IEC TR 61000-3-18

Edition 1.0 2024-02

TECHNICAL REPORT

colour inside

Electromagnetic compatibility (EMC) –
Part 3-18: Limits – Assessment of network characteristics for the application of harmonic emission limits – Equipment connected to LV distribution systems not covered by IEC 61000-3-2 and IEC 61000-3-12

IEC TR 61000-3-18:2024-02(en)

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IEC TR 61000-3-18 has been prepared by subcommittee 77A: EMC – Low frequency phenomena, of IEC technical committee 77: Electromagnetic compatibility. It is a Technical Report.

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

Draft	Report on voting
77A/1197/DTR	77A/1202/RVDTR

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 Report 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 61000 series, published under the general title *Electromagnetic compatibility (EMC)*, can be found on the IEC website.

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

- reconfirmed,
- withdrawn, or
- revised.

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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 levels

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 the 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 will be 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 3-18: Limits – Assessment of network characteristics for the application of harmonic emission limits – Equipment connected to LV distribution systems not covered by IEC 61000-3-2 and IEC 61000-3-12

1 Scope

This part of IEC 61000, which is a technical report, reports on the development of a methodology for adapting IEC equipment emission limits from IEC 61000-3-2 and IEC 61000-3-12 for use in regions not covered by these documents. It identifies gaps in the existing equipment emission limit standards concerning their international applicability and identifies public power system characteristics important for the evaluation of harmonic voltage performance.

The purpose of adapting the above-mentioned IEC equipment harmonic emission standards in a particular region is to maintain similar electromagnetic compatibility (EMC) of equipment up to 75 A per phase in the public power systems in those regions.

NOTE The boundaries between the various voltage levels differ amongst different countries (see IEC 60050-601:1985, 601-01-28). This document uses the following terms when referring to 50 Hz and 60 Hz system voltages:

– low voltage (LV) refers to $U_n \leq 1$ kV;

– medium voltage (MV) refers to 1 kV < $U_n \leq 35$ kV;

– high voltage (HV) refers to 35 kV < $U_n \leq 230$ kV.

EMC requirements can have economic and societal impacts; these have not been considered in the development of this document. The consideration of these factors generally occurs in the technical committees working on development and maintenance of emission limit standards.

2 Normative references

There are no normative references in this document.

3 Terms, definitions and abbreviated terms

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 Terms and definitions

3.1.1
distribution system operator
DSO
party operating an electric power distribution system

[SOURCE: IEC 60050-617:2009, 617-02-10, modified – electric power has been added to the definition.]

3.1.2
distributed energy resource
DER
generator (with its 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 – changed to singular]

3.1.3
electromagnetic compatibility
EMC
ability of equipment or a system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment

[SOURCE: IEC 60050-161:2018, 161-01-07]

3.1.4
(electromagnetic) compatibility level
the specified electromagnetic disturbance level used as a reference level for co-ordination in the setting of emission and immunity limits

Note 1 to entry: By convention, the compatibility level is chosen so that there is only a small probability that it will be exceeded by the actual disturbance level. However electromagnetic compatibility is achieved only if emission and immunity levels are controlled such that, at each location, the disturbance level resulting from the cumulative emissions is lower than the immunity level for each device, equipment and system situated at this same location.

Note 2 to entry: The compatibility level can be phenomenon, time or location dependent.

[SOURCE: IEC 60050-161:1990, 161-03-10]

3.1.5
emission limit (of a disturbing source)
specified maximum permitted emission of a source of electromagnetic disturbance

3.1.6
electric power network
network
particular installations, substations, lines or cables for the transmission and distribution of electricity

Note 1 to entry: Electric power network can also be referred to as electric power system (system).

[SOURCE: IEC 60050-601:1985, 601-01-02]

3.1.7
harmonic (component)
component of order greater than 1 of the Fourier series of a periodic quantity

[SOURCE: IEC 60050-161:1990, 161-02-18]

3.1.8
point of connection
point of interconnection
POC
POI
reference point on the electric power system where the user’s electrical facility is connected

[SOURCE: IEC 60050-617:2009, 617-04-01, modified – in the term “point of connection” and “POI” have been added.]

3.1.9
point of common coupling
PCC
point of a power supply network, electrically nearest to a particular load, at which other loads are, or can be, connected

Note 1 to entry: These loads can be either devices, equipment or systems, or distinct customer installations.

