



BSI Standards Publication

Electromagnetic compatibility (EMC)

Part 2-5: Environment — Description and
classification of electromagnetic environments

National foreword

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TECHNICAL REPORT



BASIC EMC PUBLICATION

**Electromagnetic compatibility (EMC) –
Part 2-5: Environment – Description and classification of electromagnetic
environments**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 33.100.20

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CONTENTS

FOREWORD	7
1 Scope	9
2 Normative references	10
3 Terms, definitions and abbreviated terms	11
3.1 Terms and definitions.....	11
3.2 Abbreviated terms.....	18
4 User's guide for this document.....	22
4.1 Approach	22
4.2 Rationale for classification system	24
4.3 Electromagnetic environment phenomena	25
4.4 Relationship of disturbance levels to CISPR limits	26
4.5 Simplification of the electromagnetic environment database.....	26
5 Low-frequency electromagnetic phenomena	30
5.1 Conducted low-frequency phenomena	30
5.1.1 Harmonics of the fundamental power frequency.....	30
5.1.2 Power supply network voltage amplitude and frequency changes	32
5.1.3 Power supply network common mode voltages	34
5.1.4 Signalling voltages in power supply networks	37
5.1.5 Islanding supply networks.....	38
5.1.6 Induced low-frequency voltages.....	39
5.1.7 DC voltage in AC networks	39
5.2 Radiated low-frequency phenomena	40
5.2.1 Magnetic fields	40
5.2.2 Electric fields.....	41
6 High-frequency electromagnetic phenomena	42
6.1 Conducted high-frequency phenomena	42
6.1.1 General	42
6.1.2 Direct conducted CW phenomena.....	43
6.1.3 Induced continuous wave.....	47
6.1.4 Transients	47
6.2 Radiated high frequency phenomena	50
6.2.1 General	50
6.2.2 Radiated continuous oscillatory disturbances.....	52
6.2.3 Radiated modulated disturbances	52
6.2.4 Radiated pulsed disturbances.....	75
7 Electrostatic discharge	77
7.1 General.....	77
7.2 ESD currents	77
7.3 Fields produced by ESD currents.....	78
8 Classification of environments	79
8.1 General.....	79
8.2 Location classes	79
8.3 Residential location class.....	81
8.3.1 Description of residential locations	81
8.3.2 Equipment typical to the residential location	81

8.3.3	Boundaries relevant for equipment operated at residential locations	82
8.3.4	Interfaces and ports to residential locations	83
8.3.5	Attributes of residential locations	83
8.4	Commercial/public location class	85
8.4.1	Description of commercial/public locations	85
8.4.2	Equipment and interference sources existent in commercial/public locations	85
8.4.3	Boundaries relevant for equipment operated at commercial/public locations	85
8.4.4	Interfaces and ports to commercial/public locations	86
8.4.5	Attributes of commercial/public locations	86
8.5	Industrial location class	89
8.5.1	Description of industrial locations	89
8.5.2	Equipment and interference sources present in industrial locations	90
8.5.3	Boundaries relevant for equipment operated at industrial locations	90
8.5.4	Interfaces and ports to industrial locations	91
8.5.5	Attributes of industrial locations	91
8.6	Types of power supply networks	93
8.7	Alterations in electromagnetic environments	95
8.7.1	General	95
8.7.2	The electromagnetic environments of Smart Grid	96
8.8	Further conducted electromagnetic phenomena	96
8.8.1	Description of conducted phenomena other than those in Clause 4 and Clause 5	96
8.8.2	Repetitive electrical impulse noise	97
8.8.3	Single high intensity noise event	98
8.9	Mitigation aspects	98
8.10	Description of location classes with regard to the requirements of EMC basic standards	99
9	Principles of the selection of immunity levels	102
9.1	Approach	102
9.2	Uncertainties	102
9.2.1	Uncertainties in the test situation	102
9.2.2	Uncertainties in the application situation	102
9.2.3	Dealing with uncertainties	102
9.3	Dealing with high density sources	103
9.4	Criticality criteria	103
10	Disturbance levels of the various location classes	104
Annex A (informative)	Compatibility levels/disturbance levels for location classes	105
Annex B (informative)	Radiated continuous disturbances	115
Annex C (informative)	Review of the historical assignment of radiated disturbance degrees	124
C.1	General	124
C.2	Revised analysis of radiated disturbance degrees	124
C.2.1	Analysis	124
C.2.2	Detailed derivations	126
Annex D (informative)	Radiated pulsed disturbances	130
Annex E (informative)	Power line telecommunications (PLT)	135
Annex F (informative)	Distributed generation	135

Annex G (informative) Information on disturbance and compatibility levels available in documents of the IEC 61000-2 series	138
Bibliography.....	142
Figure 1 – Schematic of the two-step approach used for classification with phenomenon-oriented input tables and location-oriented output tables	23
Figure 2 – Ports of entry (POEs) of electromagnetic disturbances into equipment.....	24
Figure 3 – Typical voltage waveforms for dip and interruption (10 ms/horizontal division).....	33
Figure 4 – Typical configuration of the converter in a PDS	35
Figure 5 – Voltage and current waveforms of each PDS portion (1 ms/horizontal division).....	36
Figure 6 – Measured common mode voltage at the input terminal of a converter.....	36
Figure 7 – Concept of location classes.....	80
Figure 8 – Situation for TN-C power installation systems	94
Figure 9 – Situation for TN-S power installation systems.....	95
Figure 10 – Examples of electromagnetic environments associated with the Smart Grid	96
Figure B.1 – Typical waveforms for radiated disturbances.....	116
Figure C.1 – Problem geometry	125
Figure D.1 – Measured electric field and electric field derivative from a cloud-to-ground lightning strike measured at a distance of 30 m.....	130
Figure D.2 – Measured electric field from an electrostatic discharge event at a distance of 0,1 m	131
Figure D.3 – Measured magnetic field (two measurements) from an electrostatic discharge event at a distance of 0,1 m.....	131
Figure D.4 – Measured electric field in kV/m versus time in μ s in a 500 kV power substation	132
Figure F.1 – Example of disturbance voltages for electrical energy storage system (140 kVA) in situ with the frequency range of 9 kHz to about 30 MHz.....	137
Figure F.2 – Example of disturbance voltages from a photovoltaic inverter (21 kW) in situ with the frequency range of 9 kHz to about 30 MHz.....	137
Table 1 – Principal phenomena causing electromagnetic disturbances	28
Table 2 – Disturbance degrees and levels for harmonic voltages in power supply networks (in percentage to fundamental voltage, U_n/U_1).....	32
Table 3 – Disturbance degrees and levels for voltage changes within normal operating range (in percentage of nominal voltage, $\Delta U/U_n$)	33
Table 4 – Disturbance degrees and levels for voltage unbalance (in percentage of U_{neg}/U_{pos})	34
Table 5 – Disturbance degrees and levels for power frequency variation	34
Table 6 – Disturbance degrees and levels for common mode voltages.....	37
Table 7 – Disturbance degrees and levels for signalling voltages in low and medium-voltage systems (in per cent of nominal voltage U_n)	38
Table 8 – Disturbance degrees and levels for low-frequency, common mode induced voltages in signal and control cables.....	39
Table 9 – Disturbance degrees and levels for low-frequency magnetic fields at various frequencies.....	41
Table 10 – Disturbance degrees and levels for low-frequency electric fields.....	41

Table 11 – Disturbance degrees and levels of direct CW voltages	46
Table 12 – Disturbance degrees and levels of induced CW voltages with respect to reference ground	47
Table 13 – Disturbance degrees and levels for conducted unidirectional transients in low-voltage AC power systems	49
Table 14 – Disturbance degrees and levels for conducted oscillatory transients in low-voltage AC power systems.....	50
Table 15 – Radiation sources.....	51
Table 16 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Radiated continuous oscillatory disturbances.....	52
Table 17 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Amateur radio bands below 30 MHz.....	54
Table 18 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – 27 MHz CB band	55
Table 19 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Analogue communication services below 30 MHz	56
Table 20 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Analogue communication services above 30 MHz	57
Table 21 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Mobile and portable phones	57
Table 22 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Mobile and portable phones (continued)	58
Table 23 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Base stations.....	60
Table 24 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Base stations (continued)	61
Table 25 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Medical and biological telemetry items.....	63
Table 26 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Digital-television broadcast (VHF).....	64
Table 27 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Digital-television broadcast (UHF).....	65
Table 28 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Digital-television broadcast (UHF) (continued)	66
Table 29 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Unlicensed radio services	67
Table 30 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Unlicensed radio services (continued).....	68
Table 31 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Amateur radio bands above 30 MHz	69
Table 32 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Paging service base station	70
Table 33 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Other RF items (1 of 6).....	70
Table 34 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Other RF items (2 of 6).....	71
Table 35 – Disturbance degrees, levels (in V/m, rms) and distance to source – Other RF items (3 of 6).....	71
Table 36 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Other RF items (4 of 6).....	72

Table 37 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – Other RF items (5 of 6).....	72
Table 38 – Disturbance degrees, levels (in V/m, rms) and distance to source – Other RF items (6 of 6).....	73
Table 39 – Disturbance degrees, levels (in V/m, r.m.s.) and distance to source – RFID and railway transponder systems.....	74
Table 40 – Disturbance degrees, levels (in μ A/m, r.m.s.) and distance to source – RFID and railway transponder systems.....	75
Table 41 – Disturbance degrees, levels (in rate of rise) and distance to source – Radiated pulsed disturbances.....	76
Table 42 – Disturbance degrees, levels (in V/m, Pk) and distance to source – RADAR systems.....	77
Table 43 – Disturbance degrees and levels for pulsed disturbances (rate of rise) caused by ESD.....	78
Table 44 – Disturbance degrees and levels for radiated field gradients caused by ESD.....	78
Table 45 – Examples of equipment present in the residential location class.....	82
Table 46 – Attributes of the residential location class.....	84
Table 47 – Attributes of various types of the commercial/public location class.....	88
Table 48 – Attributes of various types of the industrial location class.....	92
Table 49 – Overview of phenomena versus basic standard, related table and subclause	100
Table A.1 – Disturbance levels in the residential location class.....	106
Table A.2– Disturbance levels in the commercial/public location class.....	109
Table A.3 – Disturbance levels in the industrial location class.....	112
Table B.1 – Examples of field strengths from authorized transmitters.....	117
Table B.2 – Specifications of mobile and portable units.....	118
Table B.3 – Specifications of base stations.....	119
Table B.4 – Specification of other typical RF items.....	119
Table B.5 – Data regarding RFID technology.....	120
Table B.6 – Frequency allocations of TETRA system (in Europe).....	120
Table B.7 – Amateur radiofrequencies (ITU regions 1 to 3).....	121
Table C.1 – Radiated disturbance degrees defined in Edition 1.....	124
Table D.1 – Data regarding RADAR systems.....	133
Table D.2– Examples for civil RADAR systems.....	134
Table G.1 – Overview of the IEC 61000-2 series.....	139

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROMAGNETIC COMPATIBILITY (EMC) –**Part 2-5: Environment –
Description and classification of electromagnetic environments****FOREWORD**

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IEC 61000-2-5, which is a technical report, has been prepared by technical committee 77: Electromagnetic compatibility.

It forms Part 2-5 of IEC 61000. It has the status of a basic EMC publication in accordance with IEC Guide 107.

This third edition cancels and replaces the second published in 2011. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) the description of the radiated electromagnetic environment has been updated taking into account recent communication technologies;
- b) some conducted phenomena and respective interference sources have been described in more detail.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
77/525A/DTR	77/526/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 document has been drafted in accordance with the ISO/IEC Directives, Part 2.

