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Edition 2.0 2015-03

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Guidance information on the application of capacitors, resistors, inductors and complete filter units for electromagnetic interference suppression

Guide d'emploi des condensateurs, résistances, inductances et filtres complets d'antiparasitage

IEC 60940:2015-03(en-fr)

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INTERNATIONAL
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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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GUIDANCE INFORMATION ON THE APPLICATION OF CAPACITORS, RESISTORS, INDUCTORS AND COMPLETE FILTER UNITS FOR ELECTROMAGNETIC INTERFERENCE SUPPRESSION

FOREWORD

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International Standard IEC 60940 has been prepared by IEC technical committee 40: Capacitors and resistors for electronic equipment.

This second edition cancels and replaces the first edition published in 1988. This second edition is a result of maintenance activities related to the previous edition. All changes that have been agreed upon can be categorized as minor revisions.

The text of this standard is based on the following documents:

FDIS	Report on voting
40/2337/FDIS	40/2362/RVD

Full information on the voting for the approval of this standard 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.

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- withdrawn,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.

GUIDANCE INFORMATION ON THE APPLICATION OF CAPACITORS, RESISTORS, INDUCTORS AND COMPLETE FILTER UNITS FOR ELECTROMAGNETIC INTERFERENCE SUPPRESSION

1 Scope

This international standard provides guidance applicable to information on application of capacitors, resistors, inductors, and complete filter units for electromagnetic interference suppression.

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.

IEC 60335-1, *Household and similar electrical appliances – Safety – Part 1: General requirements*

IEC 60384-14, *Fixed capacitors for use in electronic equipment – Part 14: Sectional specification – Fixed capacitors for electromagnetic interference suppression and connection to the supply mains*

3 Electromagnetic and Radio frequency interference suppression (EMI/RFI)

3.1 General

Electromagnetic interference, EMI, is any electromagnetic emission or any electric or electronic disturbance which causes an undesirable response, malfunctioning or degradation in the performance of electrical equipment.

Radio frequency interference, RFI, is any electrical energy with content within the frequency range dedicated to radio frequency transmission.

Conducted RFI is most often found in the low frequency range from 150 kHz to 30 MHz.

Radiated RFI is most often found in the frequency range from 30 MHz to 10 GHz.

EMI or RFI propagate through conduction over signal and power lines and through radiation in free space.

Electrical machines and apparatus may generate electromagnetic interferences (EMI) which are fed back into power supply mains. These electromagnetic interferences may be picked up by apparatus connected to or placed close to the same power system up to a certain distance from the machine or apparatus.

The radio-frequency voltages may be generated both between conductors (phases) of the power system (symmetrical interference) and also between conductors (phases) and earth (asymmetrical interference). These voltages can cause electromagnetic radiation from the power lines.

Radio interference can be suppressed by providing a low impedance path for radio frequency currents close to the place where the radio frequency voltages are generated. This may be combined with a high impedance element which prevents the radio frequency currents from penetrating into the power supply system, but has no appreciable effect on the flow of power current.

3.2 Limits of interference

In various countries, mandatory limits are set to the radio-frequency in a given frequency range emanating from electrical machines and apparatus.

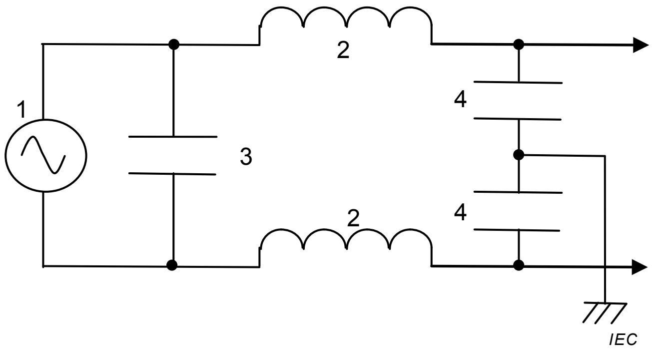
A survey of these limits is given in relevant EMC-standards such as CISPR 11.

Some electrical apparatus require for their operation a power-supply voltage free from radio-interference to a greater extent than that guaranteed by the requirements mentioned above. In these cases, similar measures should be taken at a place in the power supply system close to the place where the apparatus is connected. When the apparatus is shielded (or placed in a shielded room), interference suppression will generally be applied at each point where the power supply system enters the shielded enclosure.