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

[SOURCE: IEC 60050-161:1990, 161-07-15]

3.1.10
reference network model
RNM
95^{th} percentile representation of a power system by means of one circuit designed with lines, cables, equipment, and loads having specified configurations for an intended study

Note 1 to entry: A reference network model for obtaining the 95^{th} percentile of steady-state voltage performance might be different from a reference network model for obtaining the 95^{th} percentile of voltage harmonic distortion.

3.1.11
network sensitivity
ratio of change produced in a network variable by injection of a known disturbance

Note 1 to entry: The change in harmonic distortion level in a network by injection of harmonic current is one example of sensitivity that can be used for comparative purposes.

3.1.12
system impedance
impedance of the supply system as viewed from the point of common coupling

[SOURCE: IEC 60060-161:1990, 161-07-16, modified – “supply” has been removed from the term.]

3.1.13
topology
<network or power system> relative position of the ideal elements representing an electric network.

[SOURCE: IEC 60050-603:1986, 603-02-04]

3.2 Abbreviated terms

C_{fh} Conversion factor

CP95 95th percentile

DER Distributed energy resource

DSO Distribution system operator

EMC Electromagnetic compatibility

h Harmonic of order

LV Low voltage

MV Medium voltage

HV High voltage

NA North America

PCC Point of common coupling

POC Point of connection

POI Point of interconnection

RNM Reference network model

$S_{h_{RNM}}$ 95th percentile of the harmonic voltage at the POIs of the RNM

$S_{h_{Target}}$ 95th percentile of the harmonic voltage at the POIs of the targeted network

S_R Sensitivity ratio

SSE Sum-squared error

SWER Single-wire earth-return

THD Total harmonic distortion

U_{NEW} Supply voltage for the new limits

U_R Voltage ratio

U_{RNM} Phase-to-neutral European voltage, which is 230,94 V computed from the phase-phase nominal voltage, which is 400 V

xPyW x-phase y-wire where x and y are numeric

4 General

IEC documents defining equipment harmonic current emission limits are largely based on European power systems having three-phase three-wire (3P3W) MV feeder topologies supplying three-phase four-wire (3P4W) LV distribution networks through delta-wye transformation. Typically, such LV systems serve hundreds of customers via many kilometres of cables, usually in a grounded configuration. This feeder topology results in a significant portion of the voltage total harmonic distortion (THD) at any given LV point of interconnection (POI) being caused by aggregation of harmonic currents flowing through the LV network impedance.

According to available historical information, existing emission limit studies were based on this European feeder topology with the knowledge that approximately 25 % of the contribution to voltage distortion comes from the LV system. Even though the use of delta-wye transformation effectively blocks zero-sequence harmonics from returning to the MV network, there was no special consideration given for modelling different sequence harmonics, only h5 (negative sequence) and h7 (positive sequence) orders were simulated. Historical documents explaining the method used to establish the emission limits that led to the IEC documents are no longer available, thus the exact method used at that time is difficult to recover. However, recent field measurements carried out in European countries have shown that the actual limits are effective in keeping the harmonic voltage below compatibility levels at most locations. This document does not redefine the approach used to establish emission limits. The objective is to report an appropriate methodology to adapt the existing limits in order to reproduce, for other countries, the same performance as observed in European countries.

Numerous power system topologies exist around the world that have characteristics differing from the 3P3W MV distribution systems used in Europe, which supply a small number of large MV/LV transformer stations. The following are examples of regions having power systems sufficiently different from those of Europe; adaptation of IEC emission limits can be beneficial for them in pursuit of EMC:

