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

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FOREWORD

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IEC/TR 61000-3-6, which is a technical report, has been prepared by subcommittee 77A: Low frequency phenomena, of IEC technical committee 77: Electromagnetic compatibility.

This Technical Report forms Part 3-6 of IEC 61000. It has the status of a basic EMC publication in accordance with IEC Guide 107 [29][1].

This second edition cancels and replaces the first edition published in 1996 and constitutes a technical revision.

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1 Figures in square brackets refer to the Bibliography.

This edition is significantly more streamlined than first edition, and it reflects the experiences gained in the application of the first edition. As part of this streamlining process, this second edition of IEC/TR 61000-3-6 does not address communications circuit interference. Clause 9 on this (section 10) was removed, as this did not suitably address emission limits for telephone interference. The scope has been adjusted to point out that IEC/TR 61000-3-6 does not address communications circuit interference. This edition has also been harmonised with IEC/TR 61000-3-7 [30] and IEC/TR 61000-3-13 [31].

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

Enquiry draft	Report on voting
77A/575/DTR	77A/637/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.

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

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

The committee has decided that the contents of this publication will remain unchanged until the maintenance result 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- withdrawn,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.

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 will be published with the part number followed by a dash and a second number identifying the subdivision (example: IEC 61000-6-1).

ACKNOWLEDGMENT

In 2002, the IEC subcommittee 77A made a request to CIGRE Study Committee C4 and CIRED Study Committee S2, to organize an appropriate technical forum (joint working group) whose main scope was to prepare, among other tasks, the revision of the technical report IEC 61000-3-6 concerning emission limits for harmonics for the connection of distorting installations to public supply systems at MV, HV and EHV.

To this effect, joint working group CIGRE C4.103/ CIRED entitled ''*Emission Limits for Disturbing Installations*'' was appointed in 2003. Some previous work produced by CIGRE JWG C4.07-Cired has been used as an input to the revision, in particular the planning levels and associated indices. In addition, using experience since the technical report IEC 61000-3-6 was initially published in 1996, WG C4.103 reviewed the procedure used to determine emission limits and the assessment methods used to evaluate emission levels for installations.

Subsequent endorsement of the document by IEC was the responsibility of SC 77A.

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 3-6: Limits – Assessment of emission limits for the connection of distorting installations to MV, HV and EHV power systems

1 Scope

This Technical Report, which is informative in its nature, provides guidance on principles which can be used as the basis for determining the requirements for the connection of distorting installations to MV, HV and EHV public power systems (LV installations are covered in other IEC documents). For the purposes of this report, a distorting installation means an installation (which may be a load or a generator) that produces harmonics and/or interharmonics. The primary objective is to provide guidance to system operators or owners on engineering practices, which will facilitate the provision of adequate service quality for all connected customers. In addressing installations, this document is not intended to replace equipment standards for emission limits.

The report addresses the allocation of the capacity of the system to absorb disturbances. It does not address how to mitigate disturbances, nor does it address how the capacity of the system can be increased.

Since the guidelines outlined in this report are necessarily based on certain simplifying assumptions, there is no guarantee that this approach will always provide the optimum solution for all harmonic situations. The recommended approach should be used with flexibility and judgment as far as engineering is concerned, when applying the given assessment procedures in full or in part.

The system operator or owner is responsible for specifying requirements for the connection of distorting installations to the system. The distorting installation is to be understood as the customer's complete installation (i.e. including distorting and non-distorting parts).

Problems related to harmonics fall into two basic categories.

- Harmonic currents that are injected into the supply system by converters and harmonic sources, giving rise to harmonic voltages in the system. Both harmonic currents and resulting voltages can be considered as conducted phenomena.
- Harmonic currents that induce interference into communication systems. This phenomenon is more pronounced at higher order harmonic frequencies because of increased coupling between the circuits and because of the higher sensitivity of the communication circuits in the audible range.

This report gives guidance for the co-ordination of the harmonic voltages between different voltage levels in order to meet the compatibility levels at the point of utilisation. The recommendations in this report do not address harmonic interference phenomena in communication circuits (i.e. only the first of the above categories is addressed). These disturbances need to be addressed in terms of international directives concerning the Protection of Telecommunication Lines against Harmful Effects from Electric Power and Electrified Railway Lines, International Telecommunication Union, ITU-T Directives [1][2] or in terms of locally applicable standards such as [2], [3] or [4].

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2 Figures in square brackets refer to the bibliography.

NOTE The boundaries between the various voltage levels may be different for different countries (see IEV 601-01-28 [32]). This report uses the following terms for system voltages:

– low voltage (LV) refers to Un ≤ 1 kV;

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

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

– extra high voltage (EHV) refers to 230 kV < Un.

