Fourier series of a periodic quantity having the frequency of the quantity itself

2.14
harmonic frequency
frequency which is an integer multiple of the fundamental frequency

NOTE The ratio of the harmonic frequency to the fundamental frequency is the harmonic order (recommended notation: “h”).

2.15
interharmonic frequency
frequency which is a non-integer multiple of the reference fundamental frequency

NOTE 1 By extension from harmonic order, the inter-harmonic order is the ratio of an inter-harmonic frequency to the fundamental frequency. This ratio is not an integer. (Recommended notation “m”).

NOTE 2 In the case where $m < 1$, the term sub-harmonic frequency may be used.

2.16
total harmonic distortion
THD
ratio of the r.m.s. value of the harmonic content of an alternating quantity to the r.m.s. value of the fundamental component of the quantity

2.17
voltage unbalance
in a poly-phase system, a condition in which the magnitudes of the phase voltages or the phase angles between consecutive phases are not all equal (fundamental component)

2.18
flicker
impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates with time

2.19
short-term flicker indicator
P_{st}
measure of flicker evaluated over a specified time interval of a relatively short duration

NOTE The duration is typically 10 min, in accordance with IEC 61000-4-15.

2.20
long term flicker indicator
P_{lt}
measure of flicker evaluated over a specified time interval of a relatively long duration, using successive values of the short-term flicker indicator

NOTE The duration is typically 2 h, using 12 successive values of P_{st}, in accordance with IEC 61000-4-15.

2.21
voltage fluctuation
series of voltage changes or a continuous variation of the r.m.s. or peak value of the voltage

2.22
voltage dip (voltage sag)
sudden reduction of the voltage at a point in an electrical system followed by voltage recovery after a short period of time from a few cycles to a few seconds

2.23
short interruption (of supply voltage)
disappearance of the supply voltage for a time interval whose duration is between two specified limits

2.24
distribution system operator, distribution network operator
DSO
party operating a distribution system

2.25
product test
test which assesses the DG current emissions in worst case conditions

NOTE This test method is based on the test circuits specified in IEC 61000-3-2 (up to 16 A), and IEC 61000-3-12 (up to 75 A).

2.26
system test
test which emulates the DG actual condition in the public supply network

NOTE This test method is based on the test circuits specified in IEC 61000-3-3 (up to 16 A), and IEC 61000-3-11 (up to 75 A), including the impedance, with the addition of a defined load and specified pre-distortion levels.

2.27
islanding protection
protection against the continuous operation of the inverter and part of the utility load once isolated from the remainder of the electric utility system

2.28
active infeed converter
AIC
self commutated electronic power converter of all technologies, topologies, voltages and sizes which are connected between the electrical a.c. power supply system (lines) and a d.c. side (current source or voltage source) and which can convert electrical power in both directions (generative or regenerative) and control the power factor of an applied voltage or current

NOTE Some of them can additionally control the harmonic distortion of an applied voltage or current. Basic topologies may be realized as a Voltage Source Converter (VSC) or a Current Source Converter (CSC).

3 General

This Technical Report applies to DG and primarily concerns the critical assessment of several common low frequency electromagnetic emission and immunity requirements.

It can be considered an initial proposal in order to gain experience toward the definition of appropriate EMC limits and test conditions for the connection of potentially disturbing installations to LV power systems.

This Technical Report focuses on emission caused by DG (mainly harmonics and inter-harmonics, DC emissions flicker, rapid voltage changes and fluctuations), as well as immunity aspects to normally occurring events in the public supply network (voltage dips and short interruptions, frequency variations, harmonics and interharmonics).

In addition, every effort has been made to utilize already existing emission and immunity standards, including the test set-up and existing test equipment in use.

The existing standards, in combination with the requirements of DG equipment, lend themselves to the definition of two types of emission tests:

- the “product test”;
- the “system test”.

The application of these two test methods is believed to meet the demands from both DSO and DG manufacturers and should result in reliable operation of DG equipment up to 75 A when connected under typical network conditions. It should be noted that these tests, although being primarily emission tests, also deal to some extent with the immunity of the DG against normally occurring events in the public supply.

At this time, DG equipment is generally not designed to compensate for current or voltage distortions but this possibility may be evaluated for future developments. For such developments no requirements are included in this Technical Report, but the method of the system test introduced in this report could be used to evaluate compensating behaviour.

The suggested emissions and immunity tests are devised to assure that DG equipment connected to the network may be expected to function acceptably in the EMC environment.

4 Classification of DG generators

4.1 General

The aim of the following short description of different generation systems is to highlight the behavior of static power supplies connected to the electrical network compared with other types of generators.

There are three main types of generation systems that interface to the power system. These include:

- induction (asynchronous) generators;
- synchronous generators;
- static power converters.

Each type has its own specific characteristic regarding synchronization equipment, protective functions, starting practices, and electrical operating behavior. The primary energy source of generating plant can be internal or external combustion, wind, fuel cells, electrochemical accumulators flywheel storage systems, small scale hydro and photovoltaic cells.

In this Technical Report both current and voltage source inverters are addressed. Although, most DG inverters might be considered as voltage source inverters based on their topology, they behave with a current source control strategy when viewed from the network integration perspective.

This means that it is generally assumed that the line voltage at the point of DG connection can be regarded as constant, so the desired power injection is achieved by controlling the current injected by the inverter.

4.2 Induction (asynchronous) generators

An induction generator, "asynchronous" generator, operates on the principles of an AC induction motor, except that in normal operation it has a speed of rotation slightly greater than the synchronous speed of the power system. Induction generators, however, are commonly used in power plants that only need to operate in parallel with another source (such as the utility system).