The reader's attention is drawn to the fact that Annex E lists some "in-some-country" clauses on differing practices regarding a particular electromagnetic phenomenon.

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 document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

- reconfirmed,
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A bilingual version of this publication may be issued at a later date.

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ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 2-5: Environment – Description and classification of electromagnetic environments

1 Scope

Knowledge of the electromagnetic environment that exists at locations where electrical and electronic equipment and systems are intended to be operated is an essential precondition in the process of achieving electromagnetic compatibility. This knowledge can be obtained by various approaches, including a site survey of an intended location, the technical assessment of the equipment and system, as well as the general literature.

This part of IEC 61000

- introduces the concept of disturbance degrees and defines these for each electromagnetic phenomena,
- classifies into various location classes and describes them by means of attributes,
- provides background information on the different electromagnetic phenomena that may exist within the environment and
- compiles tables of compatibility levels for electromagnetic phenomena that are considered to be relevant for those location classes.

This part of IEC 61000 is intended for guidance for those who are in charge of considering and developing immunity requirements. It also gives basic guidance for the selection of immunity levels. The data are applicable to any item of electrical or electronic equipment, sub-system or system that operates in one of the locations as considered in this document.

NOTE 1 This document considers relevant electromagnetic phenomena when describing and classifying electromagnetic environments (except HEMP and HPEM which are covered in other IEC 61000-2 standards). It makes use of the specification of technologies, of published data and of results from measurements. Not all electromagnetic phenomena considered here are described in detail in this document, but rather in other documents of the IEC 61000-2 series from which the relevant information and data are taken and used in this document. For more detailed information about those phenomena the user is referred to this series. See also Annex F for an overview of the various parts of the IEC 61000-2 series.

NOTE 2 It is noted that immunity requirements and immunity levels determined for items of equipment which are intended to be used at a certain location class are not inevitably bound to the electromagnetic environment present at the location, but also to requirements of the equipment itself and the application in which it is used (e.g. when taking into account requirements regarding availability, reliability or safety). These could lead to more stringent requirements with respect to immunity levels or with respect to applicable performance criteria. These levels can also be established for more general purposes such as in generic and product standards, taking into account statistical and economic aspects as well as common experience in certain application fields.

NOTE 3 Electromagnetic phenomena in general show a broad range of parameters and characteristics and hence cannot be related one-to-one to standardized immunity tests which basically reflect the impact of electromagnetic phenomena by a well described test setup. Nonetheless, this document follows an approach to correlate electromagnetic phenomena and standardized immunity tests up to a certain extent. This might allow users of this document to partly take into account standardized immunity tests such as given for example in IEC 61000-4(all parts), when specifying immunity requirements.

The descriptions of electromagnetic environments in this document are predominantly generic ones, taking into account the characteristics of the location classes under consideration. Hence, it should be kept in mind that there might be locations for which a more specific description is required in order to conclude on immunity requirements applicable for those specific locations.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-161:1990, *International Electrotechnical Vocabulary – Chapter 161: Electromagnetic compatibility* (available at www.electropedia.org)

IEC 61000-2-2, *Electromagnetic compatibility (EMC) – Part 2-2: Environment – Compatibility levels for low-frequency conducted disturbances and signalling in public low-voltage power supply systems*

IEC TR 61000-2-3, *Electromagnetic compatibility (EMC) – Part 2: Environment – Section 3: Description of the environment – Radiated and non-network-frequency-related conducted phenomena*

IEC 61000-2-4, *Electromagnetic compatibility (EMC) – Part 2-4: Environment – Compatibility levels in industrial plants for low-frequency conducted disturbances*

IEC TR 61000-2-8, *Electromagnetic compatibility (EMC) – Part 2-8: Environment – Voltage dips and short interruptions on public electric power supply systems with statistical measurement results*

IEC 61000-2-9, *Electromagnetic compatibility (EMC) – Part 2: Environment – Section 9: Description of HEMP environment – Radiated disturbance*

IEC 61000-2-12, *Electromagnetic compatibility (EMC) – Part 2-12: Environment – Compatibility levels for low-frequency conducted disturbances and signalling in public medium-voltage power supply systems*

IEC 61000-2-13, *Electromagnetic compatibility (EMC) – Part 2-13: Environment – High-power electromagnetic (HPEM) environments – Radiated and conducted*

IEC 61000-4-2, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

IEC 61000-4-3, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*

IEC 61000-4-4, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

IEC 61000-4-5, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*

IEC 61000-4-6, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61000-4-8, *Electromagnetic compatibility (EMC) – Part 4-8: Testing and measurement techniques – Power frequency magnetic field immunity test*

IEC 61000-4-9, *Electromagnetic compatibility (EMC) – Part 4-9: Testing and measurement techniques – Impulse magnetic field immunity test*

IEC 61000-4-10, *Electromagnetic compatibility (EMC) – Part 4-10: Testing and measurement techniques – Damped oscillatory magnetic field immunity test*

IEC 61000-4-11, *Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests*

IEC 61000-4-12, *Electromagnetic compatibility (EMC) – Part 4-12: Testing and measurement techniques – Ring wave immunity test*

IEC 61000-4-13, *Electromagnetic compatibility (EMC) – Part 4-13: Testing and measurement techniques – Harmonics and interharmonics including mains signalling at a.c. power port, low frequency immunity tests*

IEC 61000-4-14, *Electromagnetic compatibility (EMC) – Part 4-14: Testing and measurement techniques – Voltage fluctuation immunity test for equipment with input current not exceeding 16 A per phase*

IEC 61000-4-16:2015, *Electromagnetic compatibility (EMC) – Part 4-16: Testing and measurement techniques – Test for immunity to conducted, common mode disturbances in the frequency range 0 Hz to 150 kHz*

IEC 61000-4-18, *Electromagnetic compatibility (EMC) – Part 4-18: Testing and measurement techniques – Damped oscillatory wave immunity test*

IEC 61000-4-19, *Electromagnetic compatibility (EMC) – Part 4-19: Testing and measurement techniques – Test for immunity to conducted, differential mode disturbances and signalling in the frequency range 2 kHz to 150 kHz at a.c. power ports*

IEC 61000-4-27, *Electromagnetic compatibility (EMC) – Part 4-27: Testing and measurement techniques – Unbalance, immunity test for equipment with input current not exceeding 16 A per phase*

IEC 61000-4-28, *Electromagnetic compatibility (EMC) – Part 4-28: Testing and measurement techniques – Variation of power frequency, immunity test for equipment with input current not exceeding 16 A per phase*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-161 and the following apply.

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

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

3.1.1

active infeed converter

AIC

self-commutated electronic power converter of all technologies, topologies, voltages and sizes which is connected between the AC power supply network (lines) and usually a stiff DC side (current source or voltage source) and which can convert electric power in both directions (generative or regenerative) and control the reactive power or the power factor

Note 1 to entry: Some active infeed converters can additionally control the harmonics to reduce the distortion of an applied AC voltage or current.

3.1.2

blackout

cutoff of electrical power, especially as a result of shortage, mechanical failure, or overuse by consumers

EXAMPLE A power cut due to a short- or long-term electric power loss in an area.

3.1.3

brownout

reduction or cutback in electric power, especially as a result of shortage, mechanical failure, or overuse by consumers

EXAMPLE Reduction in the voltage of commercially supplied power. It is caused by the failure of the generation, transmission, or distribution system, or deliberately by the power utility when demand exceeds supply. The consumer may or may not notice the difference. In the worst case, damage may result.

3.1.4

burst

sequence of a limited number of distinct pulses or an oscillation of limited duration

[SOURCE: IEC 60050-161:1990, 161-02-07]

3.1.5

burst (in TDMA)

signals transmitted by a terminal in the form of a block of predetermined structure during a time interval allotted to the terminal by a TDMA protocol

[SOURCE: IEC 60050-725:1994, 725-14-15]

3.1.6

characteristic impedance of a medium

wave impedance for a travelling wave in a specific medium

Note 1 to entry: The characteristic impedance of a homogeneous isotropic medium is given by $\eta_t = \sqrt{\frac{\mu}{\varepsilon}}$,

where

μ is the permeability of the homogeneous isotropic medium, and

ε is the permittivity of the homogeneous isotropic medium.

[SOURCE IEC 60050-705:1995, 705-03-23, modified – the formula for characteristic impedance has been simplified.]

3.1.7

commercial, public and light-industrial location

location which exists as areas of the city centre, offices, public transport systems (road/train/underground), and modern business centres containing a concentration of office automation equipment (PCs, fax machines, photocopiers, telephones, etc.), and characterized by the fact that equipment is directly connected to a low-voltage public mains network or connected to a dedicated DC source which is intended to interface between the equipment and the low-voltage mains network

EXAMPLE Examples of commercial, public or light-industrial locations are:

- retail outlets, for example shops, supermarkets;
- business premises, for example offices, banks, hotels, data centers;
- areas of public entertainment, for example cinemas, public bars, dance halls;

- places of worship, for example temples, churches, mosques, synagogues;
- outdoor locations, for example petrol stations, car parks, amusement and sports centers;
- general public locations, for example park, amusement facilities, public offices;
- hospitals, educational institutions, for example schools, universities, colleges;
- public traffic area, railway stations, and public areas of an airport;
- light-industrial locations, for example workshops, laboratories, service centers.

Note 1 to entry: The connection between location and electromagnetic environment is given in 3.1.15.

3.1.8

(electromagnetic) compatibility level

specified electromagnetic disturbance level used as a reference level for co-ordination in the setting of emission and immunity limits

Note 1 to entry: By convention, the compatibility level is chosen so that there is only a small probability that it will be exceeded by the actual disturbance level. However, electromagnetic compatibility is achieved only if emission and immunity levels are controlled such that, at each location, the disturbance level resulting from the cumulative emissions is lower than the immunity level for each device, equipment and system situated at this same location.

Note 2 to entry: The compatibility level may be phenomenon, time or location dependent.

[SOURCE: IEC 60050-161:1990, 161-03-10]

3.1.9

disturbance degree

specified and quantified intensity within a range of disturbance levels corresponding to a particular electromagnetic phenomenon encountered in the environment of interest

3.1.10

disturbance level

amount of magnitude of an electromagnetic disturbance, measured and evaluated in a specified way

3.1.11

earth port

cable port other than signal, control or power port, intended for connection to earth

3.1.12

electric field

constituent of an electromagnetic field which is characterized by the electric field strength E together with the electric flux density D

[SOURCE: IEC 60050-121:1998, 121-11-67]

3.1.13

electromagnetic compatibility

EMC

ability of a device, equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment

[SOURCE: IEC 60050-161:1990, 161-01-07, modified – the terms "device" and "equipment" have been added to the definition.]

3.1.14

electromagnetic disturbance

any electromagnetic phenomenon which can degrade the performance of a device, equipment or system, or adversely affect living or inert matter

Note 1 to entry: An electromagnetic disturbance can be electromagnetic noise, an unwanted signal or a change in the propagation medium itself.

[SOURCE: IEC 60050-161:1990, 161-01-05]

3.1.15

electromagnetic environment

totality of electromagnetic phenomena existing at a given location

Note 1 to entry: In general, this totality is time-dependent and its description may need a statistical approach.

Note 2 to entry: It is very important not to confuse the electromagnetic environment and the location itself.

[SOURCE: IEC 60050-161:1990, 161-01-01, modified – a Note 2 to entry has been added.]

