IEC TR 61000-1-8

Edition 1.0 2019-01

TECHNICAL REPORT

colour inside

Electromagnetic compatibility –
Part 1-8: General – Phase angles of harmonic current emissions and voltages in the public supply networks – Future expectations

IEC TR 61000-1-8:2019-01(en)

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

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 corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,…). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 000 terminological entries in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary
67 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

IEC TR 61000-1-8

Edition 1.0 2019-01

TECHNICAL REPORT

colour inside

Electromagnetic compatibility –
Part 1-8: General – Phase angles of harmonic current emissions and voltages in the public supply networks – Future expectations

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 33.100.10, 33.100.01

ISBN 978-2-8322-6416-4

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROMAGNETIC COMPATIBILITY –

Part 1-8: General – Phase angles of harmonic current emissions and voltages in the public supply networks – Future expectations

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 TR 61000-1-8, which is a Technical Report, has been prepared by subcommittee 77A: EMC – Low frequency phenomena, of IEC technical committee 77: Electromagnetic compatibility.

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

Draft TR	Report on voting
77A/1002/DTR	77A/1012/RVDTR

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

A list of all parts in the IEC 61000 series, published under the general title *Electromagnetic compability*, 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 "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

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

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

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.

INTRODUCTION

0.1 Series overview

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 the product committees)

Part 4: Testing and 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: 61000-6-1).

0.2 Purpose of this document

This part of IEC 61000 documents measurements at a number of public supply networks in Germany, and explains the analysis of the obtained data. Data were acquired under certain conditions. These conditions include categories of different network structures, load structures and power generation structures, especially including a review of networks with varying degrees of renewable energy. The loads in various networks include mainly consumers, office buildings, and retail/shopping centres, and thus represent several categories of technologies in the input circuit of the electrical devices.

This document provides statistical evaluations aimed at quantifying the level of diversification of the prevailing harmonic current phase angles, and, where possible, to identify methods to reduce the overall emissions of dominant harmonics in the network.

For that purpose, the existing prevailing phase angle in the network at this time is analysed, and the type of prevailing phase angle expected in the future is evaluated. In particular, the potential changes in phase angle that can be expected, because of new technologies and/or network structures, are of interest. This would mean determining what harmonic compensation, if any, can be expected from various products. The goal is to determine or verify the existing phase angle (mainly of the 5^{th} harmonic) and to assess the possible influences of future developments – such as changes in lighting types and other electronic equipment.

This document is exclusively applicable to public low-voltage electricity supply networks.

ELECTROMAGNETIC COMPATIBILITY –

Part 1-8: General – Phase angles of harmonic current emissions and voltages in the public supply networks – Future expectations

1 Scope

The objective of this part of IEC 61000 is to provide information about the current conditions, and project future developments, of prevailing phase angles, predominantly for the 3rd and 5th harmonic currents, on public supply networks. This objective is accomplished by monitoring a number of networks, and efforts to forecast the effects of changes in technologies.

This document presents information to guide the discussion about the effectiveness of potential mitigation techniques and the generalisation of effects of the prevailing angle positions of selected current harmonics.

This document mainly deals with the phase angles of the 3rd and 5th harmonic currents, but also contains information about other harmonics.

2 Normative references

There are no normative references in this document.

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
phase angle of I_5 related to the fundamental phase-to-neutral voltage U_{p1}
phase angle of the 5th harmonic current determined as described in Figure 1

[SOURCE: IEC 61000-3-12:2011, 3.16, modified – the reference to Figure 2 has been removed.]

