



TECHNICAL REPORT



**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

FOREWORD.....	6
INTRODUCTION.....	8
0.1 Series overview.....	8
0.2 Purpose of this document.....	8
1 Scope.....	10
2 Normative references.....	10
3 Terms and definitions.....	10
4 Summary of field measurements and data analysis.....	12
4.1 Field measurement methods and concepts.....	12
4.2 Summary of measurement results, analysis, and conclusions.....	14
5 Critical appraisal of potential economic impact.....	18
5.1 General.....	18
5.2 Dependencies on electrical parameters.....	19
5.3 Dependencies on non-electrical influence quantities.....	19
5.3.1 General.....	19
5.3.2 Development of economic sectors and demand of energy.....	19
5.3.3 Consumer durables.....	21
5.3.4 Capital-income ratio in rich industrial countries.....	25
6 Data evaluation concepts and principles.....	27
6.1 Concept of data evaluation.....	27
6.2 Principles of statistical survey.....	28
6.2.1 Correlation.....	28
6.2.2 Review of correlation coefficient calculation with complex numerical series.....	29
6.2.3 Prevailing phase angle and prevailing vector.....	32
7 Detailed analysis of data.....	35
7.1 Overview.....	35
7.2 Time series analysis of electrical basic parameters and concept of statistical survey.....	35
7.3 Time series analysis of selected harmonics.....	36
7.4 Phase angle of selected harmonic currents.....	44
7.4.1 Time series analysis of phase angle.....	44
7.4.2 Phase angle in polar coordinates.....	46
7.5 Harmonic spectra.....	49
7.6 Correlations.....	51
8 Empirical evidence.....	54
8.1 Inductive versus deductive approach.....	54
8.2 Laboratory tests.....	55
8.3 Field measurements.....	57
9 Conclusions and recommendations.....	60
Annex A (informative) Prevailing vectors at test sites.....	61
A.1 Prevailing vectors at test sites M1 to M16.....	61
A.2 Prevailing vectors at test site M17.....	65
Bibliography.....	67

Figure 1 – Definition of the 5th harmonic current phase angle (I_5 leads U_{p1} , $\alpha_5 > 0$)..... 11

Figure 2 – Polar diagrams with prevailing vector for each of the three phases of the 3 rd , 5 th and 7 th harmonic currents at test site M1	15
Figure 3 – Polar diagrams with prevailing vector for each of the three phases of the 3 rd , 5 th and 7 th harmonic currents at test site M7	15
Figure 4 – Polar diagrams with prevailing vector for each of the three phases of the 3 rd , 5 th and 7 th harmonic currents at test site M16	16
Figure 5 – Computed prevailing phase angle of the 5 th harmonic current.....	16
Figure 6 – Computed in-phase factor of the 5 th harmonic current	17
Figure 7 – Prevailing vectors of the 3 rd harmonic current (three phases, all test sites)	17
Figure 8 – Prevailing vectors of the 5 th harmonic current (three phases, all test sites).....	17
Figure 9 – Prevailing vectors of the 7 th harmonic current (three phases, all test sites).....	18
Figure 10 – Development of demand of energy	20
Figure 11 – Development of economic sectors in industrial countries	20
Figure 12 – Growth rates of product ownership of electrical household appliances	22
Figure 13 – Growth rates of product ownership of ICT	23
Figure 14 – Growth rates of product ownership of entertainment electronics	24
Figure 15 – Capital income ratio [5]	26
Figure 16 – Capital share of national income [5]	26
Figure 17 – Representative prevailing vector	34
Figure 18 – Unrepresentative prevailing vector	35
Figure 19 – Diurnal cycle of magnitude of the 5 th harmonic current at test site M1	36
Figure 20 – Diurnal cycle of magnitude of the 5 th harmonic voltage at test site M1	37
Figure 21 – Diurnal cycle of total harmonic current distortion in percent at test site M1	37
Figure 22 – Diurnal cycle of total harmonic voltage distortion in percent at test site M1	37
Figure 23 – Minimum-maximum envelope of the 5 th harmonic phase angle curve at site M1.....	38
Figure 24 – Minimum-maximum envelope curves of the 5 th harmonic current level at site M1.....	38
Figure 25 – Minimum-maximum envelope curves of the 5 th harmonic voltage level at test site M1	39
Figure 26 – Minimum-maximum envelope curves of the total harmonic current distortion at site M1	39
Figure 27 – Minimum-maximum envelope curves of the total harmonic voltage distortion at site M1	40
Figure 28 – Histogram of the 5 th harmonic current phase angle at test site M1	40
Figure 29 – Histogram of the 5 th harmonic current level in percent at test site M1	41
Figure 30 – Histogram of the 5 th harmonic voltage level in percent at test site M1	41
Figure 31 – Histogram of total harmonic current distortion in percent at test site M1	42
Figure 32 – Histogram of total harmonic voltage distortion in percent at test site M1.....	42
Figure 33 – Cumulative frequency of the 5 th harmonic current phase angle at site M1.....	43
Figure 34 – Cumulative frequency of the 5 th harmonic current level at test site M1.....	43
Figure 35 – Cumulative frequency of the 5 th harmonic voltage level at test site M1	43
Figure 36 – Cumulative frequency of the total harmonic current distortion at test site M1.....	44
Figure 37 – Cumulative frequency of the total harmonic voltage distortion at test site M1.....	44

