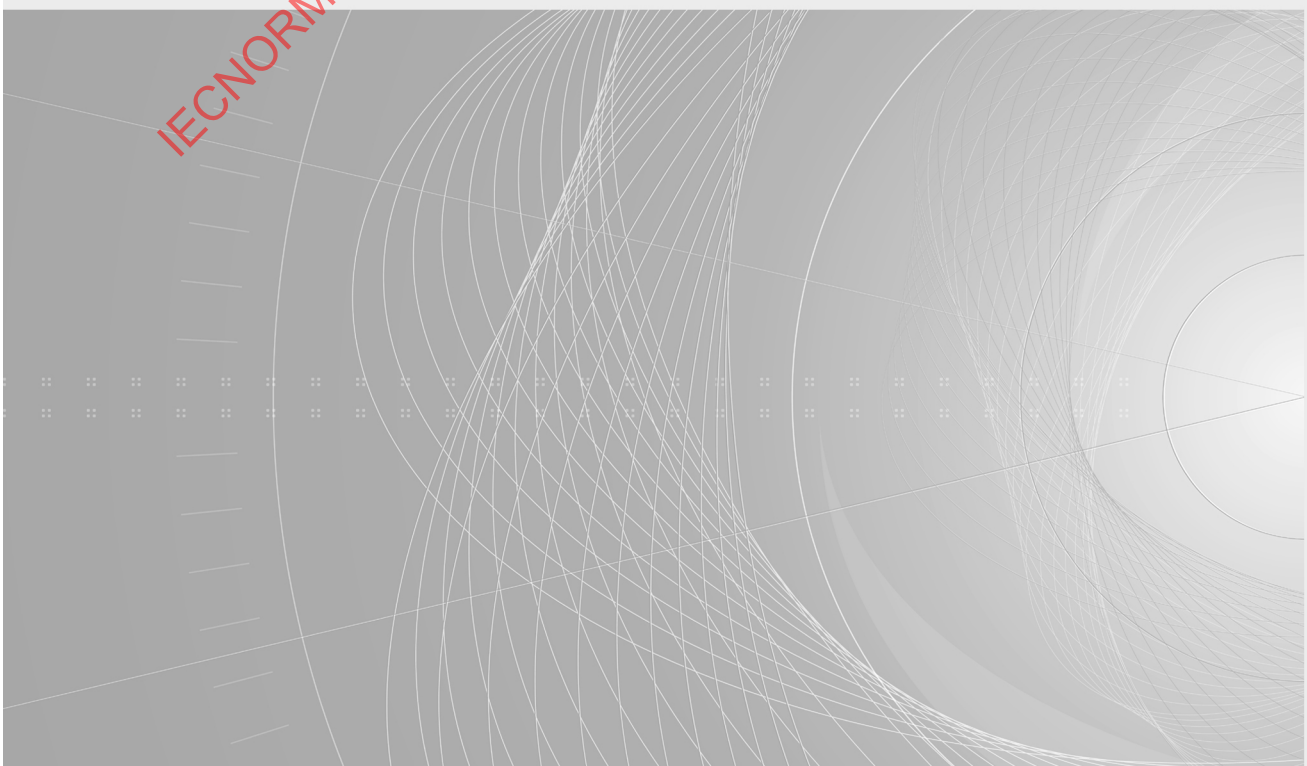
IEC TR 63216

Edition 1.0 2019-10

TECHNICAL REPORT

colour inside

Low-voltage switchgear and controlgear – Electromagnetic compatibility assessment for switchgear and controlgear and their assemblies



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LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Electromagnetic compatibility assessment for switchgear and controlgear and their assemblies

FOREWORD

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The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

IEC TR 63216, which is a technical report, has been prepared by subcommittee 121A: Low-voltage switchgear and controlgear, of IEC technical committee 121: Switchgear and controlgear and their assemblies for low voltage.

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

Enquiry draft	Report on voting
121A/292/DTR	121A/306A/RVDTR

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 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,
- withdrawn,
- replaced by a revised edition, or
- amended.

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

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

Low-voltage switchgear and controlgear and their assemblies (hereinafter referred to as "equipment") compliant with their standards, when installed and used in accordance with manufacturer's instructions, operate safely and reliably with a good level of immunity and do not produce interferences in normal operation or reasonably foreseeable faulty conditions.