3.1.16

electromagnetic field

field, determined by a set of four interrelated vector quantities, that characterizes, together with the electric current density and the volumic electric charge, the electric and magnetic conditions of a material medium or of vacuum

Note 1 to entry: The four interrelated vector quantities, which obey Maxwell Equations, are by convention:

- the electric field strength, E ,
- the electric flux density, D ,
- the magnetic field strength, H ,
- the magnetic flux density, B .

[SOURCE: IEC 60050-121:1998, 121-11-61]

3.1.17

(electromagnetic) susceptibility

inability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance

Note 1 to entry: Susceptibility is a lack of immunity.

[SOURCE: IEC 60050-161:1990, 161-01-21]

3.1.18

enclosure port

physical boundary of the equipment, through or on which electromagnetic fields may impinge

3.1.19

far field

region where the angular distribution of the electromagnetic field is independent of distance from the antenna

Note 1 to entry: When the antenna dimensions are smaller than the wavelength, then this region is defined as $d > \lambda / 2\pi$, where d is the distance from the antenna and λ is the wavelength of the electromagnetic field.

3.1.20

high voltage

HV

- 1) in a general sense, the set of voltage levels in excess of low voltage
- 2) in a restrictive sense, the set of upper voltage levels used in power systems for bulk transmission of electricity

[SOURCE: IEC 60050-601:1985, 601-01-27]

3.1.21**immunity (to a disturbance)**

ability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance

[SOURCE: IEC 60050-161:1990, 161-01-20]

3.1.22**immunity level**

maximum level of a given electromagnetic disturbance incident on a particular device, equipment or system, for which it remains capable of operating at a required degree of performance

[SOURCE: IEC 60050-161:1990, 161-03-14]

3.1.23**industrial location**

location characterized by a separate power network, supplied from a high- or medium-voltage transformer, dedicated for the supply of the installation

EXAMPLE Metalworking, pulp and paper, chemical plants, car production, farm building, high-voltage (HV) areas of airports.

Note 1 to entry: Industrial locations can generally be described by the existence of an installation with one or more of the following characteristics:

- items of equipment installed and connected together and working simultaneously;
- significant amount of electrical power is generated, transmitted and/or consumed;
- frequent switching of heavy inductive or capacitive loads;
- high currents and associated magnetic fields;
- presence of industrial, high power scientific and medical (ISM) equipment (for example, welding machines).

The electromagnetic environment at an industrial location is predominantly produced by the equipment and installation present at the location. There are types of industrial locations where some of the electromagnetic phenomena appear in a more severe degree than in other installations.

Note 2 to entry: Industrial locations can be further distinguished, for example into general, process, heavy or power industrial locations.

Note 3 to entry: The connection between location and electromagnetic environment is given in 3.1.15.

[SOURCE: IEC 61000-6-2:2016, 3.7]

3.1.24**infeed converter**

self-commutated electronic power converter of all technologies, topologies, voltages and sizes which is connected between the AC power supply network (lines) and usually a stiff DC side (current source or voltage source) and which can convert electric power only in one direction (from AC to DC) and limit harmonic current emissions of the converter and control the power factor to be close to one

EXAMPLE A switch mode power supply with active power factor correction (PFC) circuit.

3.1.25**islanding**

process whereby a power system is split into two or more islands

Note 1 to entry: Islanding is either a deliberate emergency measure, or the result of automatic protection or control action, or the result of human error.

[SOURCE: IEC 60050-603:1986, 603-04-31]

3.1.26**ITU regions**

the three geographic regions defined within the Radio Regulations are as follows:

Region 1: Europe, Africa, the Middle East west of the Persian Gulf including Iraq, the former Soviet Union and Mongolia.

Region 2: The Americas, Greenland and some of the eastern Pacific Islands.

Region 3: Most of non-former-Soviet-Union Asia, east of and including Iran, and most of Oceania.

[SOURCE: ITU Radio Regulations, Section I, 5.2 to 5.4, 2012]

3.1.27**location (EMC)**

position or site marked by distinguishing electromagnetic features

3.1.28**location class**

set of locations having a common property related to the types and density of electrical and electronic equipment in use, including installation conditions and external influences

Note 1 to entry: See Annex A.

3.1.29**low voltage****LV**

set of voltage levels used for the distribution of electricity and whose upper limit is generally accepted to be 1 000 V AC

[SOURCE: IEC 60050-601:1985, 601-01-26]

3.1.30**magnetic field**

constituent of an electromagnetic field which is characterized by the magnetic field strength H together with the magnetic flux density B

[SOURCE: IEC 60050-121:1998, 121-11-69]

3.1.31**maximum burst power**

maximum instantaneous power achieved during a burst

3.1.32**medium voltage****MV**

any set of voltage levels lying between low and high voltage

Note 1 to entry: The term medium voltage is commonly used for distribution systems with voltages above 1 kV and generally applied up to and including 52 kV (see IEC 62271-1).

[SOURCE: IEC 60050-601:1985, 601-01-28, modified – the note has been replaced by the current note.]

3.1.33**near field**

region where the angular distribution of the electromagnetic field is dependent on the distance from the antenna

Note 1 to entry: When the antenna dimensions are smaller than the wavelength, then this region is defined as $d < \lambda/2\pi$, where d is the distance from the antenna and λ is the wavelength of the electromagnetic field.

3.1.34

port

particular interface of the specified equipment with the external electromagnetic environment

SEE: Figure 1.

Note 1 to entry: In some cases different ports may be combined.

3.1.35

power line telecommunications

PLT

use of existing in-building or network distribution power cabling as a metallic path for the distribution of data

Note 1 to entry: Power line telecommunications is also known as broadband power line (BPL) and power line communication (PLC).

3.1.36

power port

port at which a conductor or cable carrying the primary electrical power needed for the operation (functioning) of equipment or associated equipment is connected to the equipment

3.1.37

residential location

location which exists as an area of land designated for the construction of domestic dwellings, and is characterized by the fact that equipment is directly connected to a low-voltage public mains network or connected to a dedicated DC source which is intended to interface between the equipment and the low-voltage mains network

EXAMPLE Examples of residential locations are houses, apartments, and farm buildings used for living.

Note 1 to entry: The function of a domestic dwelling is to provide a place for one or more people to live. A dwelling can be a single, separate building (as in a detached house) or a separate section of a larger building (as in an apartment in an apartment block).

Note 2 to entry: The connection between location and electromagnetic environment is given in 3.1.15.

[SOURCE: IEC 61000-6-1:2016, 3.8]

3.1.38

signal port

port at which a conductor or cable intended to carry signals is connected to the equipment

EXAMPLE Analogue inputs, outputs and control lines, data busses, antennas, communication networks, etc.

3.1.39

short interruption

sudden reduction of the voltage on all phases at a particular point of an electric supply system below a specified interruption threshold followed by its restoration after a brief interval

Note 1 to entry: Short interruptions are typically associated with switchgear operations related to the occurrence and termination of short circuits on the system or on installations connected to it.

3.1.40

TN system

power system that has one point directly earthed at the source, the exposed conductive parts of the installation being connected to that point by protective conductors

Note 1 to entry: There are three types of TN systems: TN-S, TN-C and TN-C-S.

Note 2 to entry: A description of power systems is given in IEC 60364-1.

3.1.41

unbalance factor

in a three-phase system, the degree of unbalance expressed by the ratio (in per cent) between the r.m.s. values of the negative sequence (or the zero sequence) component and the positive sequence component of voltage or current

3.1.42

voltage change

variation of the r.m.s. or peak value between two consecutive levels sustained for definite but unspecified durations

Note 1 to entry: Whether the r.m.s. or peak value is chosen depends upon the application, and which is used should be specified.

[SOURCE: IEC 60050-161:1990, 161-08-01]

3.1.43

voltage dip

sudden reduction of the voltage at a particular point of an electricity supply system below a specified dip threshold followed by its recovery after a brief interval

Note 1 to entry: Typically, a dip is associated with the occurrence and termination of a short circuit or other extreme current increase on the system or installations connected to it.

Note 2 to entry: A voltage dip is a two-dimensional electromagnetic disturbance, the level of which is determined by both voltage and time (duration).

3.1.44

voltage fluctuation

series of changes of r.m.s. voltage evaluated as a single value for each successive half-period between zero-crossings of the source voltage

3.1.45

wave impedance

for a sinusoidal electromagnetic wave, using complex notation, the quantity representing the electric field at a point divided by the quantity representing the magnetic field at the same point

[SOURCE: IEC 60050-705:1995, 705-03-22]

3.1.46

Smart Grid

intelligent grid

electric power system that utilizes information exchange and control technologies, distributed computing and associated sensors and actuators, for purposes such as:

- to integrate the behaviour and actions of the network users and other stakeholders,
- to efficiently deliver sustainable, economic and secure electricity supplies via an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies

[SOURCE: IEC 60050-617:2011, 617-04-13, modified – the second bullet point has been updated.]

3.2 Abbreviated terms

AC	alternating current
AIC	active infeed converter

AM	amplitude modulation
AMN	artificial mains network
ASD	adjustable speed drive (also variable speed drive)
ATSC	advanced television systems committee
AV	average
AVE	audio-visual equipment
BPL	broadband over power line
CATV	communal antenna TV
CB	citizen band
CDMA	code division multiple access
CEPT	Conférence Européenne des administrations des Postes et des Télécommunications European Conference of Postal and Telecommunications Administrations
CISPR	Comité International Spécial des Perturbations Radioélectriques International Special Committee on Radio Interference
CMA	constant modulus algorithm
CT	cordless telephony
CT-2	cordless telephone, second generation
CW	continuous wave
DC	direct current
DCCS	digital cross connect system
DCS	digital cellular system
DECT	digital enhanced cordless telecommunications
DTX	discontinuous transmission
DVB-T	digital video broadcasting – terrestrial
DVD	digital versatile disc
DVR	digital video recorder
EAS	electronics article surveillance
EDM	electro-discharge machining
EIRP	effective isotropic radiated power
EM	electromagnetic
EMC	electromagnetic compatibility
EN	European Standard
ERC	European Radiocommunications Committee
ERMES	European radio messaging system
ERP	effective radiated power
ESD	electrostatic discharge
ETSI	European Telecommunications Standardisation Institute
EU	European Union
EUT	equipment under test
FCC	Federal Communications Commission
FDD	frequency division duplex
FDMA	frequency division multiple access
FHSS	frequency hopping spread spectrum

FM	frequency modulation
FOMA	freedom of mobile multimedia access
FRS	family radio service
FSK	frequency shift keying
GMSK	Gaussian minimum shift keying
GSM	global system for mobile communications
HIPERLAN	high performance radio local area network
HEMP	high-altitude EM pulse
HPEM	high power EM
HSPA	high speed packet access
HVAC	heating, ventilation and air conditioning
IEC	International Electrotechnical Commission
iDEN	integrated dispatch enhanced network
IEEE	Institute of Electrical and Electronics Engineers
IMT	international mobile telephone
ISDB-T	integrated services digital broadcasting – terrestrial
ISM	industrial, scientific and medical
ISO	International Organization for Standardization
ITE	information technology equipment
ITU	International Telecommunications Union
JP	Japan
LAN	local area network
LCL	longitudinal conversion loss
LF	low frequency
LPRS	low power radio service
LTE	long term evolution
LTE-A	long term evolution advanced
MRI	magnetic resonance imaging (also nuclear magnetic resonance)
MURS	multi-user radio service
N	neutral
NADC	North American digital cellular
OFDM	orthogonal frequency division multiplexing
PC	personal computer
PCC	point of common coupling
PDC	personal digital cellular
PDS	power drive system (also known as an adjustable speed drive or variable speed drive)
PE	indication for protective conductor
PEN	protective earth – neutral
PEP	peak envelope power
PHS	personal handy phone system
PK	peak
PLC	power line communications

