

Industrial a.c. networks affected by harmonics — Application of filters and shunt capacitors

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British Standard

ICS 31.060.99; 31.160

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the EN title page, pages 2 to 28 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

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Descriptors: Capacitors, shunts, power capacities, alternating current, electric filters, definitions, generalities

English version

Industrial a.c. networks affected by harmonics Application of filters and shunt capacitors

(IEC 61642:1997)

Réseaux industriels à courant alternatif
affectés par les harmoniques — Emploi de
filtres et de condensateurs shunt
(CEI 61642:1997)

Von Oberschwingungen beeinflusste
industrielle Wechselstromnetze Anwendung
von Filtern und Parallelkondensatoren
(IEC 61642:1997)

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
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Foreword

The text of document 33/255/FDIS, future edition 1 of IEC 61642, prepared by IEC TC 33, Power capacitors, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 61642 on 1997-10-01.

The following dates were fixed:

- latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 1998-07-01
- latest date by which the national standards conflicting with the EN have to be withdrawn (dow) 1998-07-01

Annexes designated “normative” are part of the body of the standard. Annexes designated “informative” are given for information only. In this standard, Annex ZA is normative and Annex A is informative. Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 61642:1997 was approved by CENELEC as a European Standard without any modification.

In the official version, for Annex A, Bibliography, the following notes have to be added for the standards indicated:

IEC 60110, NOTE Harmonized as HD 207 S1:1977 (not modified).

IEC 60143, NOTE Harmonized in the EN 60143 series.

IEC 60358, NOTE Harmonized as HD 597 S1:1992 (not modified).

IEC 60252, NOTE Harmonized as EN 60252:1994 (modified).

IEC 61048, NOTE Harmonized, together with its corrigendum 1992, as EN 61048:1993 (modified).

IEC 61049, NOTE Harmonized, together with its corrigendum 1992, as EN 61049:1993 (modified).

IEC 60056, NOTE Harmonized, together with its amendments 1:1992 and 2:1995, as HD 348 S6:1995.

IEC 60255-6, NOTE Harmonized as EN 60255-6:1994 (modified).

IEC 60265-1, NOTE Harmonized, together with its amendments 1:1984 and 2:1994, as HD 355.1 S3:1995 (not modified).

IEC 60265-2, NOTE Harmonized, together with its corrigendum 1990, as EN 60265-2:1993 (not modified).

IEC 60269, NOTE Harmonized in the EN 60269 series and in the HD 630 series.

IEC 60282, NOTE Harmonized as EN 60282-1:1996 (not modified) and as HD 636 S1:1996 (not modified).

IEC 60289, NOTE Harmonized as EN 60289:1994 (modified).

IEC 60831-1, NOTE Harmonized as EN 60831-1:1996 (not modified).

IEC 60871-1, NOTE Harmonized as HD 525.1 S1:1989 (not modified).

IEC 60871-2, NOTE Harmonized as HD 525.2 S1:1989 (not modified).

IEC 60931-1, NOTE Harmonized as EN 60931-1:1996 (not modified).

IEC 61000-2-2, NOTE Harmonized as ENV 61000-2-2:1993 (modified).

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1 General

1.1 Scope and object

This International Standard gives guidance for the use of passive a.c. harmonic filters and shunt capacitors for the limitation of harmonics and power factor correction intended to be used in industrial applications, at low and high voltages. The measures proposed in this standard are applicable to harmonic orders greater than 1 and up to and including 25.

The following capacitors are excluded from this standard:

- capacitors for inductive heat generating plants, operating at frequencies between 40 Hz and 24 000 Hz (see IEC 60110 [1]¹⁾);
- series capacitors for power systems (see IEC 60143 [2]);
- coupling capacitors and capacitor dividers (see IEC 60358 [3]);
- power electronic capacitors (see IEC 61071 [4]);
- AC motor capacitors (see IEC 60252 [5]);
- capacitors for use in tubular fluorescent and other discharge lamp circuits (see IEC 61048 [6] and IEC 61049 [7]);
- capacitors for the suppression of radio interference;
- capacitors intended to be used in various types of electric equipment and thus considered as components;
- capacitors intended for use with d.c. voltage superimposed on a.c. voltage;
- capacitors intended for use with arc furnaces.

The object of this standard is to identify problems and give recommendations for general applications of capacitors and a.c. harmonic filters in a.c. power systems affected by the presence of harmonic voltages and currents.

1.2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All normative documents are subjected to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60050(131):1978, *International Electrotechnical Vocabulary (IEV) — Chapter 131: Electric and magnetic circuits*.

IEC 60050(161):1990, *International Electrotechnical Vocabulary (IEV) — Chapter 161: Electromagnetic compatibility*.

1.3 Definitions

For the purpose of this International Standard, the following definitions apply.