This document is intended to support discussions within IEC TC 121 and its sub-committees, and with other TCs/SCs, by explaining electromagnetic compatibility assessment of equipment and compatibility measures contained in the IEC 60947 series of standards.

Those measures are based on a system approach, depending on the EMC environment in industrial applications. They include design rules and type tests to ensure the compatibility of equipment to the intended electromagnetic environment.

The collection of IEC 61000 series is very large and very generic. The intent of this document is to provide the essential applicable EMC concepts for IEC TC 121 and its sub-committees' working groups, maintenance teams and project teams.

For this intent, this document defines specific descriptions of the relevant EMC environments which are derived from the generic ones of IEC 61000 series. In addition, these environments are consistent with the zones defined by IEC 61131-2.

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Electromagnetic compatibility assessment for switchgear and controlgear and their assemblies

1 Scope

The purpose of this document is to define homogeneous categories for the electromagnetic environments in order to harmonize as far as practicable all general rules and product standard requirements of electromagnetic compatibility (EMC), applicable to low-voltage switchgear, controlgear and their assemblies with built-in electronic circuits.

This document also addresses incorporated radiocommunication functions.

The typical application environments for such equipment include the electrical distribution in infrastructure, commercial and industrial buildings and the control systems of machinery, including motor-driven systems.

The primary intention of EMC requirements is to ensure the safe and reliable operation of the equipment, as well as the communication efficiency of the radiocommunication equipment within their intended environments.

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 (IEV) – Part 161: Electromagnetic compatibility*
IEC 60050-161:1990/AMD1:1997
IEC 60050-161:1990/AMD2:1998
IEC 60050-161:1990/AMD3:2014
IEC 60050-161:1990/AMD4:2014
IEC 60050-161:1990/AMD5:2015
IEC 60050-161:1990/AMD6:2016
IEC 60050-161:1990/AMD7:2017
IEC 60050-161:1990/AMD8:2018

IEC 60050-441, *International Electrotechnical Vocabulary (IEV) – Part 441: Switchgear, controlgear and fuses*

IEC 60364-4-44, *Low-voltage electrical installations – Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances*

IEC 60364-5-53, *Low-voltage electrical installations – Part 5-53: Selection and erection of electrical equipment – Devices for protection for safety, isolation, switching, control and monitoring*

IEC 60364-5-54, *Low-voltage electrical installations – Part 5-54: Selection and erection of electrical equipment – Earthing arrangements and protective conductors*

IEC 60947-1, *Low-voltage switchgear and controlgear – Part 1: General rules*

IEC 61000-2-4:2002, *Electromagnetic compatibility (EMC) – Part 2-4: Environment – Compatibility levels in industrial plants for low-frequency conducted disturbances*

IEC 61000-4-2:2008, *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 61000-4-11, *Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests*

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 61000-4-16, *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 61000-6-1, *Electromagnetic compatibility (EMC) – Part 6-1: Generic standards – Immunity standard for residential, commercial and light-industrial environments*

IEC 61000-6-2, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity standard for industrial environments*

IEC 61000-6-3, *Electromagnetic compatibility (EMC) – Part 6-3: Generic standards – Emission standard for residential, commercial and light-industrial environments*

IEC 61000-6-5, *Electromagnetic compatibility (EMC) – Part 6-5: Generic standards – Immunity for equipment used in power station and substation environment*

IEC 61000-6-7, *Electromagnetic compatibility (EMC) – Part 6-7: Generic standards – Immunity requirements for equipment intended to perform functions in a safety-related system (functional safety) in industrial locations*

IEC 61131-2, *Industrial-process measurement and control – Programmable controllers – Part 2: Equipment requirements and tests*

IEC 61439-1:2011, *Low-voltage switchgear and controlgear assemblies – Part 1: General rules*

IEC 61800-3, *Adjustable speed electrical power drive systems – Part 3: EMC requirements and specific test methods*

IEC Guide 107, *Electromagnetic compatibility – Guide to the drafting of electromagnetic compatibility publications*

CISPR 11:2015, *Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement*
CISPR 11:2015/AMD1:2016
CISPR 11:2015/AMD2:2019

CISPR 32, *Electromagnetic compatibility of multimedia equipment – Emission requirements*

EN 50160, *Voltage characteristics of electricity supplied by public electricity networks*

3 Terms and definitions

For the purposes of this document, the terms and definitions of IEC 60050-441 and IEC 60050-161 as well as the following terms and definitions 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
compatibility level
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]

3.2
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 60050-161:2018, 161-01-07, modified – Addition of “device".]