In the context of this report, the function of the system is more important than its nominal voltage. For example, a HV system used for distribution may be given a "planning level" which is situated between those of MV and HV systems.

2 Normative references

The following referenced documents are indispensable for the application 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 60050(161), *International Electrotechnical Vocabulary – Chapter 161: Electromagnetic compatibility*

3 Terms and definitions

For the purposes of this document, the following definitions apply as well as the definitions in IEC 60050(161).

3.1
agreed power
value of the apparent power of the disturbing installation on which the customer and the system operator or owner agree. In the case of several points of connection, a different value may be defined for each connection point

3.2
customer
person, company or organisation that operates an installation connected to, or entitled to be connected to, a supply system by a system operator or owner

3.3
(electromagnetic) disturbance
any electromagnetic phenomenon which, by being present in the electromagnetic environment, can cause electrical equipment to depart from its intended performance

3.4
disturbance level
the amount or magnitude of an electromagnetic disturbance measured and evaluated in a specified way

3.5
distorting installation
an electrical installation as a whole (i.e. including distorting and non-distorting parts) which can cause distortion of the voltage or current into the supply system to which it is connected

NOTE For the purpose of this report, all references to distorting installations not only include linear and non-linear loads, but generating plants, and any source of non-sinusoidal current emissions such as regenerative braking systems,

3.6
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

NOTE 1 Electromagnetic compatibility is a condition of the electromagnetic environment such that, for every phenomenon, the disturbance emission level is sufficiently low and immunity levels are sufficiently high so that all devices, equipment and systems operate as intended.

NOTE 2 Electromagnetic compatibility is achieved only if emission and immunity levels are controlled such that the immunity levels of the devices, equipment and systems at any location are not exceeded by the disturbance level at that location resulting from the cumulative emissions of all sources and other factors such as circuit impedances. Conventionally, compatibility is said to exist if the probability of the departure from intended performance is sufficiently low. See Clause 4 of IEC 61000-2-1 [33].

NOTE 3 Where the context requires it, compatibility may be understood to refer to a single disturbance or class of disturbances.

NOTE 4 Electromagnetic compatibility is a term used also to describe the field of study of the adverse electromagnetic effects which devices, equipment and systems undergo from each other or from electromagnetic phenomena.

3.7
(electromagnetic) compatibility level
specified electromagnetic disturbance level used as a reference level in a specified environment for co-ordination in the setting of emission and immunity limits

NOTE By convention, the compatibility level is chosen so that there is only a small probability (for example 5 %) that it will be exceeded by the actual disturbance level.

3.8
emission
phenomenon by which electromagnetic energy emanates from a source of electromagnetic disturbance

[IEV 161-01-08 modified]

NOTE For the purpose of this report, emission refers to phenomena or conducted electromagnetic disturbances that can distort the supply voltage waveform.

3.9
emission level
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

3.10
emission limit
maximum emission level specified for a particular device, equipment, system or disturbing installation as a whole

3.11
generating plant
any equipment that produces electricity together with any directly connected or associated equipment such as a unit transformer or converter

3.12
immunity (to a disturbance)
ability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance

3.13
immunity level
the 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

3.14
non-linear load or equipment (see also distorting installation)
any load or equipment that draws a non-sinusoidal current when energised by a sinusoidal voltage

3.15
normal operating conditions
operating conditions of the system or of the disturbing installation typically including all generation variations, load variations and reactive compensation or filter states (e.g. shunt capacitor states), planned outages and arrangements during maintenance and construction work, non-ideal operating conditions and normal contingencies under which the considered system or the disturbing installation have been designed to operate

NOTE Normal system operating conditions typically exclude: conditions arising as a result of a fault or a combination of faults beyond that planned for under the system security standard, exceptional situations and unavoidable circumstances (for example: force majeure, exceptional weather conditions and other natural disasters, acts by public authorities, industrial actions), cases where system users significantly exceed their emission limits or do not comply with the connection requirements, and temporary generation or supply arrangements adopted to maintain supply to customers during maintenance or construction work, where otherwise supply would be interrupted.

3.16
planning level
level of a particular disturbance in a particular environment, adopted as a reference value for the limits to be set for the emissions from the installations in a particular system, in order to co-ordinate those limits with all the limits adopted for equipment and installations intended to be connected to the power supply system

NOTE Planning levels are considered internal quality objectives to be specified at a local level by those responsible for planning and operating the power supply system in the relevant area.

3.17
point of common coupling (PCC)
point in the public supply system, which is electrically closest to the installation concerned, at which other installations are, or could be, connected. The PCC is a point located upstream of the considered installation

NOTE A supply system is considered as being public in relation to its use, and not its ownership.

3.18
point of connection (POC)
point on a public power supply system where the installation under consideration is, or can be connected

NOTE A supply system is considered as being public in relation to its use, and not its ownership.

3.19
point of evaluation (POE)
point on a public power supply system where the emission levels of a given installation are to be assessed against the emission limits. This point can be the point of common coupling (PCC) or the point of connection (POC) or any other point specified by the system operator or owner or agreed upon

NOTE A supply system is considered as being public in relation to its use, and not its ownership.

3.20
short circuit power
a theoretical value expressed in MVA of the initial symmetrical three-phase short-circuit power at a point on the supply system. It is defined as the product of the initial symmetrical short-circuit current, the nominal system voltage and the factor $\sqrt{3}$ with the aperiodic component (DC) being neglected

3.21
spur
a feeder branch off a main feeder (typically applied on MV and LV feeders)

3.22
supply system
all the lines, switchgear and transformers operating at various voltages which make up the transmission systems and distribution systems to which customers' installations are connected

3.23
system operator or owner
the entity responsible for making technical connection agreements with customers who are seeking connection of load or generation to a distribution or transmission system

3.24
transfer coefficient (influence coefficient)
the relative level of disturbance that can be transferred between two busbars or two parts of a power system for various operating conditions

3.25
voltage unbalance (imbalance)
in a polyphase system, a condition in which the magnitudes of the phase voltages or the phase angles between consecutive phases are not all equal (fundamental component) [IEV 161-08-09 modified]

NOTE In three phase systems, the degree of the inequality is usually expressed as the ratio of the negative and zero sequence components to the positive sequence component. In this technical report, voltage unbalance is considered in relation to three-phase systems and negative sequence only.

3.26
phenomena related definitions
the definitions below that relate to harmonics are based on the analysis of system voltages or currents by the Discrete Fourier Transform method (DFT). This is the practical application of the Fourier transform as defined in IEV 101-13-09 [28]

NOTE 1 The Fourier Transform of a function of time, whether periodic or non-periodic, is a function in the frequency domain and is referred to as the frequency spectrum of the time function, or simply spectrum. If the time function is periodic the spectrum is constituted of discrete lines (or components). If the time function is not periodic, the spectrum is a continuous function, indicating components at all frequencies.

NOTE 2 For simplicity the definitions given in this report refer only to (inter)harmonic components, however, these should not be interpreted as a restriction on the use of other definitions given in other IEC documents, for example, IEC 61000-4-7 [11] where the reference to (inter)harmonic groups or subgroups are more appropriate for measuring rapidly varying signals.

3.26.1
fundamental frequency
frequency in the spectrum obtained from a Fourier transform of a time function, to which all the frequencies of the spectrum are referred. For the purpose of this technical report, the fundamental frequency is the same as the power supply frequency

NOTE In the case of a periodic function, the fundamental frequency is generally equal to the frequency corresponding to the period of the function itself.

3.26.2
fundamental component
component whose frequency is the fundamental frequency

3.26.3
harmonic frequency
frequency which is an integer multiple of the fundamental frequency. The ratio of the harmonic frequency to the fundamental frequency is the harmonic order (recommended notation: “h”)

3.26.4
harmonic component
any of the components having a harmonic frequency. For brevity, such a component may be referred to simply as a harmonic

3.26.5
interharmonic frequency
any frequency which is not an integer multiple of the fundamental frequency

NOTE 1 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 In the case where m < 1 the term subharmonic frequency may be used.

3.26.6
interharmonic component
component having an interharmonic frequency. For brevity, such a component may be referred to simply as an “interharmonic”

3.26.7
total harmonic distortion – THD
ratio of the r.m.s. value of the sum of all the harmonic components up to a specified order (H) to the r.m.s. value of the fundamental component

$$THD = \sqrt{\sum_{h=2}^{H} \left(\frac{Q_h}{Q_1}\right)^2}$$

where

Q represents either current or voltage,

Q_1 is the r.m.s. value of the fundamental component,

h is the harmonic order,

Q_h is the r.m.s. value of the harmonic component of order h,

H is generally 40 or 50 depending on the application.

4 Basic EMC concepts related to harmonic distortion

The development of emission limits (voltage or current) for individual equipment or a customer’s installation should be based on the effect that these emission limits will have on the quality of the voltage. Some basic concepts are used to evaluate voltage quality. In order for these concepts to be used for evaluation at specific locations, they are defined in terms of where they apply (locations), how they are measured (measurement duration, sample times, averaging durations, statistics), and how they are calculated. These concepts are described hereafter and illustrated in Figures 1 and 2. Definitions may be found in IEC 60050(161).

4.1 Compatibility levels

These are reference values (see Table 1) for co-ordinating the emission and immunity of equipment which is part of, or supplied by, a supply system in order to ensure the EMC in the whole system (including system and connected equipment). Compatibility levels are generally based on the 95 % probability levels of entire systems, using statistical distributions which represent both time and space variations of disturbances. There is allowance for the fact that