1.3.1

harmonic

the component of the Fourier-series decomposition of a voltage or current periodic wave
[IEV 161-02-18 modified]

1.3.2

harmonic order, h

the ratio of the frequency of a harmonic (f_h) to the fundamental (rated) network frequency (f_1)
[IEV 161-02-19 modified]

¹⁾ Figures in square brackets refer to the bibliography given in Annex A.

1.3.3**characteristic harmonics**

those harmonics produced by static converters in the course of theoretically ideal operation. The characteristic-harmonic order of static a.c./d.c. converters is given by $h = mp \pm 1$, where p is the pulse number of the converter and m is any integer. For example, the six-pulse converter circuit has characteristic harmonics with order numbers $h = 5, 7, 11, 13, 17, 19 \dots$

1.3.4**non-characteristic harmonics**

those harmonics which are produced as a result of imbalance in the a.c. power system or asymmetrical delay of firing angle of the converter. They are also produced by other non-linear, time-varying devices, for example frequency changers, fluorescent lamps, arc furnaces, electric welding machines, etc.

1.3.5**power factor**

the ratio of the active power to the apparent power [IEV 131-03-20]

1.3.6**displacement factor**

the ratio of the active power of the fundamental wave to the apparent power of the fundamental wave [IEV 131-03-21 modified]

1.3.7**distortion factor**

the ratio of the root-mean-square value of the harmonic content to the root-mean-square value of the fundamental quantity, expressed as a percentage of the fundamental [IEV 131-03-04 modified]

$$DF = \frac{(\text{Sum of the squares of r.m.s values of the harmonics})^{1/2}}{\text{r.m.s value of the fundamental}} 100 \%$$

1.3.8**filter**

an equipment generally constituted of reactors, capacitors and resistors if required, tuned to present a known impedance over a given frequency range

1.3.9**tuning frequency**

the frequency for which the filter impedance, calculated from the rated values, has a minimum or maximum value

1.3.10**tuned filter**

a filter with a tuning frequency which differs by no more than 10 % from the frequency which is to be filtered

1.3.11**detuned filter**

a filter with a tuning frequency more than 10 % below the lowest harmonic frequency with considerable current/voltage amplitude

1.3.12**damped filter**

a filter with low, predominantly resistive, impedance over a wide band of frequencies

1.3.13**ripple control installation**

an installation to inject audio-frequency signals into the high voltage (HV) network in order to control receivers on the low voltage (LV) network

1.3.14**reference voltage**

the voltage to which the impedance calculations are referred

1.4 General considerations**1.4.1 AC harmonics**

Harmonic currents in power networks are produced, in general, when the loads are non-linear or time-varying. One of the main sources of harmonics in industrial networks are static converters.

There are two groups of converter a.c. current harmonics: characteristic and non-characteristic. The characteristic harmonics correlate strongly with the converter circuit and have a constant frequency spectrum. Their magnitude is approximately in inverse proportion to the harmonic number.

The main sources of non-characteristic harmonics are frequency changers, although small amounts of non-characteristic harmonics can result from system imbalances (voltage and impedance) and imbalance in the converter firing angle.

The rectifiers for d.c. drives produce mostly characteristic harmonics.

The effect of non-linear and time-varying loads can be amplified under certain conditions of the electrical supply-network, for example by resonances. Depending on the network conditions and on the amplification effect of the resonances, the supply voltage can be distorted even in electrical installations where non-linear and time-varying loads are absent or represent a small part of the total utility power.

Harmonics increase the losses in power networks and may affect the correct operation of various equipments, in particular electronic circuits.

To keep the harmonic disturbances to an acceptable level, local requirements and national and international standards may specify limits for the harmonic distortion. For the reduction of harmonic distortion, filters can be used.

1.4.2 Reactive power

In general, the reactive power flowing in networks is caused by inductive loads and static converters.

In a network the power factor is determined by the most economical use of the distribution system or is imposed by the utility. Penalties may be imposed through the tariff structure for poor power factor. It is therefore advisable to compensate the inductive reactive power by fitting suitable compensating equipments.

For power factor correction shunt capacitors are normally used. If there are harmonics in the network, unwanted overvoltages and/or overcurrents can appear. In addition, ripple control installations may be disturbed. In these cases, filters can be used in place of shunt capacitors alone.

2 Resonance problems and solutions**2.1 Introduction**

In electrical networks, different components are connected together, for example generators, power lines, cables, transformers, capacitors and loads.

The impedance at any point of the network is dependent on the frequency, on the components and on the configuration.

The series connection of an inductance and a capacitance will result in a very low impedance in a certain frequency range, close to the resonance frequency. This effect is called series resonance.

The parallel connection of an inductance and a capacitance will result in a very high impedance in a certain frequency range, close to the resonance frequency. This effect is called parallel resonance.

Series resonance and parallel resonance may occur in the same network over a wide range of frequencies.

If harmonic voltage- or current-sources excite such resonance circuits, an amplification of voltages and currents may occur which can disturb, overload or even destroy network components.

An example of a simplified network and its one-line diagram is shown in Figure 1.