



# TECHNICAL REPORT

---

**Electromagnetic compatibility (EMC) –  
Part 1-7: General – Power factor in single-phase systems under non-sinusoidal  
conditions**

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

---

ICS 33.100.01

ISBN 978-2-8322-3196-8

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

## CONTENTS

|                                                                                                         |    |
|---------------------------------------------------------------------------------------------------------|----|
| FOREWORD .....                                                                                          | 4  |
| INTRODUCTION .....                                                                                      | 6  |
| 0.1 Series overview .....                                                                               | 6  |
| 0.2 Purpose of this document .....                                                                      | 6  |
| 1 Scope .....                                                                                           | 8  |
| 2 Normative references .....                                                                            | 8  |
| 3 Terms and definitions .....                                                                           | 8  |
| 4 General .....                                                                                         | 14 |
| 5 Electric power quantities under non-sinusoidal conditions .....                                       | 15 |
| 5.1 Voltages and currents .....                                                                         | 15 |
| 5.1.1 Instantaneous values .....                                                                        | 15 |
| 5.1.2 Reference fundamental components .....                                                            | 16 |
| 5.1.3 Total distortion contents .....                                                                   | 16 |
| 5.1.4 RMS values of the voltage and current .....                                                       | 16 |
| 5.1.5 RMS values of total distortion contents .....                                                     | 17 |
| 5.1.6 DC ratios .....                                                                                   | 17 |
| 5.1.7 Total distortion ratios .....                                                                     | 17 |
| 5.2 Instantaneous power .....                                                                           | 18 |
| 5.3 Definitions related to the active power .....                                                       | 18 |
| 5.3.1 Active power .....                                                                                | 18 |
| 5.3.2 DC power .....                                                                                    | 18 |
| 5.3.3 Fundamental active power .....                                                                    | 19 |
| 5.3.4 Distortion active power .....                                                                     | 19 |
| 5.4 Definitions related to the apparent power .....                                                     | 19 |
| 5.4.1 Apparent power .....                                                                              | 19 |
| 5.4.2 Fundamental apparent power .....                                                                  | 20 |
| 5.5 Definitions related to the power factor .....                                                       | 20 |
| 5.5.1 Power factor .....                                                                                | 20 |
| 5.5.2 Fundamental power factor .....                                                                    | 21 |
| 5.5.3 Non-fundamental power factor .....                                                                | 21 |
| 5.6 Summary .....                                                                                       | 21 |
| 6 Electric power quantities with a sinusoidal voltage and a current distorted only with harmonics ..... | 22 |
| 6.1 Voltages and currents .....                                                                         | 22 |
| 6.1.1 Instantaneous values .....                                                                        | 22 |
| 6.1.2 Fundamental components .....                                                                      | 22 |
| 6.1.3 Harmonic content of the current .....                                                             | 23 |
| 6.1.4 RMS values of the voltage and current .....                                                       | 23 |
| 6.1.5 RMS value of the harmonic content of the current .....                                            | 23 |
| 6.1.6 Total harmonic ratio of the current .....                                                         | 24 |
| 6.1.7 Fundamental factor .....                                                                          | 24 |
| 6.2 Instantaneous power .....                                                                           | 24 |
| 6.3 Active power .....                                                                                  | 24 |
| 6.4 Definitions related to the apparent power .....                                                     | 25 |
| 6.4.1 Apparent power .....                                                                              | 25 |

|                                                                                                                                       |                                                       |    |
|---------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|----|
| 6.4.2                                                                                                                                 | Fundamental apparent power .....                      | 25 |
| 6.5                                                                                                                                   | Definitions related to the power factor .....         | 25 |
| 6.5.1                                                                                                                                 | Power factor .....                                    | 25 |
| 6.5.2                                                                                                                                 | Fundamental power factor .....                        | 26 |
| 6.5.3                                                                                                                                 | Non-fundamental power factor.....                     | 26 |
| 6.6                                                                                                                                   | Summary .....                                         | 27 |
| Annex A (normative) Electric power quantities under sinusoidal conditions .....                                                       |                                                       | 28 |
| A.1                                                                                                                                   | Instantaneous values of the voltage and current ..... | 28 |
| A.2                                                                                                                                   | Instantaneous power .....                             | 29 |
| A.3                                                                                                                                   | Active power .....                                    | 30 |
| A.4                                                                                                                                   | Reactive power .....                                  | 30 |
| A.5                                                                                                                                   | Apparent power .....                                  | 30 |
| A.6                                                                                                                                   | Power factor .....                                    | 30 |
| Annex B (informative) Fundamental active factor.....                                                                                  |                                                       | 32 |
| B.1                                                                                                                                   | Fundamental active factor and its use .....           | 32 |
| B.2                                                                                                                                   | Consumer convention .....                             | 32 |
| Bibliography .....                                                                                                                    |                                                       | 34 |
|                                                                                                                                       |                                                       |    |
| Figure A.1 – Illustration of the displacement angle ( $\varphi$ ) when the voltage leads the current, $\varphi > 0$ .....             |                                                       | 28 |
| Figure A.2 – Illustration of the displacement angle ( $\varphi$ ) when the voltage lags the current, $\varphi < 0$ .....              |                                                       | 29 |
| Figure B.1 – Consumer sign convention of the fundamental active factor, fundamental active power and fundamental reactive power ..... |                                                       | 33 |
|                                                                                                                                       |                                                       |    |
| Table 1 – Summary of the power quantities under non-sinusoidal conditions .....                                                       |                                                       | 21 |
| Table 2 – Summary of the power quantities with a sinusoidal voltage and a current distorted only with harmonics .....                 |                                                       | 27 |

## INTERNATIONAL ELECTROTECHNICAL COMMISSION

---

### **ELECTROMAGNETIC COMPATIBILITY (EMC) –**

#### **Part 1-7: General – Power factor in single-phase systems under non-sinusoidal conditions**

#### 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 61000-1-7, 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:

|               |                  |
|---------------|------------------|
| Enquiry draft | Report on voting |
| 77A/911/DTR   | 77A/920/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.

This publication 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 (EMC)*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website 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

### 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 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 sections which are to be published either as international standards, technical specifications, or as technical reports.

These standards and reports will be published in chronological order and numbered accordingly (for example, 61000-6-1).

### 0.2 Purpose of this document

The prevalence of loads drawing non-sinusoidal current from power systems requires clarification of such concepts as power and power factor, in order to avoid confusion due to

implied assumptions of sinusoidal voltage and current. This document specifically addresses the terms related to the power factor of equipment that are applicable regardless of the voltage and current waveforms.

When voltages and currents on power supply networks are perfectly sinusoidal,  $\cos \varphi$  corresponds to the power factor. But this is not true anymore when electric quantities are distorted. In some existing documents,  $\cos \varphi$  is still used as power factor, leading to an incorrect assessment of the equipment impact to supply networks.

The purpose of this Technical Report is to give clear information on both components in the power factor:

- the fundamental power factor, which is due to the phase difference between the voltage and current at the fundamental frequency ( $\cos \varphi_1$ ), and
- the non-fundamental power factor, which is related to the distortion of the voltage and/or current.

## **ELECTROMAGNETIC COMPATIBILITY (EMC) –**

### **Part 1-7: General – Power factor in single-phase systems under non-sinusoidal conditions**

#### **1 Scope**

This part of IEC 61000, which is a Technical Report, provides definitions of various electrical power quantities and the relationship between them under non-sinusoidal conditions, in order to give clear information on both components in the power factor: the fundamental power factor, which is due to the phase difference between the voltage and current at the fundamental frequency, and the non-fundamental power factor, which is related to the distortion of the voltage and/or current. This Technical Report is applicable only to single-phase systems.

This Technical Report provides definitions for the three following cases:

- the general case where the voltage and current are both distorted (Clause 5),
- the case where the voltage is assumed to be sinusoidal and the current is only distorted with harmonic components (Clause 6),
- the particular case where the voltage and current are both sinusoidal (Annex A).

Annex B gives information on the fundamental active factor, which is used to describe the behaviour of a piece of equipment as a load or a generator.

#### **2 Normative references**

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Void.