3.3
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 can need a statistical approach.

[SOURCE: IEC 60050-161:2018, 161-01-01, modified – In Note 1 to entry, replacement of "the electromagnetic environment" by "this totality".]

3.4
immunity
<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]

3.5
radiocommunication equipment
telecommunications equipment which includes one or more radio transmitters and/or receivers and/or parts thereof for use in a fixed, mobile or portable application

Note 1 to entry: It can be operated with ancillary equipment but if so, is not dependent on it for basic functionality.

[SOURCE: ITU-T K.48:2006, 3.21]

3.6
radio link
telecommunication facility of specified characteristics between two points provided by means of radio waves

[SOURCE: ITU-R V.573-5:2015, A21]

3.7
enclosure port
physical boundary of the equipment that electromagnetic fields may radiate through or impinge on

3.8
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

3.9
signal port
port at which a conductor or cable intended to carry signals is connected to the equipment

3.10
antenna port
port that is connected to an antenna, which can be external or internal to the building, either directly or by a cable

Note 1 to entry: Antenna ports connected to antennas internal to the building are covered by signal ports.

[SOURCE: IEC 61000-6-6:2003, 4.1, modified – Definition reworded to comply with the latest ISO/IEC Directives Part 2.]

4 Classification of the electromagnetic environments

4.1 General

Classification of an electromagnetic environment is based on the electromagnetic phenomena prevailing at typical locations.

The purpose of a classification system is to identify a limited set of parameters and associated values, which can be used to determine performance requirements.

Electromagnetic disturbances impact equipment by radiation or by conduction. A useful concept is to consider a set of ports, as shown in Figure 1, through which the disturbances enter (or exit) the equipment under evaluation. The nature and degree of disturbing phenomena depends on the type of port, so that the tables in this report will take this into consideration.

Electromagnetic radiated disturbances impact 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.

The enclosure port shown in Figure 1 concerns only the radiated disturbances that enter the equipment through its housing (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 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, 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 (alternating current or direct current) needed for operation. The power port can be both the input and output power port.

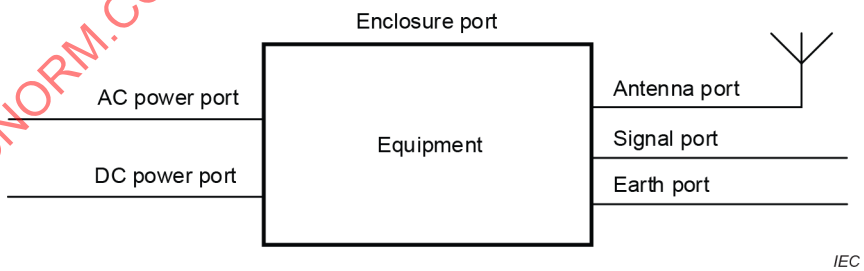


Figure 1 – Ports of entry of electromagnetic disturbances into equipment

4.2 Emission classification

According to CISPR 11 and CISPR 32, equipment is classified into two classes depending on their intended use.

Class B equipment is intended to be used in residential areas and in establishments directly connected to a low-voltage power supply network which supplies buildings used for domestic purposes. This class is not normally included in IEC 60947 (all parts), and therefore not addressed in this document.

Class A equipment is intended to be used in all locations other than those allocated in residential areas and those directly connected to a low-voltage power supply network which supplies buildings used for domestic purposes.

NOTE Class A and B are only related to emission phenomena. Environment A in IEC 60947-1 and IEC 61439-1:2011 corresponds to Environment E-III. Environment B of IEC 60947-1 corresponds to equipment Class B in CISPR 11.

The manufacturer and/or supplier of equipment shall ensure that the user is informed about the class of the equipment, either by labelling or by the accompanying documentation. In both cases the manufacturer/supplier shall explain the meaning of the class in the documentation accompanying the equipment (see 7.2).

4.3 Environments

The electromagnetic environments are not the same at all locations of a building or of an industrial plant (see Figure 2). The following definitions of the environments, necessary for managing their appropriate separation are consistent with those defined in IEC 61131-2 and the associated generic EMC standards:

Environment E-IV: Power distribution

LV power distribution where the interconnections are running as outdoor cables along with power cable or next to a high-voltage power station or substation.