PLT	power line telecommunications
PMR	public mobile radio
POCSAG	Post office code standard advisory group
PoE	ports of entry
POS	point of sale
PSD	power spectral density
PSTN	public switched telephone network
PV	photovoltaic
PVR	personal video recorder
PWM	pulse width modulated
RADAR	Radio Detection And Ranging
REIN	repetitive electrical impulse noise
RF	radio frequency
RFID	radio frequency identification
r.m.s.	root mean square
RTTT	road traffic and transport telematics
SHF	super high frequency
SHINE	single high intensity noise event
SRD	short range device
SNR	signal to noise ratio
SSB	single side band
TDD	time domain division
TDMA	time domain multiple access
TETRA	terrestrial trunked radio
THD	total harmonic distortion
TN-C	T means direct connection of one pole to earth, N means direct electrical connection of the equipment to the earthed point of the power distribution system (in AC systems, the earthed point of the power distribution system is normally the neutral point or, if a neutral point is not available, a phase conductor); C means the neutral and protective functions are combined in a single conductor.
TN-S	T means direct connection of one pole to earth, N means direct electrical connection of the equipment to the earthed point of the power distribution system (in AC systems, the earthed point of the power distribution system is normally the neutral point or, if a neutral point is not available, a phase conductor), S means the neutral and protective functions are separate conductors.
TV	television
UHF	ultra high frequency
UK	United Kingdom
UMTS	Universal Mobile Telecommunications System
UPCS	Unlicensed Personal Communications Services
UPS	uninterruptable power system
US	United States of America

UTP	unscreened twisted pair
UV	ultra violet
UWB	ultra wide band
VCR	video cassette recorder
VDU	video display unit
VHF	very high frequency
WMTS	wireless medical telemetry service
WLAN	wireless local area network

4 User's guide for this document

4.1 Approach

Classification of the electromagnetic environment is based on the classification or a description of the electromagnetic phenomena prevailing at typical locations, not on existing test specifications. However, given a choice among equal possibilities, harmonization with existing test specifications (if appropriate) will simplify the situation and promote easier acceptance of the recommendations. The definition of electromagnetic environment in 3.1.15 refers to “electromagnetic phenomena”. The term “disturbance degree” (3.1.9) is used in this document to quantify the phenomena contributing to the electromagnetic environment and it is independent of any consideration of test levels. The term “severity level” is not used in this document to describe the environment, as it is reserved for specifying immunity test levels in other IEC publications.

Thus, the concept and term of electromagnetic phenomenon is the starting point for defining the environment and selecting disturbance degrees in a classification document. Clauses 5, 6 and 7 of this document are the first step of the process. Three basic categories of phenomena have been identified: low-frequency phenomena, high-frequency phenomena and electrostatic discharge. In the first stage, attributes of the phenomena (amplitudes, waveforms, source impedance, frequency of occurrence, etc.) are defined generically, and the expected range of disturbance degrees established. Then, in the second stage, one single value from that range has been identified as most representative value for each phenomenon at a specific class of location and set forth as the compatibility level for that location class.

The process is illustrated in Figure 1, showing how two sets of tables are used: a set of input tables that are phenomena-oriented and establish a range of disturbance degrees for a given phenomenon, and a set of output tables that are location-oriented and propose a table for each class, with one value of compatibility level for each of the phenomena identified in the set of input tables.

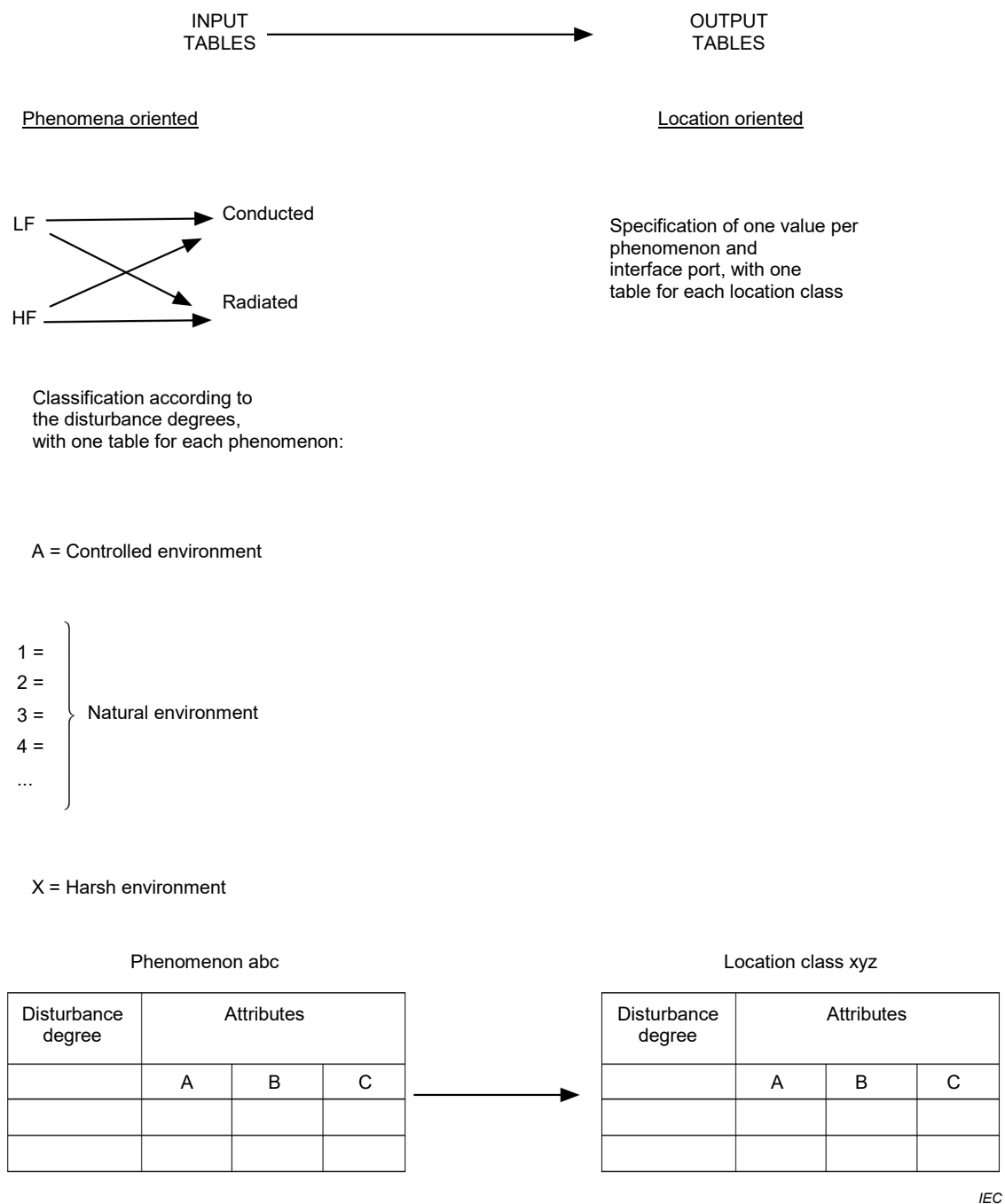


Figure 1 – Schematic of the two-step approach used for classification with phenomenon-oriented input tables and location-oriented output tables

Electromagnetic disturbances impinge on equipment by radiation or by conduction. A useful concept is to consider a set of ports, as shown in Figure 2, through which the disturbances enter (or exit) the equipment under consideration. The nature and degree of disturbing phenomena depends on the type of port, so that the tables in this document will take this into consideration. Electromagnetic radiated disturbances impinge on equipment from distant or close sources, hence the propagation and coupling can be governed by far-field or by near-field characteristics. Radiated disturbances that couple into the conductors connected to the equipment, but outside the equipment enclosure, become conducted disturbances. These are addressed under the various phenomena listed under conducted disturbances. The enclosure port shown in Figure 2 concerns only the radiated disturbances that enter the equipment

through its envelope (either an actual barrier such as a shield, metallic cabinet, etc., or a physical barrier with no electromagnetic impact, such as a plastic housing).

The equipment shown in Figure 2 is a finished product with an intrinsic function for final use.

- The enclosure port is the physical boundary of the equipment, which electromagnetic fields may radiate through or impinge upon. The equipment case is normally considered the enclosure port.
- The signal port is the point where a cable carrying signals to or from the equipment or controlling the equipment can be connected. Examples are input/output (I/O) data/control lines, telecom lines, antenna cables, wired network lines, etc.
- The earth port is the point where a cable intended for connection to earth for functional or safety purposes can be connected.
- The power port is the point where a conductor or cable is connected to the equipment carrying the electrical power (AC or DC) needed for operation. The power port can be both input or output power port.

The significance of differentiating ports for conducted disturbances reflects the different types of phenomena that can occur in power systems versus communication systems, as well as the importance of earthing practices for each of the systems, as earth often serves as a reference for the equipment. For the purposes of this classification, the signal and control ports are considered similar and are therefore combined into the signal port. Users need to recognize that the values shown correspond to disturbances measured between the conductors of the specific systems, in what is described as a differential mode, a common mode or an asymmetrical mode.

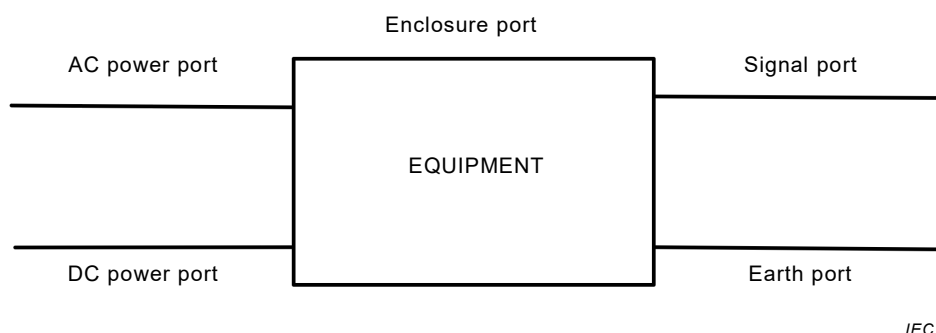


Figure 2 – Ports of entry (POEs) of electromagnetic disturbances into equipment

The final classification of environments into location classes and corresponding compatibility levels is discussed in Clause 8, with specific examples of location classes given in the tables of Annex A. In that respect three location classes have been identified in this document (see Figure 7). The attributes of these location classes are based on the significant electromagnetic characteristics of a location, rather than geographical or structural aspects. The location labels of the final classification imply specific definition of significant electromagnetic attributes. Classes of locations other than those listed in Annex A may be identified and added to the set as the need arises.

It should be noted that this classification is based on environment data collected up to 2015. The disturbance degrees shown in Annex A are offered as examples of compatibility levels for the guidance of product committees, not as immunity requirements. Those values are affected by uncertainties, and they may not cover extreme environments.

4.2 Rationale for classification system

The purpose of a classification system is to identify a limited set of parameters and associated values which may be chosen when identifying performance requirements. The

purpose of such a system is primarily economic, in that it limits the number of variations in the number of types of equipment which a manufacturer may produce. It also identifies the need (if any) for appropriate interfaces.