- North America: While there are regional differences within North America, generally the MV networks are 3P4W systems with multi-grounded neutrals. They supply hundreds of small MV/LV transformers (mixed single-phase and three-phase), and each serves only a few customers compared to those of Europe which serve hundreds of customers. MV feeders tend to be significantly longer than in Europe, so shunt capacitors and regulating transformers installed at various locations along the feeders are used to control the voltage. Of special note are the 1P3W LV networks supplying 120/240 V service to residential and other small single-phase customers. The three-phase LV networks used for larger multi-unit residential buildings, larger commercial, or industrial customers are 3P4W grounded systems having very short service cables, often less than 100 m in length.
- Japan: The population density in Japan is comparable to that of Europe. The MV system is significantly shorter than that in North America; its 3P3W MV distribution system operates at 6,6 kV to supply residential, commercial, and small industrial sectors. Since this MV system distributes the phase voltage without a neutral conductor, the single-phase LV systems are powered by transformers connected phase-to-phase. An open-delta transformer is used when three-phase voltage is required. Unlike in Europe, the connection of MV/LV transformers allows for triplen harmonics to circulate on the MV network (though not as zero-sequence components). Since the MV network voltage is about three times lower than that found in Europe, the number of customers supplied from it is also lower. On the other hand, an extension of the MV network at 22 kV, like that of Europe, is used to supply the 6,6 kV power system as well as larger MV customers. As in North America, the MV/LV transformers supply residential and small commercial customers with two voltages, however the supply is 100/200 V instead of 120/240 V.
- Australia: The Australian power system might be described as a hybrid topology having characteristics similar to both European and North American networks. They are similar in urban environments to Europe where short MV systems supply a few larger MV/LV transformers which in turn supply many customers in densely populated areas at 230/400 V. However, Australian systems also cover vast open territories using 1P1W MV networks using earth for return currents, called a single-wire earth-return (SWER) system. These are like North America in the sense that they serve rural areas using long single-phase networks, specifically like Canada where some distribution feeders exceed 200 km in length. However, the SWER system serves very few customers and has a lot of capacitance to ground due to its long length, thus the Ferranti effect – normally seen on lightly loaded transmission systems – is a concern here. For this reason, voltage regulation is implemented using shunt reactors instead of shunt capacitors.

Given the physical differences in systems such as impedance, customer density, service voltage, wiring, and grounding configurations it is reasonable to conclude that such topologies are impacted differently by harmonic emissions. As such, emission limits might be adjusted according to the power system capability to maintain the harmonic voltages below the applicable targets. Consider the following important characteristics that impact harmonic distortion performance differently:

– North American lower-impedance LV systems served by higher-impedance MV systems perform differently than European distribution systems in the sense that most of the harmonic aggregation occurs at the MV level. The harmonic voltage drops at the LV level due to having shorter cables and fewer customers, and therefore contribution to voltage THD in each LV network is very small (<< 5 % of voltage THD); when aggregated at the MV level it becomes apparent that most of the voltage distortion occurs by aggregation of load currents flowing through the impedance of the MV system (>> 95 % of voltage THD).
– The very long single-wire earth-return (SWER) distribution systems in Australia are characterized by light loading and high capacitance to ground; thus, shunt inductors are used to lower the voltage level along the MV lines. The high capacitance of the system in parallel with these inductors leaves it vulnerable to resonances.

The two examples noted above are causes for uncertainty as regions having different power system characteristics than Europe adopt the IEC harmonic emission limits without any local adaptations.

This document reports on the development of design characteristics for a benchmark European distribution power system that can be used for the purpose of modelling harmonic performance. The harmonic distortion level of the reference network model (RNM), when used with the recommended harmonic load, aligns well with present-day IEC compatibility levels. Subclause 7.2 describes in detail the origins of the data used to develop the RNM. A methodology is described for comparing other distribution systems to the European benchmark system for the purpose of adapting IEC harmonic current emission limits (IEC 61000-3-2 and IEC 61000-3-12) for effective use with those networks. The methodology was developed and tested using power system models from both Canada and Japan. Annex B and Annex C include power system details and the resulting limits from applying the methodology for both Canada and Japan respectively.

5 State of existing IEC standards

5.1 Overview of existing standards

IEC 61000-3-2 and IEC 61000-3-12 establish harmonic emission limits for equipment with input currents ≤16 A per phase and ≤ 75 A per phase, respectively. The limits are intended for equipment that is connected to the public LV distribution system in attempt to control the voltage THD in the electromagnetic environment. These standards form one part of the harmonic EMC framework intended to control harmonic distortion in the environment. When these standards are adopted in a region, then a baseline distortion level can be expected if these standards function as intended. DSOs can then enforce further harmonic controls on large customers through application of IEC TR 61000-3-6, which accounts for the baseline distortion level controlled by IEC 61000-3-2 and IEC 61000-3-12. The proper application of these standards is therefore of utmost importance to maintain EMC in the network.

The existing standards were created for European public distribution systems, and as such are based on characteristics of those systems. This leaves potential gaps with respect to their applicability in other regions of the world where the characteristics of the public supply systems differ. The obvious gaps which exist in the standards relate to applicable voltage levels and frequencies. The less obvious gaps with respect to differing system and sequence impedances exist because only one network model was used to determine the limits.

5.2 Voltage gaps

IEC 61000-3-2:2018 states the following in 6.1: