

TECHNICAL REPORT

BASIC EMC PUBLICATION

**Electromagnetic compatibility (EMC) –
Part 3-14: Assessment of emission limits for harmonics, interharmonics, voltage
fluctuations and unbalance for the connection of disturbing installations to LV
power systems**



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2011 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester.

If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de la CEI ou du Comité national de la CEI du pays du demandeur.

Si vous avez des questions sur le copyright de la CEI ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de la CEI de votre pays de résidence.

IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland
Email: inmail@iec.ch
Web: www.iec.ch

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

- Catalogue of IEC publications: www.iec.ch/searchpub

The IEC on-line Catalogue enables you to search by a variety of criteria (reference number, text, technical committee,...). It also gives information on projects, withdrawn and replaced publications.

- IEC Just Published: www.iec.ch/online_news/justpub

Stay up to date on all new IEC publications. Just Published details twice a month all new publications released. Available on-line and also by email.

- Electropedia: www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing more than 20 000 terms and definitions in English and French, with equivalent terms in additional languages. Also known as the International Electrotechnical Vocabulary online.

- Customer Service Centre: www.iec.ch/webstore/custserv

If you wish to give us your feedback on this publication or need further assistance, please visit the Customer Service Centre FAQ or contact us:

Email: csc@iec.ch
Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00

TECHNICAL REPORT

BASIC EMC PUBLICATION

**Electromagnetic compatibility (EMC) –
Part 3-14: Assessment of emission limits for harmonics, interharmonics, voltage
fluctuations and unbalance for the connection of disturbing installations to LV
power systems**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

PRICE CODE

XD

ICS 33.100.10

ISBN 978-2-88912-742-9

CONTENTS

FOREWORD.....	6
INTRODUCTION.....	8
1 Scope.....	9
2 Normative references	10
3 Terms and definitions	11
4 Basic EMC concepts.....	18
4.1 General.....	18
4.2 Compatibility levels	18
4.2.1 General	18
4.2.2 Harmonics	18
4.2.3 Interharmonics.....	19
4.2.4 Voltage fluctuations	20
4.2.5 Unbalance	20
4.3 Planning levels.....	20
4.3.1 Indicative values of planning levels.....	20
4.3.2 Assessment procedure for evaluation against planning levels.....	21
4.4 Illustration of EMC concepts.....	22
4.5 Emission levels	23
5 General principles	24
5.1 General.....	24
5.2 Stage 1: simplified evaluation of disturbance emission	24
5.3 Stage 2: emission limits relative to actual system characteristics.....	25
5.4 Stage 3: acceptance of higher emission levels on a conditional basis.....	25
5.5 Responsibilities	26
6 General guidelines for the assessment of emission levels	26
6.1 Point of evaluation.....	26
6.2 Concept of emission level.....	26
6.3 Operating conditions	27
6.4 System impedance characteristics.....	28
7 General summation law	28
7.1 General.....	28
7.2 For harmonics	29
7.3 For flicker and rapid voltage changes	29
7.4 For voltage unbalance	29
8 Harmonic emission limits for distorting installations in LV systems	30
8.1 Stage 1: simplified evaluation of disturbance emission	30
8.2 Stage 2: emission limits relative to actual system characteristics.....	31
8.2.1 General	31
8.2.2 Global emission to be shared between the customers.....	31
8.2.3 Individual emission limits	32
8.2.4 Alternative methods for stage 2	34
8.3 Stage 3: acceptance of higher emission levels on a conditional basis.....	34
8.4 Emission limits for interharmonics	34
9 Voltage fluctuation emission limits for installations in LV systems.....	35
9.1 Stage 1: simplified evaluation of disturbance emission	35

9.2	Stage 2: emission limits relative to actual system characteristics.....	36
9.2.1	General	36
9.2.2	Global emission to be shared between the customers' installations	36
9.2.3	Individual emission limits	37
9.3	Stage 3: acceptance of higher emission levels on a conditional basis.....	38
9.4	Rapid voltage changes	38
9.4.1	General considerations	38
9.4.2	Emission limits	39
10	Unbalance emission limits for unbalanced installations in LV systems	39
10.1	General.....	39
10.2	Stage 1: simplified evaluation of disturbance emission	39
10.3	Stage 2: emission limits relative to actual system characteristics.....	40
10.3.1	General	40
10.3.2	Global emission to be shared between the sources of unbalance	40
10.3.3	Individual emission limits	41
10.4	Stage 3: acceptance of higher emission levels on a conditional basis.....	43
11	Summary diagrams of the evaluation procedure	43
Annex A (informative)	Example of application of the general method for the derivation of limits for a specific type of LV networks	47
Annex B (informative)	Example of application of the general method for the calculation of emission limits for a specific installation.....	59
Annex C (informative)	Harmonic emission limits at stage 2	64
Annex D (informative)	Calculation of the reduction factors for harmonics and unbalance.....	77
Annex E (informative)	Example of method to allocate harmonic emission limits at stage 3	88
Annex F (informative)	Example of application of the approach presented in Annex E	93
Annex G (informative)	List of principal letter symbols, subscripts and symbols.....	98
Bibliography	102
Figure 1	– Illustration of basic voltage quality concepts with time/location statistics covering the whole system.....	22
Figure 2	– Illustration of basic voltage quality concepts with time statistics relevant to one site within the whole system.....	23
Figure 3	– Illustration of the emission vector U_{di} and its contribution to the measured disturbance vector U_d at the point of evaluation	27
Figure 4	– Simplified scheme of an LV public system for harmonics.....	32
Figure 5	– Equivalent circuit and vector diagram for simple assessments	38
Figure 6	– Example of rapid voltage change associated with motor starting	38
Figure 7	– Simplified scheme of an LV public system for unbalance.....	41
Figure 8	– Diagram of evaluation procedure for harmonics	44
Figure 9	– Diagram of evaluation procedure for voltage fluctuations	45
Figure 10	– Diagram of evaluation procedure for unbalance.....	46
Figure A.1	– Simplified scheme of an LV public system for the calculation of harmonic voltage levels.....	51
Figure C.1	– Scheme of an LV public system	65
Figure C.2	– Scheme of an LV public system in order to work out the global emission to be shared between the customers.....	66

Figure C.3 – Simplified scheme of an LV public system in order to work out the condition at the LV busbar	68
Figure C.4 – Simplified scheme of an LV public system in order to work out the condition for the LV feeder to which a large installation is connected	71
Figure D.1 – General scheme of an LV public system	78
Figure D.2 – Simplification of the general scheme of an LV public system for the calculation of harmonic voltage levels at node N_i – 1st step.....	79
Figure D.3 – Simplification of the general scheme of an LV public system for the calculation of harmonic voltage levels at node N_i – 2nd step.....	79
Figure D.4 – Simplified scheme of an LV public system for the calculation of harmonic voltage levels at the far end of LV feeders	81
Figure D.5 – Simplified scheme of an LV public system for the calculation of voltage unbalance levels at the far end of LV feeders	85
Figure E.1 – LV system under study	88
Figure E.2 – Large installation components	90
Figure F.1 – System under study	93
Figure F.2 – Data for large installations	95
Table 1 – Compatibility levels for individual harmonic voltages in LV networks (percent of fundamental component) reproduced from IEC 61000-2-2.....	19
Table 2 – Compatibility levels for flicker in LV networks reproduced from IEC 61000-2-2	20
Table 3 – Summation exponent for harmonics (indicative values)	29
Table 4 – Stage 1 limits for the relative power variations as a function of the number of voltage changes per minute	36
Table 5 – Minimum emission limits at LV	37
Table A.1– Example of maximum acceptable global contribution to harmonic voltages	48
Table A.2 – Influence of the total supply capacity of the LV system on ratio U_{hB}/U_{hFj} (example)	54
Table A.3 – Influence of the number of LV feeders on ratio U_{hB}/U_{hFj} (example).....	54
Table A.4 – Influence of the length of LV feeders on ratio U_{hB}/U_{hFj} (example).....	54
Table A.5 – Influence of the impedance of LV feeders on ratio U_{hB}/U_{hFj} (example)	55
Table A.6 – Influence of the (odd non-triplen) harmonic order on ratio U_{hB}/U_{hFj} (example)	55
Table A.7 – Influence of the summation law exponent on ratio U_{hB}/U_{hFj} (example).....	55
Table A.8 – ratio U_{hB}/U_{hFj} for an LV feeder length of 100 m (example).....	56
Table A.9 – ratio U_{hB}/U_{hFj} for an LV feeder length of 300 m (example).....	56
Table A.10 – ratio U_{hB}/U_{hFj} for an LV feeder length of 500 m (example).....	56
Table A.11 – ratio U_{hB}/U_{hFj} for an LV feeder length of 1000 m (example).....	57
Table A.12 – Reduction factor K_{hB} as a function of the harmonic order (example).....	58
Table B.1 – Example of conservative harmonic current emission limits for stage 1 assessment	60
Table B.2 – values of global parameters for harmonics	60
Table B.3 – Emission limits for harmonics (with a single value of K_{hB})	61
Table B.4 – emission limits for harmonics (K_{hB} value depending on real network characteristics)	62
Table B.5 – Emission limit for voltage unbalance (with a single value of K_{uB}).....	63

Table D.1 – Summation law exponent values used for small installations	83
Table D.2 – values of the reduction factors in the case of a particular rural overhead LV system	84
Table D.3 – values of the reduction factors in the case of a particular urban underground LV system	84
Table D.4 – Example of typical values of the reduction factors $K_h B$ for harmonics	84
Table F.1 – Main system data	93
Table F.2 – Known large installation data	94
Table F.3 – Harmonic voltages due to large installations (all values are in pu, h has the value 5 and A_h is provisionally taken as 1).....	97

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROMAGNETIC COMPATIBILITY (EMC) –**Part 3-14: Assessment of emission limits for harmonics, interharmonics, voltage fluctuations and unbalance for the connection of disturbing installations to LV power systems**

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

IEC 61000-3-14, which is a technical report, has been prepared by subcommittee 77A: Low frequency phenomena, of IEC technical committee 77: Electromagnetic compatibility.

It forms part 3-14 of IEC 61000. It has the status of a basic EMC publication in accordance with IEC Guide 107.

The first edition of this technical report has been harmonised with IEC/TR 61000-3-6, IEC/TR 61000-3-7 and IEC/TR 61000-3-13.

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

Enquiry draft	Report on voting
77A/741/DTR	77A/748/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.

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.

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).

ACKNOWLEDGEMENT

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, a technical report concerning emission limits for the connection of disturbing installations to LV public supply systems.

To this effect, joint working group CIGRE C4.103/ CIRED entitled "*Emission Limits for Disturbing Installations*" was appointed in 2003. The working group held 11 formal meetings dedicated to the revision of IEC/TR 61000-3-6 and IEC/TR 61000-3-7, and the preparation of two other technical reports on emission limits for voltage unbalance (IEC/TR 61000-3-13) and emission limits for disturbing installations connected at LV (this report).

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

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 3-14: Assessment of emission limits for harmonics, interharmonics, voltage fluctuations and unbalance for the connection of disturbing installations to LV power systems

1 Scope

This part of IEC 61000, which is informative in its nature, provides guidance on principles that can be used as the basis for determining the requirements for the connection of disturbing installations to low voltage (LV) public power systems. For the purposes of this part of IEC 61000, a disturbing installation means an installation (which may be a load or a generator) that produces disturbances: harmonics and/or interharmonics, voltage flicker and/or rapid voltage changes, and/or voltage unbalance. The primary objective is to provide guidance to system operators or owners for engineering practices, which will facilitate the provision of adequate service quality for all connected customer installations. In addressing installations, this report is not intended to replace equipment standards for emission limits.

NOTE 1 In this report, low voltage (LV) refers to $U_n \leq 1$ kV.

This 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.

This technical report only applies to installations connected to LV public power systems that supply or may supply other LV loads or installations. It is intended to apply to large installations exceeding a minimum size. This minimum size (S_{\min}) is to be specified by the system operator or owner depending on the system characteristics.