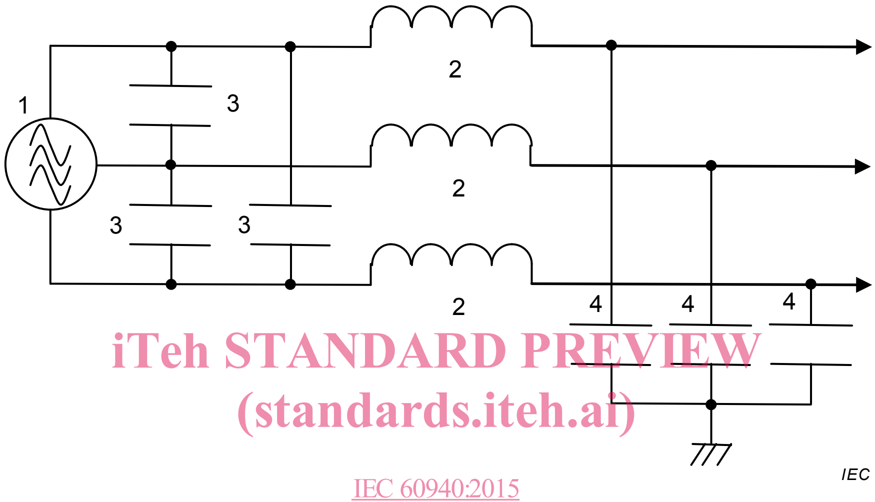
4 Classification of suppression components

4.1 Suppression components

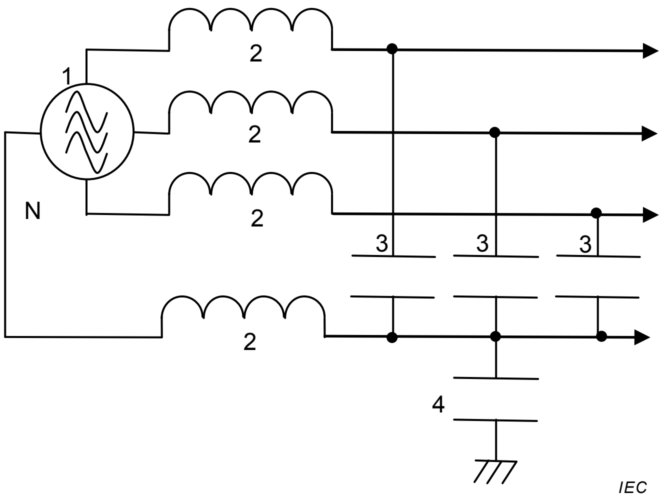
An example of use of suppression components in EMI filter is shown in Figure 1.



a) Single phase EMI filter



b) Three phase three wires EMI filter



c) Three phase four wires EMI filter

Key

1 Mains
2 Inductor
3 X-capacitor
4 Y-capacitor
N Neutral

Figure 1 – Example use of suppression components in EMI filter

4.2 Capacitors

Radio interference suppression capacitors may be divided into the following groups:

a) Two-terminal capacitors, which can be connected to the machine, apparatus or supply system to provide for either symmetrical or asymmetrical interference suppression.
b) Combinations of capacitors (either combinations of separate capacitors or multi-section capacitor the sections of which may be connected in a certain manner), which can be connected to the machine, apparatus or supply system to provide for both symmetrical and asymmetrical interference suppression.
c) Lead-through capacitors (asymmetrical or symmetrical) or combinations thereof, in which one or more sets of terminations are interconnected by means of a conductor intended to carry the power supply current. These capacitors are especially suited to provide interference suppression at the place where the supply system phases through a shielded housing.
d) Resistor-capacitor combinations consisting of a capacitor with the capacitor utilizing the resistance of the capacitor electrodes. RC combinations are often used for the suppression of switching surges.

4.3 Inductors

Radio interference suppression inductors may be divided into the following groups:

a) Simple coils either with an air core or wound on a magnetic core. The UHF choke is an example of this type of inductor.
b) Coils wound on a closed magnetic core. These inductors may have two or more coils wound on the same core, which is often of ferrite material. The windings are often arranged so that there is no resultant magnetization induced in the core due to the power current, when the inductor is known as current-compensated.
c) Inductance, at high frequencies, may be obtained for suppression purposes by threading ferrite beads on to lead wires.
d) Some core materials, especially ferrite materials, can be designed to introduce fairly high resistive losses at VHF and UHF, adding to the suppression obtained by the inductance of the coil.

4.4 Filters

Radio interference filters are construed from inductors and capacitors, sometimes with the addition of resistors, varistors, etc. Two different types may be distinguished:

a) Filters constructed from approved components either as an unprotected assembly or with a simple protective casing. The approval testing of these filters can be simplified since it is not necessary to repeat the tests already carried out on the components.
b) Filters constructed from components which are not approved, or which are constructed from capacitive, inductive or resistive elements all contained in housing. For such filters it is necessary to carry out a full range of qualification approval tests.

5 Choice of ratings for specific applications

5.1 Voltage

When selecting components for connection to a.c. mains, consideration shall be given to possible mains voltage fluctuations. When operation under high pulse conditions is required for capacitors connected across the mains, then class X1 capacitors should be used (see IEC 60384-14).

For d.c. components the rated voltage shall be the maximum which the component will encounter, unless there is a special test for behaviour under transient conditions.