The classification system proposed is rather exhaustive, and shows numerous electromagnetic phenomena. It does not necessarily mean that the immunity of a given item shall be tested against all these phenomena, but that a limited set of them may be chosen according to the environment of concern and inherent characteristics of the item.

4.3 Electromagnetic environment phenomena

The electromagnetic environment in which electrical and electronic items are expected to operate without interference is very complex. For the purpose of this classification, three categories of electromagnetic environment phenomena have been defined to describe all disturbances:

- electrostatic discharge (ESD) phenomena (conducted and radiated);
- low-frequency phenomena (conducted and radiated, from any source except ESD);
- high-frequency phenomena (conducted and radiated, from any source except ESD).

This distinction is necessary in order to recognize that electromagnetic disturbances occur in a particular medium. Formally, when dealing with the electromagnetic environment, the wavelength λ of the considered disturbance is the gauge for “long or large” and for “short or small”. An item is small or a line is short if the wavelength is much greater than its dimensions. Consequently, in that situation the frequency is low, as the frequency is inversely proportional to wavelength. An item is large or a line is long if the wavelength is much smaller than its dimensions. However, in the context of the present document and in accordance with the IEC EMC approach, the term low frequency applies to frequencies up to and including 9 kHz; the term high frequency applies to frequencies above 9 kHz.

Electromagnetic radiation in different locations may be a result of intentional or unintentional radiators and may include electromagnetic fields on frequencies from 0 Hz (static fields) to 400 GHz. Electromagnetic fields can be radiated from distant or close sources, hence the propagation and coupling can be governed by far-field or by near-field characteristics. The resulting field strength at a location is typically controlled by the radiated power, the distance from the radiator and coupling effectiveness. The frequency is also an important factor in order to describe electromagnetic fields at a location.

Radiated disturbances occur in the medium surrounding the equipment, while conducted disturbances occur in various metallic media. The concept of ports as shown in Figure 2, through which disturbances have an impact on the item, allows a distinction among the following various media:

- 1) enclosure;
- 2) AC power mains;
- 3) DC power mains;
- 4) signal lines;
- 5) interface between items and earth or reference.

The source, the coupling and the propagation characteristics depend on the type of medium. The final tables of Annex A show the compatibility levels for various location classes, and are structured along this concept of corresponding ports.

4.4 Relationship of disturbance levels to CISPR limits

In general compatibility levels are used as reference for coordination in the setting of emission limits and immunity levels (see also IEC TR 61000-1-1). The disturbance levels given in this document should be used to determine the compatibility levels.

Emissions from equipment (or from a system made of items of equipment) should be set in such a way that together with appropriate immunity levels of other items of equipment electromagnetic compatibility is achieved. The easiest approach would be to set the emission limits lower than the immunity levels, placing a margin between limits and levels which takes into account, for example, tolerances in the hardware properties of the items of equipment, potential coupling mechanisms between items of equipment and statistical considerations.

Hence, setting emission limits in this way predominantly aims at the achievement of electromagnetic compatibility. Such types of emission limits are not related to CISPR emission limits as for the specification of CISPR limits a different approach is applied.

CISPR limits are developed for protection of radio communications. They take into account aspects such as field strength signals needed for radio reception or typical protection distances between radio receivers and potential interference sources (typically 10 m or 30 m). They do not take into account the situation in very close proximity of disturbance sources (as this is not a typical situation for reliable radio reception) or immunity issues as the CISPR emission limits are normally far below (several magnitudes) typical immunity levels. In this respect, emission limits derived from the disturbance levels of this document and CISPR limits are not always correlated with each other. Consequently, the disturbance levels of this document are in most cases not appropriate to derive CISPR limits.

NOTE More detailed information about determining CISPR emission limits are given in CISPR TR 16-4-4.

4.5 Simplification of the electromagnetic environment database

It is neither possible nor absolutely necessary to describe completely an electromagnetic environment. Consequently, any description is limited to certain properties of this environment. The first step of a description should be the selection of appropriate electromagnetic properties corresponding to the various phenomena that can create electromagnetic disturbances. Table 1 lists these phenomena. In this document, the boundary between low frequency and high frequency is generally understood as being 9 kHz; however, when addressing a type of disturbance prevailing in one frequency range with a small overlap into the other range, the boundary might be slightly shifted to keep the phenomenon within one descriptive range.

An appropriate selection is only valid if its purpose is also specified. Considering the many possible coupling mechanisms between an item and its electromagnetic environment, it becomes apparent that, in order to accurately assess the necessary level of immunity for any item, more information than is available about the environment would be needed. Accuracy of electromagnetic environment descriptions is necessarily limited, as follows:

- some aspects of the environment are disregarded because the information is not available;
- some aspects of the environment are disregarded because a classification system taking them into account would become too complex;
- a statistical approach may be necessary, in order to consider only those events for which the occurrence is likely.

The first two limitations are embedded in the selection of the disturbance types, while the statistical aspect appears in the definition of environment classes and the selection of a single value for compatibility levels, rather than a range of values.

Available databases at the time of elaboration of this document indicate the wide variety of conducted and radiated disturbances that can be expected to occur in the diverse environments encountered in the use of equipment. Evaluation by laboratory tests of the ability of equipment to withstand these environments, or of the effectiveness of mitigation methods, can be facilitated by a synthesis of the database. This synthesis leads to selecting a few representative disturbance phenomena that will make tests uniform, meaningful and replicable.

Table 1 – Principal phenomena causing electromagnetic disturbances

Phenomena		Table	Subclause
LF-conducted			
Power supply networks	Harmonics/inter-harmonics	2	5.1.1
	Voltage fluctuations	3	5.1.2.1 a)
	Voltage dips	None	5.1.2.1 b)
	Voltage interruptions	None	5.1.2.1 c)
	Voltage unbalance	4	5.1.2.1 d)
	Voltage frequency variations	5	5.1.2.2
Power supply networks	Common mode voltages	6	5.1.3
	Signalling voltage 0,1 kHz to 3 kHz	7	5.1.4
	Induced LF	8	5.1.6
	DC in AC networks	None	5.1.7
Signal and control cables	Induced LF (normal conditions)	8	5.1.6
	Induced LF (fault conditions)	8	5.1.6
LF magnetic field	DC	9	5.2.1
	Railway	9	5.2.1
	Power system	9	5.2.1
	Power system harmonics (n = harmonics)	9	5.2.1
	not power system related	9	5.2.1
LF electric field	DC lines	10	5.2.2
	Railway (16,7 Hz)	10	5.2.2
	Power system (50 Hz/ 60 Hz)	10	5.2.2
HF phenomena			
Signalling voltage/PLT	3 kHz to 95 kHz	7	5.1.4
	95 kHz to 148,5 kHz	7	5.1.4
	148,5 kHz to 500 kHz	7	5.1.4
Direct-conducted CW/PLT (intentional)	1,606 5 MHz to 87,5 MHz	None	6.1.2
Direct-conducted CW (unintentional)	9 kHz to 150 kHz	11	6.1.2.4
HF-conducted induced CW	10 kHz to 150 kHz	12	6.1.3
	0,15 kHz to 150 MHz	12	6.1.3
Unidirectional transients	Nanoseconds	13	6.1.4
	Microseconds, close	13	6.1.4
	Microseconds, distant	13	6.1.4
	Milliseconds	13	6.1.4
HF-conducted oscillatory transients	High frequency	14	6.1.4
	Medium frequency	14	6.1.4
	Low frequency	14	6.1.4
HF radiated			

Phenomena		Table	Subclause
Radiated CW	ISM Group 2	16	6.2.2
Radiated modulated	Mobile units GSM DCS1800 DECT	21, 22	6.2.3.2
	Base stations	23, 24	6.2.3.2
	Medical and biological telemetry items	25	6.2.3.2
	Digital television broadcast	26, 27, 28	6.2.3.2
	Unlicensed radio services	29, 30	6.2.3.2
	Paging services (base station)	32	6.2.3.2
	RFID + railway transponder	39, 40	6.2.3.3
	Other RF items	19, 20, 33, 34, 35, 36, 37, 38	6.2.3.2
	Amateur radio stations	17 31	6.2.3.1 6.2.3.2
	CB	18	6.2.3.1
Radiated pulsed	Radiated transients	41	6.2.4
	RADAR	42	6.2.4
ESD	Slow	43 / 44	7.2 / 7.3
	Fast	43 / 44	7.2 / 7.3
High altitude electromagnetic pulse (HEMP)	Not considered in this document; for further information see IEC 61000-2-9		
High power electromagnetic pulse (HPEM)	Not considered in this document; for further information see IEC 61000-2-13		

To assist equipment designers and users in making appropriate choices in defining immunity test levels, the classification shows, for each phenomenon, only one compatibility level per class of location. The characterization of each phenomenon is presented in tabular form, from which a selection can be made. This approach gives a common base of reference for specifying immunity requirements for an item of equipment expected to be installed at various locations, and yet provides the appropriate degree of compromise between a conservative overdesign and a cost-conscious reduction of margins. The specification of these requirements for specific equipment remains the field of product standards and, therefore, cannot be addressed in the present document.

For a given equipment, the surrounding environment in which it is required to operate results from the presence and nature of disturbance sources, as well as from the installation conditions adopted. Typical installation practices take into consideration the mitigation which can be obtained by separation, shielding and suppression. Therefore, it is important to take into consideration the effect of these practices when suggesting disturbance degrees in specific locations where various installation practices are generally applied. This document assigns a representative degree for the various types of installations likely to be found at those locations.

The listing of disturbance degrees includes an "A" degree, for an environment where some mitigation or control might be necessary to satisfy specific requirements, and an "X" degree

recognizing that in some situations exceptional conditions could prevail that need specific recognition. The "A" degree corresponds to a situation where the environment is somewhat controlled by the nature of the building, or installation practices inherent to a particular location class. The "X" degree corresponds to a degree of disturbance higher than is generally encountered.

As with any classification scheme, its value lies in its generality. This classification recognizes that there could be exceptional requirements associated with any specified location. The consequences of such an occurrence shall be taken into account in designing equipment for operation in a particular classification category. For example, a particular type of switching transient can occur infrequently in some location classes. Whether the equipment should be designed to be "immune" to this particular disturbance depends upon whether its effects are temporary (for instance, a reduction of reception quality that might be acceptable although undesirable), or permanent and unacceptable (equipment damage or malfunction with unacceptable consequences).

If no special performance requirement is expected at a given location, which is the general case, the procedure is reduced to:

- selecting the appropriate location class from those defined in Clause 8 and Annex A;
- selecting the required immunity in accordance with the principles stated in Clause 9.

The purpose of this document is not to specify immunity, but to allow product committees to make a selection on a rational and informed basis, without specifying equipment immunity. Data shown in the Table 2 to Table 14 and Table 16 to Table 44 refer to well-known electromagnetic environment conditions, such as low-frequency phenomena or, in other cases, only proposed as representative levels for classification.

5 Low-frequency electromagnetic phenomena

5.1 Conducted low-frequency phenomena

5.1.1 Harmonics of the fundamental power frequency

Harmonic voltages of the fundamental power frequency exist on power supply networks. The source is harmonic currents of the fundamental power frequency that are injected into the power supply network by attached non-linear loads, where they are converted into voltages by the network impedance.