Induction generators take their excitation current via their stators. Thus, they consume reactive power from the system. This causes voltage drop and increased losses in the distribution system. In situations where system losses and voltage drop are significant, the induction generator may need provisions to correct its power factor to near unity.

Induction generators cannot sustain an appreciable fault current at their terminals for a long time due to the collapse of excitation source voltage during the fault. However, they will inject a large amount of current for a short transient period of time and this can impact the power system. Because of the characteristics of the induction generator described above, its protection and interface is somewhat different from that of the synchronous generator.

4.3 Synchronous generators

Synchronous generators (acting as voltage sources) are rotating energy conversion machines capable of operating as stand-alone power sources (running independently of any other source). They also can operate in parallel with other sources (such as a utility distribution system) if they are properly synchronized to those sources and have appropriate protection/controls.

One of the synchronous generator's characteristics is that the integral exciter and exciter controls allow it to operate as a stand-alone source. This is particularly useful for DG installations that can serve the dual function of stand-alone (standby) power unit and also grid parallel operation. Extra care in the anti-island protection is required with these units.

In addition, synchronous generators, unlike induction generators, shall be precisely synchronized with the utility system at the instant of connection and during operation. This means matching the frequency, phase angle and voltage magnitude within certain tight tolerances at the instant of interconnection of the customer's circuit breaker interface between the utility network in order to avoid damage to, or problems with, the generator or utility system equipment.

The unit's load shall be controlled in order to maintain synchronicity. If the unit slips out of synchronism and is not immediately separated from the system equipment, damage or power quality problems are likely to occur.

Synchronous generators, due to their exciters, can sustain fault currents for much longer than an induction generator (assuming the exciter energy source is separately derived). This makes fault protection more critical on a synchronous unit than on an induction unit.

4.4 Static power converters

The static power converter (inverter) provides the interface between direct current (DC) energy sources or variable frequency sources and the power distribution system. Examples of generation systems employing inverter units include photovoltaic arrays, fuel cells, battery storage systems, some types of micro-turbines, and some types of wind turbines.

Unlike an induction or synchronous generator that uses rotating coils and magnetic fields to convert mechanical into electrical energy, the inverter normally converts one form of electricity into another (i.e. DC to AC) using solid state electronics, and it is typically controlled and protected by its internal electronic circuits. The internal controller detects abnormal voltage, current and/or frequency conditions and quickly disables the injection of power into the utility system if maximum tolerances for voltage or frequency deviations are exceeded. It also controls synchronization and start-up procedures.

While most small converter units designed for grid parallel operation can rely totally upon their internal protection functions, larger and special feature inverter units may also require external protection/control functions.

There are differences between inverters and rotating machines. For example, as the inverter has no moving or rotating parts, it utilizes the on/off switching of semiconductor devices to "synthesize" the AC power frequency waveform from the energy source. In addition, due to the fast switching response of solid state switching devices, a converter is usually able to stop producing energy much faster than a typical rotating machine, once the controller protection scheme identifies the need to interrupt flow of energy.

5 Survey of EMC requirements for DG

The need for testing and certification of distributed generation equipment to ensure a compatible, reliable interconnection with the electric power grid and other load equipment is leading research bodies, such as IEEE, EPRI, UL, CIGRE and CIRED to increase the investigations on this matter to arrive at operating guidelines or standards that find widespread acceptance.

Within the framework of international EMC standardization regarding integration of renewable energy sources and distributed energy generation in the electricity supply, the development of common EMC requirements is more and more required.

The most frequently used specifications and emission requirements in different countries are summarized in Table 1.

The aim of Table 1 is mainly to assess how low frequency emission requirements are taken into account in different countries and to summarize the possible national/international standards and common practice specifications that are normally applied to DG and comply with DSOs' restrictions.

In Table 1, data related to voltage fluctuations, harmonics and DC injection were mainly provided by CIGRE TF C6.04.01, a Task Force dedicated to the connection criteria at the distribution network for distributed generation [1][1].

The Table was subsequently updated on the basis of the contributions from National Committees. The last column in Table 1 lists the references to National Specifications.

The proposed emission tests in this Technical Report are derived with these existing standards in mind.

Data on EMC low frequency immunity requirements were insufficient for a dedicated table.

Table 1 – DG specifications and emission requirements applied in different countries

Country	*Voltage fluctuations*	*Harmonics*	*DC injection*	*National specifications*
Austria	P_{lt} = 0,46 Resulting from all the connected generators at the PCC mostly affected	Individual limits based on the available short-circuit power (half of the limits used for loads of the same power)	Systems which inject DC current by design (e.g. half wave operation) are not permitted. (Ref to EN 50438:2007)	TOR D2:2006 Assessment of network interferences for any installation (MV and LV) ÖVE/ÖNORM E 8001-4-172:2009 (for PV installations)
Belgium	informative IEC 61000-3-3, IEC 61000-3-5 to IEC 61000-3-11	informative IEC 61000-3-2, IEC 61000-3-4 IEC 61000-3-12	< 1 % of rated current; if > 1 %, trip after 0,2 s	Synergrid – Specific technical requirements for connection of DG systems operating in parallel on the distribution network (C10/11 – revision 12 May 2009)
Canada	IEEE 519 or IEC 61000 series	IEC 61000 series or IEEE 519	IEEE 1547: < 0,5 % rated current	C22.3 NO. 9.08 Interconnection of Distributed Resources and Electricity Supply systems CAN/CSA-C22.2 NO. 257-06 Interconnecting Inverter Based Micro-Distributed Resources to Distribution Systems

1 Numbers in square brackets refer to the Bibliography.