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

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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ELECTROMAGNETIC COMPATIBILITY (EMC) –

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

FOREWORD

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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- withdrawn,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 φ corresponds to the power factor. But this is not true anymore when electric quantities are distorted. In some existing documents, cos φ 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 φ_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.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
root-mean-square value
r.m.s. value
effective value
for a time-dependent quantity, positive square root of the mean value of the square of the quantity taken over a given time interval

Note 1 to entry: The root-mean-square value of a periodic quantity is usually taken over an integration interval the range of which is the period multiplied by a natural number.

Note 2 to entry: For a sinusoidal quantity $a(t) = \hat{A}\cos(\omega t + \vartheta_0)$, the root-mean-square value is $A_{\text{eff}} = \hat{A}/\sqrt{2}$.

Note 3 to entry: The root-mean-square value of a quantity may be denoted by adding one of the subscripts eff or rms to the symbol of the quantity.

Note 4 to entry: In electrical technology, the root-mean-square values of electric current $i(t)$ and voltage $u(t)$are usually denoted I and U, respectively.

[SOURCE: IEC 60050-103:2009, 103-02-03]

3.2
direct component
mean value of a quantity taken over a given time interval

[SOURCE: IEC 60050-103:2009, 103-06-05, modified – definition extended to quantities containing interharmonic components.]

3.3
sinusoidal, adj.
pertaining to an alternating quantity represented by the product of a real constant and a sine or cosine function whose argument is a linear function of the independent variable

Note 1 to entry: The real constant may be a scalar, vector or tensor quantity.

Note 2 to entry: Examples are $a(t) = \hat{A}\cos(\omega t + \vartheta_0)$ and $a(x) = \hat{A}\cos[k(x - x_0)]$.

[SOURCE: IEC 60050-103:2009, 103-07-01]

3.4
initial phase
phase angle
ϑ_0
value of the phase of a sinusoidal quantity when the value of the independent variable is zero

Note 1 to entry: For the quantity $a(t) = \hat{A}\cos(\omega t + \vartheta_0)$, the initial phase is ϑ_0.

[SOURCE: IEC 60050-103:2009, 103-07-05]

3.5
periodic conditions
state of an electric circuit element or electric circuit that is characterized by the electric currents and voltages all being periodic functions of time with the same period T

[SOURCE: IEC 60050-131:2002, 131-11-27, modified – addition of symbol T for the period.]

3.6
sinusoidal conditions
state of a linear electric circuit element or electric circuit that is characterized by the electric currents and voltages all being sinusoidal functions of time with the same frequency

[SOURCE: IEC 60050-131:2002, 131-11-28]

3.7
instantaneous power
$p(t)$
for a two-terminal element or a two-terminal circuit with terminals A and B, product of the voltage u_{AB} between the terminals and the electric current i in the element or circuit

$$p(t) = u_{AB}(t) \cdot i(t)$$

where u_{AB} is the line integral of the electric field strength from A to B, and where the electric current in the element or circuit is taken positive if its direction is from A to B and negative if its direction is from B to A

Note 1 to entry: The direction of electric current is as defined in IEC 60050:2002, 131-11-29.

Note 2 to entry: In circuit theory the electric field strength is generally non-rotational and thus $u_{AB} = v_A - v_B$, where v_A and v_B are the electric potentials at terminals A and B, respectively.

Note 3 to entry: The coherent SI unit of instantaneous power is watt, W.

Note 4 to entry: A two-terminal element or circuit refers to a single-phase equipment or system.

[SOURCE: IEC 60050-131:2013, 131-11-30, modified – in note 2, the term irrotational is replaced by non-rotational and a new note 4 has been added.]

3.8
apparent power
S
product of the r.m.s. voltage U between the terminals of a two-terminal element or two-terminal circuit and the r.m.s. electric current I in the element or circuit

$$S = UI$$

Note 1 to entry: The coherent SI unit for apparent power is voltampere, VA.

Note 2 to entry: A two-terminal element or circuit refers to a single-phase equipment or system.

[SOURCE: IEC 60050-131:2013, 131-11-41, modified – the existing note 1 has been removed and a note 2 has been added.]

3.9
active power
P
under periodic conditions, mean value, taken over one period T, of the instantaneous power $p(t)$

$$P = \frac{1}{T}\int_0^T p(t)dt$$

Note 1 to entry: The coherent SI unit for active power is watt, W.

Note 2 to entry: When the voltage or current contain interharmonic components, often their waveforms are no more periodic. In this document, the active power is approximated by the mean value of the instantaneous power, taken over an integer number of periods of the a.c. power supply system (see 5.3.1 and 5.1.4). This definition is also used under periodic conditions in this document (see 6.3 and Clause A.3).

[SOURCE: IEC 60050-131:2013, 131-11-42, modified – the existing note 1 has been removed and a note 2 has been added.]

3.10
non-active power
$Q\sim$
for a two-terminal element or a two-terminal circuit under periodic conditions, quantity equal to the square root of the difference of the squares of the apparent power S and the active power P

$$Q\sim = \sqrt{S^2 - P^2}$$

Note 1 to entry: The coherent SI unit for non-active power is voltampere, VA. The special name "var" and its symbol "var" are also used. See IEC 60050-131:2013, 131-11-45.

Note 2 to entry: A two-terminal element or circuit refers to a single-phase equipment or system.

[SOURCE: IEC 60050-131:2013, 131-11-43, modified – the existing note 1 has been removed and a note 2 has been added.]