5.2 Current

The rated current is the maximum which the component can carry at a temperature up to the rated temperature. Lower currents can be carried at higher temperature up to the upper category temperature. Higher currents may be carried if the component is fitted to a heat sink as specified by the manufacturer. The manufacturer may specify both a still air rated current and higher rated current when the component is used with a specified heat sink.

5.3 Environmental classification (climatic category)

This is comprised of three figures, e.g. (25/085/21). This indicates that the lower category temperature is –25 °C, the upper category temperature +85 °C and the duration of the damp heat, steady state test is 21 days.

When the suppression component is mounted and working in the equipment the case temperature should not be outside the category temperature range under any conditions of operation.

The selection of the humidity classification depends on the environment in which the equipment is expected to work. 21 days is frequently chosen for domestic appliances, for example.

5.4 Insertion loss

The performance of a component or a filter is normally described by its insertion loss measured over a range of frequencies when terminated by fixed real impedances. In practice the filter is connected between the mains supply and the source of the interference, both of which have complex impedances which vary with frequency. As a consequence insertion loss curves can only be used as an indication of suppression performance, which can be determined decisively only by connecting the filter to the apparatus and then measuring the remaining interference.

The measurement of insertion loss is useful to check stability after environmental and endurance tests, and to compare filters of different construction, but since the effectiveness of a given suppressor may be determined without insertion loss measurements the manufacturer may not declare insertion loss figures.

Where insertion loss figures are declared, it is important that it should be carefully stated whether the test circuit is asymmetric or symmetric, what test method is used, what the values of the terminating impedances are and whether the component is carrying any power current during measurements.

NOTE Methods of Measurement of Suppression Characteristics are described in CISPR 17.

6 Connection of suppression components

Symmetrical interference suppression is effected by connecting a capacitor between phases of power supply (between phase and neutral for single-phase power supply).

Asymmetrical interference suppression on machines or apparatus is usually effected by connecting a capacitor from each phase (or phase and neutral) to earthed metallic parts or the frame, metallic housing etc., where this is not earthed.

The suppression will often be more effective if the electrical parts of the apparatus are completely in the metal shielding, asymmetrical interference suppression is usually effected by connecting a capacitor from each phase (or phase and neutral) to the shielding.

During operation, the capacitors are subjected to the supply mains voltage with a superimposed radio interference voltage. In many cases, the extra load caused by the radio-frequency voltage is not important, but in other cases an appreciable radio-frequency current through the capacitor may occur or high voltage peaks may be present. This must be taken into account when choosing the capacitor and a check should be made with the capacitor under its working conditions to make sure that its ratings are not exceeded.

The presence of inductance in the supply circuits in series with the capacitor may cause the voltage at power frequency applied to the capacitor to exceed the supply voltage.

For inductors using ferromagnetic cores, it is important to be aware of the possible loss of suppression caused by saturation of the core causing decrease of inductance. This saturation may be caused by peaks of load current or interference current, or continuous excessive load current. Unbalance of winding in current-compensated inductors will also contribute to the effect.

The effectiveness of interference suppression is a function of suppression component construction, mounting of the component in the machine or apparatus, the radio-frequency voltage spectrum generated by the machine or apparatus and of characteristics of the external circuit.

Due to the complexity of the problem it is not possible to estimate with sufficient accuracy from the radio-frequency characteristics of a component how effective it will be under various conditions.

On the other hand, components for use under similar conditions can be compared on the basis of their radio-frequency characteristics. For this purpose the resonance frequency measured under given conditions and the radio-frequency resistive at resonance may be of use. For these reasons it is not required that the radio-frequency characteristics be marked on the components nor has it been attempted to standardize certain values for these characteristics.

7 Safety aspects

7.1 Class X and Y capacitors

Radio interference suppression capacitors are divided into X- and Y- capacitors.

X-capacitors are intended to be connected across the line.

Y-capacitors are allowed to be connected between line and earth for mains voltages up to 500 V.

In a.c. applications, Y-capacitors can be substituted with two X-capacitors connected in series provided that the U_R of the X-capacitors are not less than the U_R of the Y-capacitor and that the filter withstands the voltage proof as required in IEC 60939 series. In case of Y1-capacitor substitution, the X-capacitors shall be X1-capacitors.

In DC-Filters with a rated voltage of 150 V d.c. or less, a Y2- and Y4-capacitor may be substituted by X-capacitor with a rated voltage 250 V d.c. or higher.

In the case of failure by short circuit of a class X-capacitor connected between phases (or between phase and neutral) no problem arises since the apparatus will be disconnected by means of the normal short-circuit protection of the mains supply. For such capacitors a voltage proof test level appropriate for general purpose capacitors is sufficient. Such capacitors are subdivided into class X1 and class X2 according to their ability to handle levels of peak pulse voltage (see IEC 60384-14). However in the case of failure by short