IEC TR 61000-2-15

Edition 1.0 2023-02

TECHNICAL REPORT

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Electromagnetic compatibility –
Part 2-15: Description of the characteristics of networks with high penetration of power electronic converters

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Part 2-15: Description of the characteristics of networks with high penetration of power electronic converters

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IEC TR 61000-2-15 has been prepared by subcommittee 77A: EMC – Low frequency phenomena, of IEC technical committee 77: Electromagnetic compatibility. It is a Technical Report.

The text of this Technical Report is based on the following documents:

Draft	Report on voting
77A/1153A/DTR	77A/1159/RVDTR

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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 webstore.iec.ch in the data related to the specific document. At this date, the document will be

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- withdrawn,
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INTRODUCTION

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 (insofar as these limits do not fall under the responsibility of the product committees)

Part 4: Testing and measurement techniques

Measurement techniques

Testing techniques

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Part 5: Installation and mitigation guidelines

Installation guidelines

Mitigation methods and devices

Part 6: Generic standards

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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: IEC 61000-6-1).

This part of IEC 61000-2 describes the main phenomena which affect the power quality of modern distribution systems with high penetration of power electronics converters.

It focuses on the following main aspects: resonances in LV network, impact of increased number of power electronic converters, instability issues for the equipment to be connected to the LV networks.

Those new aspects, organized and described in this document, can lead to new IEC specifications; that is why a state of the art on this topic is necessary.

ELECTROMAGNETIC COMPATIBILITY –

Part 2-15: Description of the characteristics of networks with high penetration of power electronic converters

1 Scope

This part of IEC 61000, which is a Technical Report, addresses in particular the following main phenomena, which affect the power quality in modern distribution systems with high penetration of power electronics converters. As some aspects of the subject have already been addressed in the past, considering the evolution of the LV and MV networks, this document focuses on the following aspects:

- resonances in the network, modelling and on-site validation;
- supraharmonics and measurements issues;
- impact of increased number of power electronic converters;
- stability and instability issues for the equipment to be connected

The target phenomena and conditions of this document are the following:

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- frequency: ≤ 2 kHz, 2 kHz to 9 kHz, ≥ 9 kHz;
- voltage levels: LV, MV;
- harmonic sources: all types of converters (EV battery chargers, appliances, etc.…).

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Some of these frequency ranges have already been standardized in some countries (Japan, Germany, Switzerland, etc.), but the resulting phenomena developed will benefit being described in more details, with a focus on the interaction between the converters and the electrical networks. The case of the presence of a large number of converters is also at stake. Some complex phenomena can also arise when the full system is not stable anymore.

NOTE Whereas it is expected that the models and derived calculations form this document can be applied to the Americas electrical systems its formal validation studies are still pending.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

4 Resonance phenomena with network and power electronics equipment based on actual cases

4.1 Operation of overvoltage protection of earth leakage circuit breaker in Japanese LV systems

4.1.1 General

- Overview

  In Japanese LV systems, power outages due to the operation of the earth leakage circuit breaker (ELCB) with an overvoltage protection function, and due to the abnormal acoustic noises generated by peripheral appliances can occur when particular appliances with power electronics technologies are operating [1][1].

  In some cases, the overvoltages exceed the rated voltage in the same LV system, caused by harmonics within the frequency band of 2 kHz to 9 kHz in the LV line.

  As a result of investigating these phenomena through verification tests and simulations, the overvoltage was confirmed as attributable to a harmonic resonance between the harmonic current produced by the power electronics appliance and the network circuit including the MV/LV transformer inductance, the LV line inductance and the-line capacitances with peripheral appliances. These resonance phenomena are also addressed in [7] [27].

  The case is addressed in detail in the following paragraphs, and other cases are mentioned in 4.2.

- Description of the conditions and their verification

  In Figure 1, when a particular power electronics appliance in a home (source) connected to a public LV system is in operation [1], an ELCB in another home (neighbour) connected to the same LV system acted and trips or acoustic noise from appliances occurred. The ELCB has functions not only to detect the earth leakage current but also to protect against overvoltages. That overvoltage protection operates when its amplitude exceeds 130 % of the nominal voltage.