NOTE 2 Due to this minimum size, this report generally does not apply to residential customer's installations.

This technical report is not intended to set emission limits for individual pieces of equipment connected to LV systems. The emission limits for LV equipment are specified in the applicable IEC product family standards. The limits specified in these standards have been determined based on assumptions of the number, type and usage of equipment producing disturbances in an installation connected to a supply system and based on the reference impedance given in IEC 60725 considered to be representative of the source impedance for small residential installations. The assumptions may not apply to larger LV installations. Hence, the guidelines in this report are intended to provide methods for developing emission limits for such large installations.

NOTE 3 Compliance with emission limits determined by application of the methods in this report does not preclude any requirement to comply with equipment emission limits (as determined by national or regional regulatory requirements).

This technical report deals with low-frequency conducted disturbances emitted by LV installations. The disturbances considered are:

- harmonics and interharmonics;
- flicker and rapid voltage changes;
- unbalance (negative-sequence component).

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 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 disturbing installations to the system. The disturbing installation is to be understood as the customer's complete installation (i.e. including disturbing and non-disturbing parts).

This report provides recommended procedures for developing emission limits for large LV installations. In order for any network operator or owner to fully apply this report, an expert would need to derive appropriate factors for the specific types of LV networks operated.

NOTE 4 Simplification of emission limits by setting one set of tables for all LV networks may, in some cases, result in excessively conservative limits.

The main part of this report gives the general procedure to allocate emission limits for harmonics, voltage fluctuation and unbalance to large installations connected at LV.

Annexes to this report give additional information. In particular,

- Annex A gives a practical example of technical application at distribution expert level or national regulation level, in order to derive their own limits tailored on the specific characteristics of their networks from the general method.
- Annex B gives an example of practical application at distribution operator level for the connection of specific installations based on the local parameters of the LV network.
- Annex C and Annex D give details on the theoretical basis for the derivation and the understanding of the procedures in this report.

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 60050-161:1990, *International Electrotechnical Vocabulary – Chapter 161: Electromagnetic compatibility*
Amendment 1 (1997)
Amendment 2 (1998)

IEC/TR 60725, *Consideration of reference impedances and public supply network impedances for use in determining disturbance characteristics of electrical equipment having a rated current ≤ 75 A per phase*

IEC/TR 61000-2-1:1990, *Electromagnetic compatibility (EMC) – Part 2-1: Environment – Description of the environment – Electromagnetic environment for low-frequency conducted disturbances and signalling in public power supply systems*

IEC 61000-2-2:2002, *Electromagnetic compatibility (EMC) – Part 2-2: Environment – Compatibility levels for low-frequency conducted disturbances and signalling in public low-voltage power supply systems*

IEC 61000-3-2, *Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)*

IEC 61000-3-3, *Electromagnetic compatibility (EMC) – Part 3-3: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤ 16 A per phase and not subject to conditional connection*

IEC/TR 61000-3-6:2008, *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/TR 61000-3-7:2008, *Electromagnetic compatibility (EMC) – Part 3-7: Limits – Assessment of emission limits for the connection of fluctuating load installations to MV, HV and EHV power systems*

IEC 61000-3-11, *Electromagnetic compatibility (EMC) – Part 3-11: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems – Equipment with rated current ≤ 75 A and subject to conditional connection*

IEC 61000-3-12, *Electromagnetic compatibility (EMC) – Part 3-12: Limits – Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current > 16 A and ≤ 75 A per phase*

IEC/TR 61000-3-13:2008, *Electromagnetic compatibility (EMC) – Part 3-13: Limits – Assessment of emission limits for the connection of unbalanced 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*

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

95 % (99 %) probability weekly (daily) value

value that is not exceeded during 95 % (99 %) of the time over one week (day)

3.2

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

3.3

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

3.4

(electromagnetic) disturbance

any electromagnetic phenomenon which, by being present in the electromagnetic environment, can cause electrical equipment to deviate from its intended performance

3.5

disturbance level

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

3.6

disturbing installation

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