Figure 38 – Daily cycle of the 5 th harmonic current phase angle at test site M1	45
Figure 39 – Daily cycle of the 5 th harmonic current magnitude (level) at test site M1	45
Figure 40 – Minimum-maximum envelope of the 5 th harmonic phase angle curve at site M1	46
Figure 41 – Phase angle of the 3 rd harmonic current at test site M1	47
Figure 42 – Phase angle of the 5 th harmonic current at test site M1	47
Figure 43 – Phase angle of the 7 th harmonic current at test site M1	48
Figure 44 – Dispersion factor of the phase angle of the 3 rd harmonic current	48
Figure 45 – Dispersion factor of the phase angle of the 5 th harmonic current	48
Figure 46 – Dispersion factor of the phase angle of the 7 th harmonic current	49
Figure 47 – Harmonic current spectrum including level distribution at test site M1	50
Figure 48 – Harmonic voltage spectrum including level distribution at test site M1	50
Figure 49 – Harmonic phase angles including phase distribution at test site M1	51
Figure 50 – Correlations between the 5 th harmonic current phase angle and the 5 th harmonic current H05i	52
Figure 51 – Correlations between the 5 th harmonic current phase angle and the 5 th harmonic voltage H05u	52
Figure 52 – Correlations between the 5 th harmonic current phase angle and THDI	52
Figure 53 – Correlations between the 5 th harmonic current phase angle and THDV	53
Figure 54 – Correlations between the 5 th harmonic current phase angle and apparent power S	53
Figure 55 – Correlation trace between the 5 th harmonic current phase angle and THD-I	54
Figure 56 – Correlation trace between the 5 th harmonic current phase angle and P, Q and S	54
Figure A.1 – Prevailing vectors of the 3 rd , 5 th and 7 th harmonic current at test site M1	61
Figure A.2 – Prevailing vectors of the 3 rd , 5 th and 7 th harmonic current at test site M2	61
Figure A.3 – Prevailing vectors of the 3 rd , 5 th and 7 th harmonic current at test site M3	62
Figure A.4 – Prevailing vectors of the 3 rd , 5 th and 7 th harmonic current at test site M4	62
Figure A.5 – Prevailing vectors of the 3 rd , 5 th and 7 th harmonic current at test site M5	62
Figure A.6 – Prevailing vectors of the 3 rd , 5 th and 7 th harmonic current at test site M6	63
Figure A.7 – Prevailing vectors of the 3 rd , 5 th and 7 th harmonic current at test site M7	63
Figure A.8 – Prevailing vectors of the 3 rd , 5 th and 7 th harmonic current at test site M8	63
Figure A.9 – Prevailing vectors of the 3 rd , 5 th and 7 th harmonic current at test site M13	64
Figure A.10 – Prevailing vectors of the 3 rd , 5 th and 7 th harmonic current at test site M14	64
Figure A.11 – Prevailing vectors of the 3 rd , 5 th and 7 th harmonic current at test site M15	64
Figure A.12 – Prevailing vectors of the 3 rd , 5 th and 7 th harmonic current at test site M16	65
Figure A.13 – Prevailing vectors of the 3 rd , 5 th and 7 th harmonic voltage at test site M17	66
Figure A.14 – Prevailing vectors of the 3 rd , 5 th and 7 th harmonic current at test site M17	66
Table 1 – Structure of test (measurement) sites	14
Table 2 – Product ownership of electrical household appliances	22

Table 3 – Product ownership of information and communication technology.....	23
Table 4 – Product ownership of entertainment electronics.....	24
Table 5 – Example of weighting factor for a prevailing vector	34
Table 6 – Comparison between CFL, SSL and electronic devices [10]	56
Table 7 – Comparison between combinations of superpositions [10]	56
Table 8 – Structure of network [1]	58
Table 9 – Structure of load [1].....	58
Table 10 – Structure of generation [1].....	58
Table 11 – Dispersion of phase angle of the 3 rd harmonic current	58
Table 12 – Dispersion of phase angle of the 5 th harmonic current	59
Table A.1 – In-phase factor and prevailing vector of the 3 rd , 5 th and 7 th harmonic current per test-site.....	65
Table A.2 – In-phase factor and prevailing vector of the 3 rd , 5 th and 7 th harmonic current and voltage at test site M17	66

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 compatibility*, 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 5th 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.