The number of non-linear loads that are utilised in residential, commercial and industrial locations has increased significantly in recent years. There are two types of non-linear loads:

- The very large number of small capacity loads (i.e. each consuming less than 1 kW), mostly single-phase loads, that are found in the low-voltage power distribution network. Such loads typically have rectifier input and include items such as household appliances, AVE, ITE, etc.
- The small number of large capacity loads (i.e. each consuming more than 1 kW) that may be found in low-voltage, medium-voltage and high-voltage power distribution networks. Such loads include industrial power drive systems and other manufacturing devices.

For low-voltage public supply networks, the main sources of harmonic voltages are the very large number of small capacity loads. IEC 61000-1-4 reviews the sources and effects of the emissions of power frequency conducted harmonic currents in the low-voltage networks.

For low-voltage, medium-voltage and high-voltage industrial power supply networks, the main sources of harmonic voltages are the small number of large capacity loads.

Harmonics from residential, commercial and industrial areas aggregate to disturb the voltage of the supply network. Table 2 shows:

- the disturbance levels for the individual voltage harmonic components;
- the THD:

$$THD = \sqrt{\sum_{n=2}^{40} \left(\frac{U_n}{U_1} \right)^2} \quad (1)$$

where

U_n is the amplitude of the n^{th} harmonic of the fundamental power frequency;

U_1 is the amplitude of the fundamental power frequency.

NOTE 1 The definition of the THD recognises the fact that not all harmonic components will reach their peak amplitude simultaneously.

NOTE 2 Harmonics up to and including the 40th harmonic are considered, in conformity with IEC 61000-3-2.

Table 2 – Disturbance degrees and levels for harmonic voltages in power supply networks (in percentage to fundamental voltage, U_n/U_1)

Harmonic order	THD	Odd (non-multiple of 3)								Odd and multiple of 3					Even			
		5	7	11	13	17	19	23-25	>25	3	9	15	21	>21	2	4	6-10	>10
Basic document Disturbance degree	IEC 61000-2-2, IEC 61000-2-4 and IEC 61000-2-12																	
A (Controlled)	Case-by-case according to the equipment requirements																	
1	5	3	3	3	3	2	a	a	a	3	1,5	0,3	0,2	0,2	2	1	0,5	c
2	8	6	5	3,5	3	2	a	a	a	5	1,5	0,4	0,2	0,2	2	1	0,5	c
3	10	8	7	5	4,5	4	b	b	b	6	2,5	2	1,75	1	3	1,5	1	1
X (harsh)	Case-by-case according to the situation																	
NOTE 1 The disturbance degrees A, 1, 2, 3 and X correspond to the classes A, 1, 2, 3 and X defined in IEC 61000-2-4; see Clause 4.																		
NOTE 2 Class 1 applies to protected supply networks and has compatibility levels lower than those of public supply networks. It relates to the use of equipment that is very sensitive to disturbances in the power supply, for instance the instrumentation of technological laboratories, some automation and protection equipment, some computers, etc.																		
NOTE 3 Class 2 applies to low-voltage public supply networks (see IEC 61000-2-2). It can also apply to commercial and light industrial environments (small- and medium-size industrial plants, commercial buildings).																		
NOTE 4 Class 3 applies to industrial environments. It has higher compatibility levels than those of Class 2 for some disturbance phenomena. For instance, this class would be considered when any of the following conditions are met:																		
– a major part of the load is fed through power converters; – welding machines are present; – large motors are frequently started; – loads vary rapidly.																		
NOTE 5 Class X applies to an arbitrarily defined environment, for example, strongly disturbed industrial power supply networks (steel plants, power stations, etc.).																		
The above levels correspond to those values that are not exceeded by 95 % of the 10 min mean r.m.s. values during each period of one week under normal operating conditions (taken from EN 50160).																		
a = 2,27 × (17/n) – 0,27 (where n is the order of the harmonic component)																		
b = 4,5 × (17/n) – 0,5 (where n is the order of the harmonic component)																		
c = 0,25 × (10/n) + 0,25 (where n is the order of the harmonic component)																		

5.1.2 Power supply network voltage amplitude and frequency changes

5.1.2.1 Amplitude change

The voltage amplitude of the 50/60 Hz power network can be subject to various disturbances.

- a) Continuous or randomly repeated and relatively rapid fluctuations within the normal operating range occur at a frequency ranging from 25 times per second to one time per minute. The most disturbing effect of such fluctuations is a flickering of lighting levels (mainly low-voltage incandescent lamps), causing physiological discomfort. Sources are generally industrial loads such as arc furnaces (HV network), welding machines (LV network) and switching of large loads or capacitor banks. Table 3 lists disturbance levels for voltage fluctuations within normal operating range.

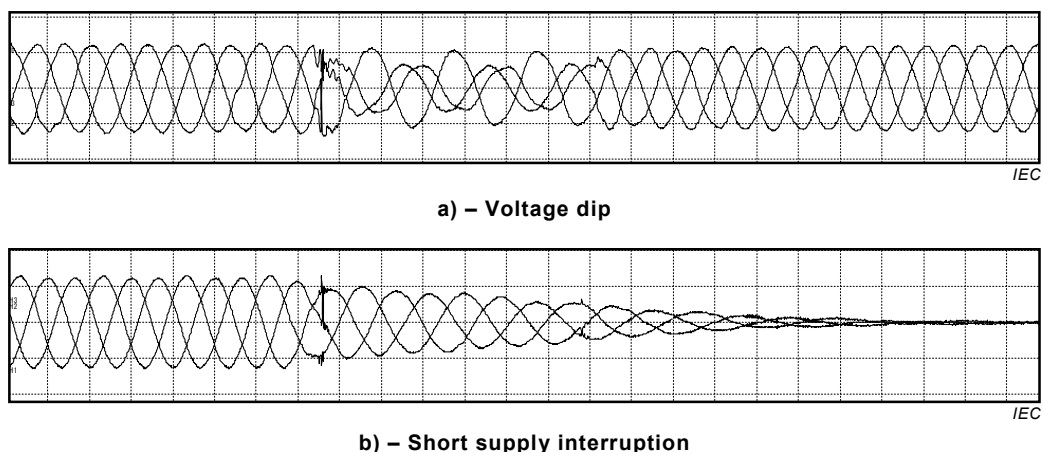
Table 3 – Disturbance degrees and levels for voltage changes within normal operating range (in percentage of nominal voltage, $\Delta U/U_n$)

Disturbance degrees	Basic standard
	IEC 61000-2-4
	Disturbance levels
A (controlled)	Case-by-case according to the equipment requirements
1	$\pm 8 \%$
2	$\pm 10 \%$
3	-15% to $+10 \%$
X (harsh)	Case-by-case according to the situation

NOTE 1 The disturbance degrees A, 1, 2, 3 and X correspond to the classes A, 1, 2, 3 and X defined in IEC 61000-2-4; see Clause 4.

NOTE 2 A range of -15% to $+10 \%$ can occur for a duration shorter than 60 s. For longer duration, a range of -10% to $+10 \%$ applies.

- b) Voltage dips last in most cases for less than 1 s. In areas supplied by overhead lines, the number of voltage dips can reach several hundreds per year, depending on the number of lightning strokes and other meteorological conditions in the area. In areas supplied by underground power cables an individual user of electricity connected at LV may be subject to voltage dips occurring at a rate that extends from around ten per year to about a hundred per year, depending on local conditions.
- c) Short supply interruptions with durations ranging up to 180 s also occur. Most of them are restored within 60 s. Interruptions lasting more than 180 s are no longer considered an EMC issue, but a blackout.
- d) Voltage unbalance can be caused by asymmetrical loads or large single-phase loads such as traction systems or single-phase furnaces. Table 4 shows the disturbance degrees.

**Figure 3 – Typical voltage waveforms for dip and interruption (10 ms/horizontal division)**

NOTE 1 Voltage dips and short interruptions have various origins:

- short circuits in LV networks cleared by fuse operation (a few milliseconds);
- faults on MV and HV overhead lines or other equipment, followed or not followed by automatic reclosure (almost 70 ms to 1 000 ms);
- switching of large loads, especially motors and capacitor banks.

Examples of voltage waveforms for voltage dip and short supply interruption are shown in Figure 3.

NOTE 2 The disturbance degrees and compatibility levels for these phenomena, i.e. voltage dips and short supply interruptions, are not yet available. Further information and suitable immunity levels on these phenomena are given in IEC 61000-2-2, IEC 61000-2-4, IEC TR 61000-2-8, IEC 61000-4-11 and IEC 61000-4-34.

**Table 4 – Disturbance degrees and levels for voltage unbalance
(in percentage of $U_{\text{neg}}/U_{\text{pos}}$)**

Disturbance degrees	Basic standard
	IEC 61000-2-2, IEC 61000-2-4 and IEC 61000-2-12
	Disturbance levels
A (controlled)	Case-by-case according to the equipment requirements
1	2 %
2	2 %
3	3 %
X (harsh)	Case-by-case according to the situation
NOTE 1 The disturbance degrees A, 1, 2, 3 and X correspond to the classes A, 1, 2, 3 and X defined in IEC 61000-2-4; see Clause 4.	
NOTE 2 Levels are indicated for the ratio of the negative phase sequence component to the positive one.	

5.1.2.2 Frequency change

The fundamental frequency of a power supply network is generally very stable, varying by no more than 0,2 %. However, during network disturbances, the fundamental frequency of the power network can vary by up to 4 % (see Table 5).

Table 5 – Disturbance degrees and levels for power frequency variation

Disturbance degrees	Basic standard
	IEC 61000-2-2, IEC 61000-2-4 and IEC 61000-2-12
	Disturbance levels
A (controlled)	Case-by-case according to the equipment requirements
1	±1 Hz
2	±1 Hz
3	±1 Hz
X (harsh)	Case-by-case according to the situation
NOTE 1 The disturbance degrees A, 1, 2, 3 and X correspond to the classes A, 1, 2, 3 and X defined in IEC 61000-2-4; see Clause 4.	
NOTE 2 For isolated power networks, ±2 Hz applies.	

5.1.3 Power supply network common mode voltages

In power supply networks, both phase voltages and phase-to-phase voltages should be identified. Phase voltages correspond to the phase conductor voltages against the ground concerned. Phase-to-phase voltages can be regarded as normal mode (or differential mode) voltages, while the common mode voltage is given by the average of the phase voltages. For polyphase systems the common mode voltage equals the neutral line voltage. Since the neutral line is usually grounded, relative current flows through the neutral conductor when the common mode voltage occurs.

A common mode voltage should be stationary in power supply networks. If high-frequency components are contained in it, insulation breakdown, increase of grounding current or noisy electromagnetic radiation may occur. An electric shock could also occur in the worst case.

Semiconductor power converters are widely adopted in industrial machines and distributed generators, such as PDS, PV generation, etc. In many cases, these devices are connected to the power supply network directly, without transformers. This arrangement may change the common mode voltage of the input/output lines rapidly with the switching frequency. In the case of PWM converters, the frequency of the common mode voltage change can range from several hundred Hertz to over 100 kHz.

Figure 4 shows a typical configuration of the semiconductor converter in a PDS: a 3-phase AC network voltage is rectified to DC voltage by a diode-rectifier. For the purpose of simplifying the explanation, the neutral point of the AC network is assumed to be grounded. The DC voltage is further converted to a 3-phase AC voltage with adjustable frequency and amplitude by a PWM inverter. The output voltage feeds an induction or synchronous motor.