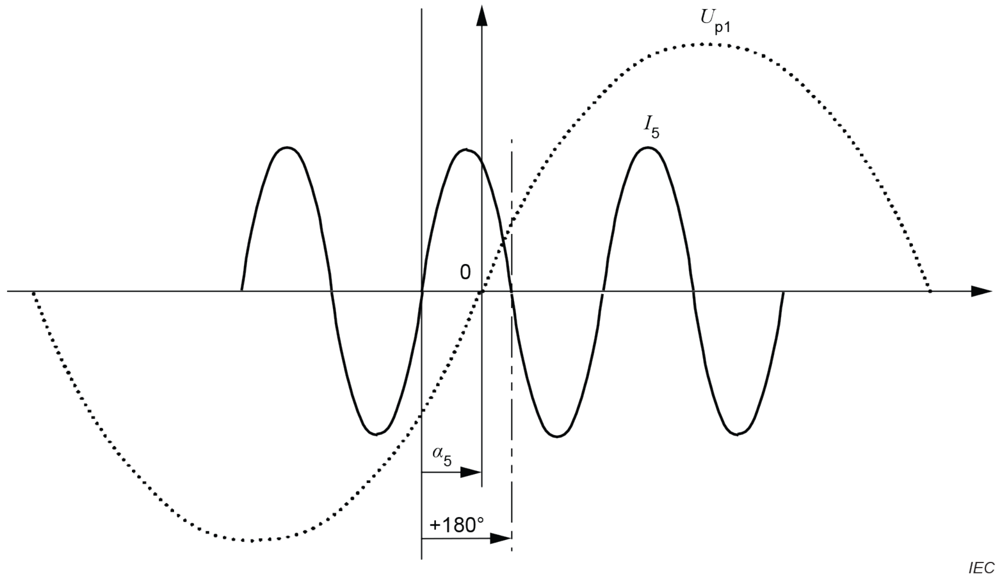

Figure 1 – Definition of the 5th harmonic current phase angle (I_5 leads U_{p1}, α_5 > 0)

3.2
prevailing vector

$$\underline{x}_{\text{pv}} = x_{\text{qm}} \cdot e^{j x_{\text{vs\_ph}}} \tag{1}$$

where the quadratic mean of magnitudes is

$$x_{\text{qm}} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left|\left(\underline{x}_i\right)^2\right|} \tag{2}$$

with $\left|\left(\underline{x}_i\right)^2\right|$ as the magnitude (absolute value) of the complex value $\underline{x}$,

and where the phase of the vectoral sum is the phase of the prevailing vector:

$$x_{\text{vs\_ph}} = \tan^{-1}\left(\frac{\sum_{i=1}^{n}\text{Im}\left(\underline{x}_i\right)}{\sum_{i=1}^{n}\text{Re}\left(\underline{x}_i\right)}\right) \tag{3}$$

Note 1 to entry: The phase of the vectoral sum is different from the definition of the vectoral mean: this is the arithmetic mean of the real-part and the arithmetic mean of the imaginary-part.

Note 2 to entry: See 6.2.3 for details.

3.3
in-phase factor

$$r_{\text{in\_phase}} = \frac{x_{\text{vs\_mg}}}{x_{\text{as\_mg}}} \tag{4}$$

where the magnitude of the vectoral sum is:

$$x_{\text{vs\_mg}} = \sqrt{\left(\sum_{i=1}^{n}\text{Re}\left(x_i\right)\right)^2 + \left(\sum_{i=1}^{n}\text{Im}\left(x_i\right)b\right)^2} \tag{5}$$

and the arithmetic sum of magnitudes is:

$$x_{\text{as\_mg}} = \sum_{i=1}^{n}\left|\underline{x}_i\right| \tag{6}$$

Note 1 to entry: See 6.2.3 for details.

3.4
dispersion factor
deviation factor
subtraction of the in-phase factor from digit 1:

$$r_{\text{disp\_phase}} = 1 - \frac{x_{\text{vs\_mg}}}{x_{\text{as\_mg}}} \tag{7}$$

Note 1 to entry: See 6.2.3 for details.

3.5
total harmonic current
THC
total RMS value of the harmonic current components of orders 2 to 40:

$$THC = \sqrt{\sum_{h=2}^{40} I_h^2} \tag{8}$$

3.6
total harmonic distortion
THD
ratio of the RMS value of the sum of the harmonic components (in this context harmonic current components I_h of orders 2 to 40) to the RMS value of the fundamental component:

$$THD = \sqrt{\sum_{h=2}^{40}\left(\frac{I_h}{I_1}\right)^2} \tag{9}$$

4 Summary of field measurements and data analysis

4.1 Field measurement methods and concepts

All measurements reported in this document have originated from an initiative by Forum Netztechnik/Netzbetrieb (FNN) and within the scope of a research assignment financed by FNN and assigned to the University of Technology of Dresden. The network operating authority N-ERGIE (today MDN) was involved, along with several other network operating authorities in the realisation of the measuring campaign. Data have been handed over to the research partner, but the network authorities could carry out their own analyses as well. Apart from the task of the research partner, additional test sites have been examined by N-ERGIE and data analyses continue, with emphasis on correlation aspects.

This document is based primarily on the results of the N-ERGIE investigations which are consistent, nevertheless, with the results of the larger FNN studies. The data pool of FNN offers the big advantage of a large number of random tests (within Germany). The enormous amount of data necessitates substantial compression for a meaningful presentation, and admittedly leads to a less-detailed consideration of the results. More detailed analysis has also been carried out, however, particularly concerning correlation, and that analysis is presented as well.

Test sites were chosen according to criteria from [1][1] with regard to network structure, load structure and generator structure. These diverse test sites, representing various topologies and load types in the network area of the N-ERGIE are listed in Table 1.

Thus, eight residential area networks (e.g. “A1” and “A2” in the column “Category” of Table 1, see Table 9 for definitions) and four networks that include commercial offices, trade, and retail stores, were examined. Additionally, one of the last four networks was a repetition of M9 concerning the phase angle of the harmonic voltage instead of the phase angle of the harmonic current, listed as M17. At the test sites M1 to M8, measurements were made from the middle of December 2012 to the middle of January, 2013, with a duration of 35 days to 40 days. The measurements at the test sites M9 to M12 followed in May 2013. These were repeated at the same test sites in July 2013, listed as M13 to M16, with a modified interval time of measurement (60 s instead of 1 s) at M10 to M12, respectively M14 to M16. These test sites (M9 to M12) are listed as M13 to M16, mainly as a means of differentiation. With a choice of the measuring period, the opportunity was consciously taken to measure, on the one hand, during the winter months and summer months and to measure, on the other hand, in a time window with varying users' behaviour (work times and holidays about the turn of the year). The background is to identify network parameter dependencies, specifically the prevailing phase angle of harmonics, resulting from the users' behaviour and load structure.

As follows from Table 1, the 16 measurement sites are representative of a good cross section of the public supply, and as follows from the more detailed data review, the analysis includes a statistically meaningful sample set that can be extrapolated to the 220/230 V 50 Hz public supply networks in general. No attempt is made to extrapolate the findings to other network topologies, but given that the load structures are similar in 120 V 60 Hz networks, the findings of this document can apply to some extent to those other networks as well.

The field measurements included exclusively the public low-voltage network at the terminals of the local network transformers. Current and voltage were measured in each of the three phases, and included magnitude and phase. The measurement window was 200 ms with a sampling rate of 100 kS/s. The measurement repetition rate amounted to 1 min, except with M10 to M12 where data were acquired with 1 s intervals. The measuring instruments used by N-ERGIE recorded the harmonics up to the 50th order and the basic electrical parameters, including phase angle information for current and voltage. The harmonic currents phase angles are measured with reference to the zero crossing of the fundamental of the voltage according to 61000-3-12 [3] (positive zero crossing).

In 4.2, a brief summary of the measurement results is presented, along with a summary review of the potential future impact of technologies and societal developments. The data are then analysed in detail, and technology and economic factors are analysed in more detail, to further explain the summary findings.

[1] Numbers in square brackets refer to the Bibliography.