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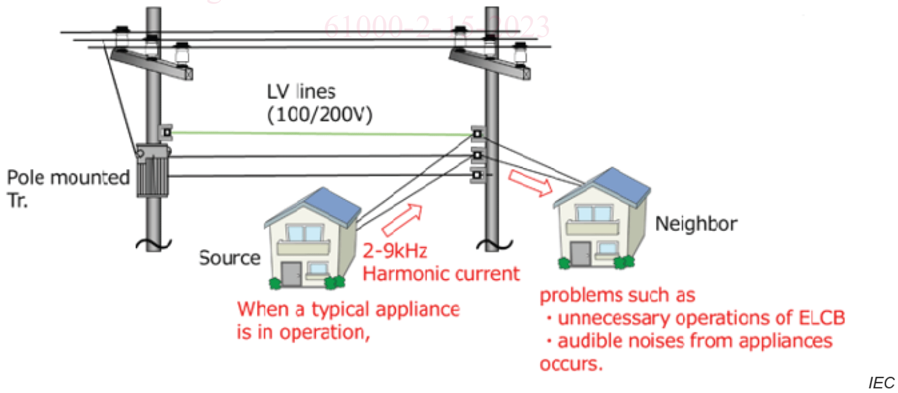

Figure 1 – Schematic illustration of a harmonic resonance issue in a LV system

The peak voltage in the waveform given by Figure 2 [1] exceeds 141 V_p of the normal peak voltage at 100 V_{rms} and includes harmonics in the higher frequency band. The overvoltage level at the neighbour location is higher than the one at the source because of a harmonic resonance.

1 Numbers in square brackets refer to the Bibliography.

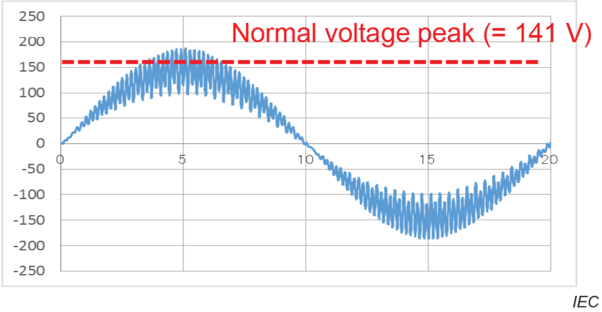

Figure 2 – Waveform of the overvoltage at the neighbour side

4.1.2 Circuit modelling

In Figure 3, the equivalent circuit of this parallel resonance consists of a harmonic current source I_n with a particular power electronics appliance, an MV/LV transformer inductance L_{tr}, an LV distributed line inductance L_{line}, a phase-to-phase capacitance C_0 connected to the appliance at the source side and a C_1 connected to appliances at the neighbour side. The voltage at the neighbor side is given by V_c as shown in Figure 2 [1]

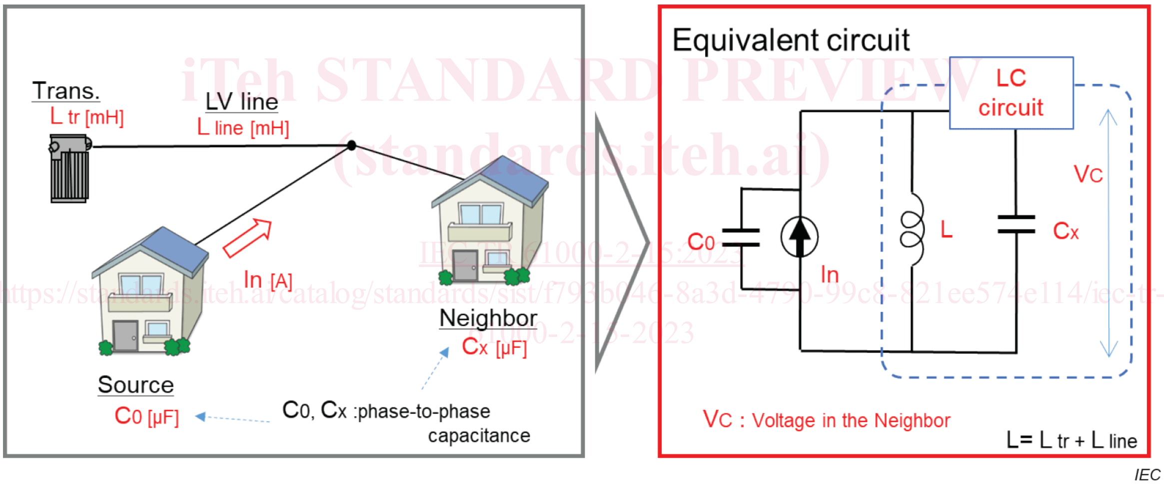

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Figure 3 – Description of an equivalent circuit modelling for harmonic resonances

- Determination of the frequency dependent grid impedance (FdGI)

  From the equivalent circuit of an L, C parallel resonance, the resonance magnification factors (RMFs) (V/A) have been determined by simulations [1]. It can be seen in Figure 4 , using the frequency dependent impedance with the inductance of the LV system and the capacitor of the phase-to-phase capacitances with appliances.

  As the analytical parameters are in the frequency range from 2 kHz to 9 kHz, C_0 = 0,1～1 000 μF and L_0 = 50 mH～1 000 mH, are used on the source side with the power electronics appliance and C_1 = 1 μF～2 0 μF is used on the neighbour side corresponding to the damaged equipment. The voltage when given by a current source of 1 A in the frequency band is defined as RMF.