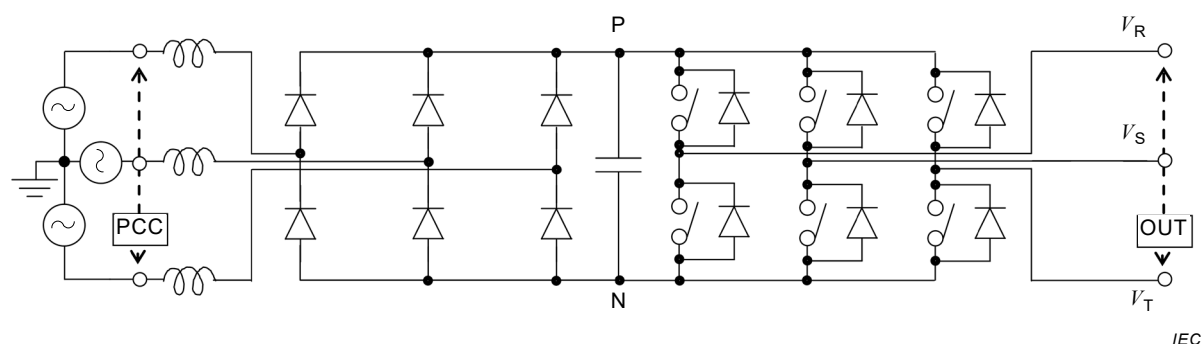
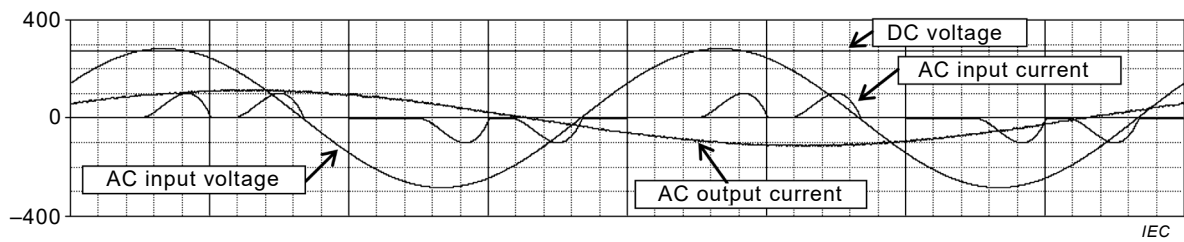


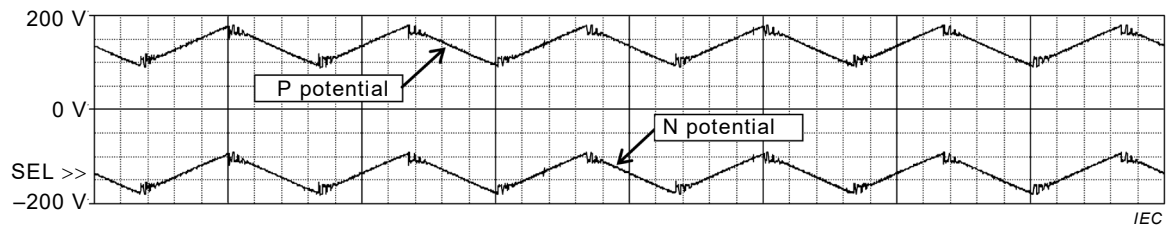
Figure 4 – Typical configuration of the converter in a PDS

Figure 5 depicts an example of the voltage and current waveforms at each position in a PDS. The AC network frequency is 50 Hz. The PDS output frequency is 25 Hz. A representative AC input phase-to-phase voltage, a representative AC input phase current, the DC voltage and a representative AC output phase current are shown in of Figure 5a). The AC input phase current includes large harmonic components, whereas the AC output current is controlled to be almost sinusoidal. Figure 5b) indicates both the DC positive pole (P) voltage potential from the ground and that of the negative pole (N). The DC line potential from the ground fluctuates at 150 Hz (50×3). The DC differential voltage fluctuates at 300 Hz (50×6), though this fluctuation is very small. Figure 5c) displays the common mode (neutral) voltage of the converter output, which contains multiples of the PWM carrier frequency (5 kHz) components. The envelope of the common mode voltage follows the DC P and N potential voltages. It is the significant feature of PDS that the output common mode voltage is pulsating at the PWM carrier frequency although the output current gets almost sinusoidal.

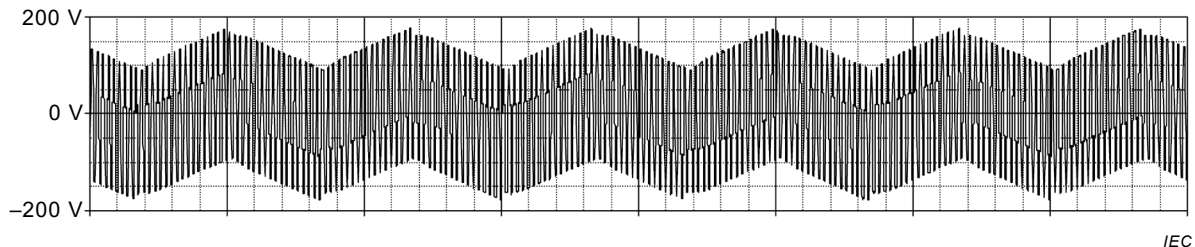
One example of a measured PDS common mode voltage is introduced in Figure 6. The Figure was taken for between 150 kHz and 30 MHz through an AMN. The motor capacity was 3,7 kW and the switching frequency of the PDS was 14,5 kHz. Since a peak measuring receiver was used instead of a quasi-peak measuring receiver, the detected value would be several dB higher. It is found that about 100 dB(μ V) conducted common mode disturbance voltage is generated.



a) – Waveforms of input and output currents, and link voltage

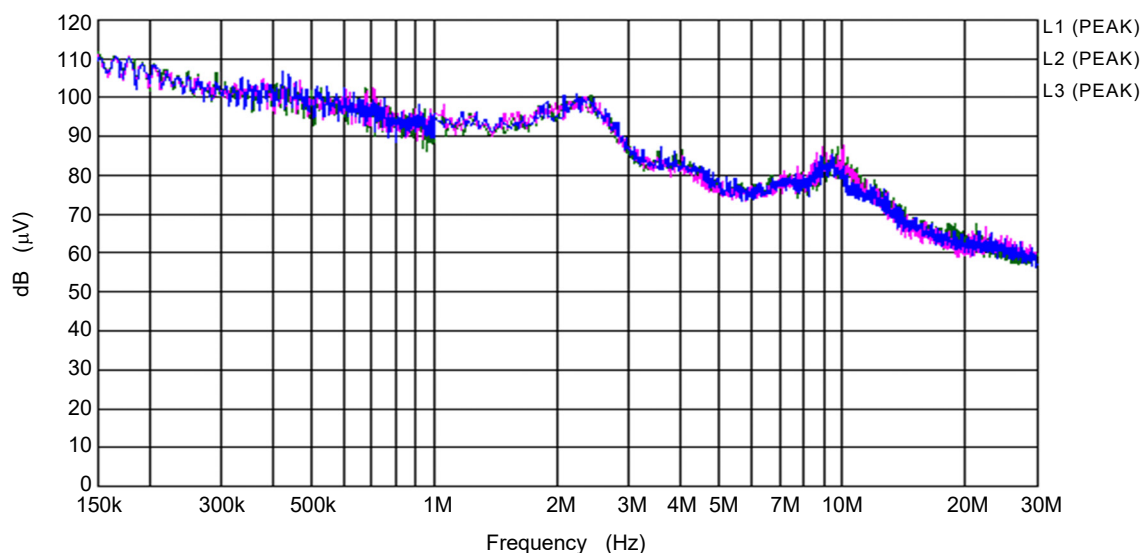


b) – DC link potential fluctuation



c) – Common mode voltage of the converter output

**Figure 5 – Voltage and current waveforms of each PDS portion
(1 ms/horizontal division)**



NOTE The common mode voltage produced by a PDS causes various interferences:

- 1) Rise of bearing current resulting in lifetime reduction.
- 2) Surge voltage resulting in insulation deterioration of motor windings.
- 3) Generation of stationary grounding current.
- 4) Induced radio interference.

Figure 6 – Measured common mode voltage at the input terminal of a converter

Disturbance degrees and levels for common mode voltages are given in Table 6.

Table 6 – Disturbance degrees and levels for common mode voltages

Disturbance degrees	Basic standard
	IEC 61000-4-16
	Disturbance levels
1	1 V
2	3 V
3	10 V
4	30 V
X (harsh)	Case-by case according to the situation
NOTE 1 A more detailed description of the environments in terms of installation conditions or equipment under operation is given in IEC 61000-4-16:2015, Annex B.	
NOTE 2 Values in V _{r.m.s.}	

5.1.4 Signalling voltages in power supply networks

Power supply networks are designed for the transmission of energy, but they can also be used for the transmission of information by mains signalling systems. The relevant standardization documents consider three types of systems:

- ripple control systems that are used by electrical utilities in public supply networks, in the range of 100 Hz to 3 kHz, generally below 500 Hz, with signals up to 5 % of U_n under normal circumstances and up to 9 % of U_n in cases of resonance. These systems are used in some countries in Europe and elsewhere;
- power-line carrier systems used by electrical utilities in public supply networks, in the range 3 kHz to 95 kHz, with allowed signal levels up to 5 % of U_n . These signals are strongly attenuated in the network (> 40 dB). These systems are used mainly in Europe, in the US and are developing elsewhere;
- signalling systems for end-user premises (residential or industrial) in the range of 95 kHz to 148,5 kHz in Europe (ITU region 1), with allowed signal levels up to 0,6 % U_n or 5 % U_n , respectively. In the US and Japan the upper frequency is 500 kHz, with allowed signal levels between 2 mV and 0,6 mV.

Disturbance degrees and levels for signalling voltages in power systems are given in Table 7.

Table 7 – Disturbance degrees and levels for signalling voltages in low and medium-voltage systems (in per cent of nominal voltage U_n)

Disturbance degrees	Frequency range in kHz			
	0,1 to 3	3 to 95	95 to 148,5	148,5 to 500
	Disturbance levels			
A (controlled) ^a	Case-by-case according to the equipment requirements			
1 ^b	0,1 kHz to 0,5 kHz: 9 % U_n^d 0,5 kHz to 0,95 kHz: 9 % U_n to 5 % U_n^d 0,95 kHz to 3 kHz: 5 % U_n^d	3 kHz to 9,5 kHz: 5 % U_n^d 9,5 kHz to 95 kHz: 5 % U_n to 1,3 % U_n^d	General: 0,6 % U_n Industrial areas: 5 % U_n	2 to 0,6 (mV, not %)
X (harsh) ^c	Case-by-case according to the situation.			
NOTE 1 Degree A: residual signals might exist, coupled from adjacent systems where intentional signals might be present. For this degree, in contrast with other tables, degree A is not a controlled environment. Furthermore, some types of installations might offer some degree of protection against this disturbance phenomenon. In case of disturbing over-spill from adjacent networks, it might be necessary to install blocking or absorbing circuits. NOTE 2 Degree 1: for the range 0,1 kHz to 3 kHz, the values correspond to normal injection levels in actual installations. For the other ranges, the values indicate the maximum allowed injection level measured on a reference impedance. These values are only applied in ITU region 1, and other values might be used in ITU region 2 or 3. NOTE 3 Degree X: normally the signals are more or less attenuated in the network. However, in certain cases of resonance the signals can be enhanced.				
^a Network without signalling.				
^b Emission level, near to the transmitter.				
^c Special cases (resonances).				
^d EN 50160:2010 (Figure 1 and Figure 2) gives information on possible levels of signaling voltages which may be present in public power supply networks. The values are valid for low-voltage and medium-voltage power supply networks.				

5.1.5 Islanding supply networks

The term islanding describes the process whereby a power system is split into two or more islands. Islanding mainly occurs when either a deliberate emergency measure or an automatic protection/control action is taken. If the scale of an islanding network is relatively small, its power frequency fluctuation and voltage fluctuation can be larger than usual.

To protect installations like hospitals, server farms, shopping centres and warehouses during 'black outs' or 'brown outs', most of these installations have an independent backup system for their power supply. This is done by either a backup generator or a UPS. When the backup system is in operation, the fluctuation in both the power frequency and the voltage amplitude can be larger than the normal conditions specified in 5.1.2.

Islanding is not limited to the situations mentioned above. For some environments the situation of a relatively small power supply network can be the normal situation. Examples of such environments include:

- a small island, town or house that is physically isolated from a public distribution network and hence has a separate, independent power supply network that is driven by diesel generator, photovoltaic power system or other power source;
- a vessel (ship or aircraft) or off-shore installation.

In these situations the normal power quality conditions may not exist. It is recommended for small power networks that a case-by-case assessment be performed to determine the various aspects of power quality.

5.1.6 Induced low-frequency voltages

Low-frequency currents in cables might (according to actual currents, physical layout, cable type and other parameters) induce low-frequency common mode voltages into adjacent cables. The coupling impedance varies according to the proximity of the cables and the effective parallel length.

Table 8 describes induced common mode voltages. Differential mode voltages may also occur and are strongly dependent on the type of cable, termination and earthing arrangement.

Table 8 – Disturbance degrees and levels for low-frequency, common mode induced voltages in signal and control cables

Disturbance degrees	Phenomena (sources) and basic standard				
	Power distribution and mains cables carrying network frequency and harmonics under normal operating conditions IEC 61000-4-16				Fault condition in power system ^a IEC 61000-4-16
	Disturbance levels				
	15 Hz to 150 Hz ^c	150 Hz to 1,5 kHz	1,5 kHz to 15 kHz ^d	15 kHz to 150 kHz	50 Hz to 1 kHz
A (controlled)	Case-by-case according to the equipment requirements				
1	1 to 0,1	0,1	0,1 to 1	1	100
2	3 to 0,3	0,3	0,3 to 3	3	300
3	10 to 1	1	1 to 10	10	1 000
4	30 to 3	3	3 to 30	30	3 000 ^b
X (harsh)	Case-by-case according to the situation				
NOTE Values in V _{r.m.s.}					
^a Values may be limited by ITU-T or other mandated mitigation methods.					
^b May be limited by sparkover of clearances. On insulated ground circuits, higher voltages might occur.					
^c The disturbance levels decrease by 20 dB/decade.					
^d The disturbance levels increase by 20 dB/decade.					

5.1.7 DC voltage in AC networks

DC voltage in AC networks is caused primarily by geomagnetic storms that may induce high levels of quasi-DC currents in the high-voltage network. DC currents as high as hundreds of amperes have been measured in high-voltage networks, thereby reducing voltages of up to 10 % of rated voltage for times of hundreds of seconds. In addition, harmonics are created in transformers, which propagate throughout the power network. As these events are rare (once per year) and regional (northern and southern latitudes), it is recommended that these events be considered as a very low probability at a particular location. It is noted that under severe circumstances, a voltage collapse of the entire power network can result.

It is difficult to assign a precise disturbance level to this rare phenomenon, however, class 3 harmonic levels in Table 2 and class 3 voltage fluctuations in Table 3 could be considered as appropriate for all locations connected to the public power supply network.

5.2 Radiated low-frequency phenomena

5.2.1 Magnetic fields

Magnetic fields in the power frequency range are produced by several types of sources:

- nearby power cables and lines, in particular overhead power lines
- stray fields from transformers
- bus bar systems
- switchgear installations
- power system equipment, such as power drive systems, rectifiers, generators, etc.

In the case of power cables, magnetic fields might occur also due to common mode currents, depending on the type of the power supply system (e.g. in the case of TN-C systems, see 8.6).

The frequencies or frequency ranges to be considered depend on the type of sources existing at the location under consideration and comprise:

- DC
- frequencies of railway traction system (e.g. DC, 16 2/3 Hz, 50 Hz, 60 Hz, ...)
- fundamental frequency of power supply systems
- harmonics occurring in a power system
- frequencies not related to power systems

Significant magnetic fields at harmonic frequencies appear only in special circumstances, for example in the presence of power electronic systems.

Case-by-case consideration is required in presence of particular nearby high power equipment (electrolysis, generators, etc.), within high power installations (switchyards, power stations, etc.) or for particular types of equipment (magnetic resonance equipment, induction heating, etc.). Table 9 quantifies the magnetic fields from various low-frequency sources.

Table 9 – Disturbance degrees and levels for low-frequency magnetic fields at various frequencies

Disturbance degree	Phenomena (sources)				
	DC ^a	Railway frequency 16,7 ^{b, f}	Power system frequency 50/60 Hz ^c	Harmonics of power system 0,1 kHz to 3 kHz ^d	Not related to power systems ^e
	Disturbance levels				
A (controlled)	Case-by-case according to the equipment requirements				
1	3	1	3	3/n	0,015
2	10	3	10	10/n	0,05
3	30	10	30	30/n	0,15
4	100	30	100	100/n	0,5
X (harsh)	Case-by-case according to the situation				
NOTE Values in A/m, r.m.s. for AC.					
^a In addition to earth magnetic field of about 20 A/m to 60 A/m, depending on location, at 1 m above ground.					
^b At 20 m from the track. The fields increase considerably the closer they get to the tracks. 1 A/m at 20 m, 1 m above ground, corresponds to a locomotive of about 3 000 kW. Some types of railway track signalling systems can also give rise to field strengths greater than level 1.					
^c For overhead lines, measured at 1 m above ground. For household or commercial environments, measured at 0,3 m from the source, the magnetic field has a range of magnitude of 1 A/m to 10 A/m.					
^d Where <i>n</i> is the order of the harmonic.					
^e Where audio-frequency inductive loops are present, the long-term average field strength in the frequency range 100 Hz to 5 kHz may be 0,1 A/m (level 3), see IEC 60118-4.					
^f Applicable also to railway systems with fundamental power frequencies other than 16,7 Hz.					

5.2.2 Electric fields

Significant electric fields appear in the vicinity of conductive structures that have a high voltage with respect to ground potential or with respect to other conductive structures. Typical situations are for example high-voltage overhead power lines or air-insulated substations. Considering a potential impact by electric fields, cables are much less important than overhead lines due to the fact that both the metallic coating and the soil isolate the electric field nearly totally.

The electric field strength increases proportionally to the nominal voltage of the high-voltage conductors. The electric field strength at 1 m height above ground under typical high-voltage overhead lines ranges from a few kV/m to approximately 15 kV/m for voltage levels from 110 kV up to 750 kV.

Equipment that is located within buildings experiences much lower electric field strength because buildings provide a reduction factor of 10 to 20, or an even higher attenuation if such buildings are mainly constructed with conductive elements.

Electric fields caused by household appliances are generally very small and are existent in close proximity to the surface of such appliances.

Table 10 quantifies the electric fields from various low-frequency sources.

Table 10 – Disturbance degrees and levels for low-frequency electric fields

Disturbance degrees	Phenomena (sources)		
	DC lines (transmission or traction)	Railway frequency 16,7 Hz lines ^a	Power frequency 50/60 Hz lines
	Disturbance levels		
A (controlled)	Case-by-case according to the requirements		
1	0,1	0,1	≤0,1 ^b
2	1,0	0,3	≤1,0 ^c
3	10	1,0	≤10 ^d
4	20	3,0	≤20 ^e
X (harsh)	Case-by-case according to the situation		
NOTE Values in kV/m, r.m.s. for AC; values are typical for a height of 1 m above ground.			
^a Applicable also to railway systems with fundamental power frequencies other than 16,7 Hz.			
^b Residential environment, far from overhead lines.			
^c Outdoor, below overhead lines up to 30 kV and indoor, below overhead lines up to 765 kV.			
^d Outdoor, below overhead lines up to 400 kV.			
^e In HV stations up to 400 kV and below overhead lines up to 765 kV.			

NOTE 1 Information about electric field coupling is given in IEC TR 61000-2-3.

NOTE 2 There is no basic immunity standard available that reflects this kind of electromagnetic stress because significant low-frequency electric fields occur in some specific situations and the amount of electromagnetic disturbances coupled into equipment by this phenomenon is generally low so that in most cases no harmful interference is produced.

6 High-frequency electromagnetic phenomena

6.1 Conducted high-frequency phenomena

6.1.1 General

This type of disturbance is generally considered as occurring within the set of conductors of a system, either in the power supply (AC or DC) or the signal lines of the many types used in modern equipment. A frequent situation is when these systems are implemented by separate organizations or different individuals, without consideration of voltage differences that might occur between physically close conductors of different systems, hence the consideration of ground coupling path (or reference) is one of the media in which a disturbance can occur.

These disturbances can be divided into two major types, each characterized by a set of attributes, as follows:

1) continuous phenomena (induced CW) attributes:

- | | | |
|--|---|---------------------------|
| <ul style="list-style-type: none"> • amplitude • frequency • modulation • source impedance | } | voltage
and
current |
|--|---|---------------------------|

2) transient phenomena (unidirectional or oscillatory) attributes:

- rate of rise
 - duration
 - amplitude
 - spectrum
 - rate of occurrence
 - frequency
 - source impedance
 - energy potential
- voltage
and
current

When a cable contains an imperfect external shield such as a braid, incident electromagnetic fields will induce voltages and currents (depending on loads) on the external shield relative to the ground (common mode coupling). Due to transfer impedance and admittance terms for a given cable, there can be leakage into the interior cable wiring, inducing voltages and currents (depending on loads) between pairs of wires (differential mode coupling). This simple example describes the conversion process. It should be noted that differential mode signals can also be converted to common mode signals in the reverse process, creating electromagnetic emissions from the common mode currents.

Clause 6 provides a detailed table for each of the conducted disturbances (continuous or transient) listed in Table 1. Each table gives appropriate degrees that will be selected for a definition of the environment at the various location classes.

6.1.2 Direct conducted CW phenomena

6.1.2.1 General

Equipment exists that produces direct conducted CW phenomena as a result of its functional principle or intended function. Basically, two types of conducted disturbances can be distinguished:

- Intentional signal voltages used, for example, for mains signalling, such as PLC communication. Although these voltages are intentionally generated for communication purposes, they act as potential interference sources for all the items of equipment connected to the same power supply network but are not part of the communication process.
- Unintentional disturbance voltages due to functional principles of the equipment under consideration, for example, the voltages at the switching frequency and its integer multiples in case of power electronic devices (i.e. power supplies, power drive systems, uninterruptable power supply, etc.).

The mechanisms behind the generation of those disturbances imply that they are predominantly of differential mode type as the disturbance source acts between the conductors of a supply cable. Due to the unbalanced termination of equipment involved in the generation and propagation of those disturbances common mode disturbances are also produced to a certain extent.

The levels of disturbances associated with the first type of conducted disturbances are generally limited due to the fact that corresponding communication equipment has to fulfil the requirements for maximum signal levels given in various standards. With regard to the frequency range in which these communication systems operate, two frequency ranges can be distinguished:

- below 150 kHz applied for example for mains signalling used by utilities in energy measurements or by private network users' mains communicating systems (see 5.1.4),
- above 150 kHz for example for wide band communication over the internet (see 6.1.2.3 and 6.1.2.4).