Protection is of particular relevance to power systems and to the safety, continuity of service and security of both substations and power stations. The precision and rapidity of electronic protection equipment shall not experience degradation of performance as a consequence of electromagnetic phenomena.

Environment E-III: Industrial

Factory or infrastructure mains distribution isolated from the electrical public network by a power distribution transformer, primary surge protection and other substantial decoupling means in order to mitigate severe interference.

Environment E-III is the standard environment for low-voltage switchgear, controlgear and their assemblies.

EXAMPLE 1 Metalworking, pulp and paper, chemical plants, car production, farm building, high-voltage (HV) areas of airports.

NOTE 1 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.

Environment E-II: Light-industrial

Dedicated power distribution separated from factory mains by a dedicated LV/LV transformer, secondary surge protection, dedicated DC power network, and other decoupling means, in order to mitigate moderate interference by means of:

– shielding and filtering, or

– proper integration within the metallic frame of machinery.

EXAMPLE 2 Light-industrial locations are workshops, laboratories, service centres, control systems of machinery, offices.

NOTE 2 Environment E-II covers zone A and zone B of IEC 61131-2.

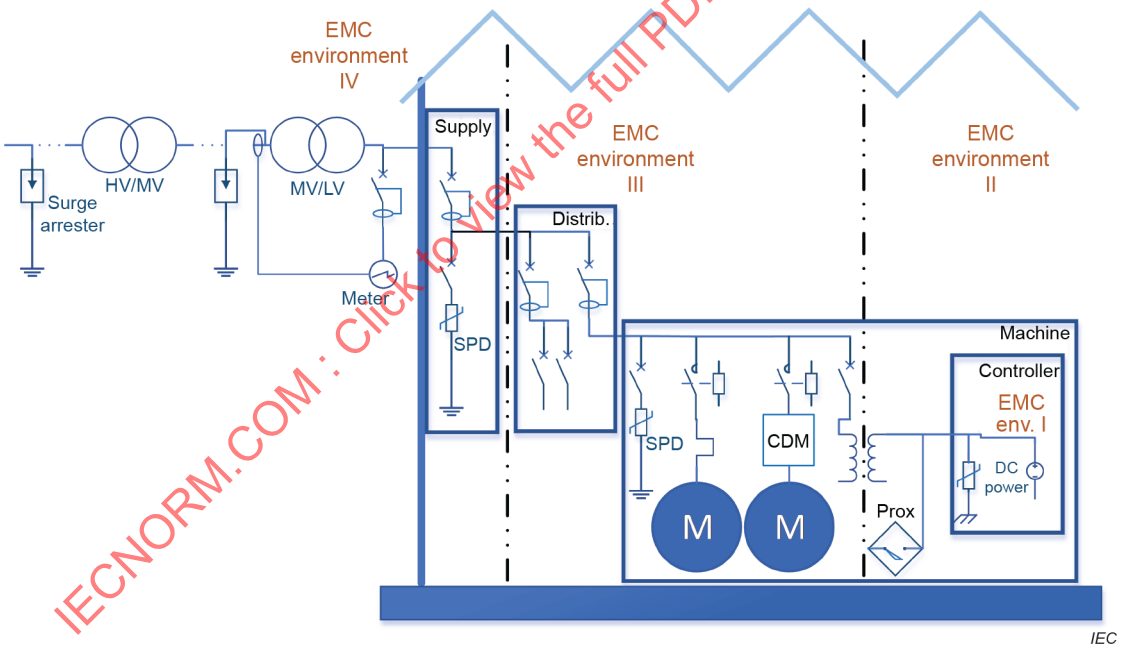
NOTE 3 The term “light-industrial” is related to the EMC environment and not the duty of the equipment, such as high operating demand or the ability to withstand shocks and vibrations.

Environment E-I: Protected zone

Environment E-I levels apply where installation practices reduce industrial environmental levels below those of environment E-II. These may be installation of protection networks, AC/DC converters, isolation transformers, surge suppressers, I/O impedance limiting, shorter wiring, well-protected power supplies, EMC enclosures, feedthrough filters, etc.

The design of Environment E-I needs a high degree of investigation by selecting appropriate shielding, filters and often needs measurement and calculation (impedances along the spectrum, propagation, attenuation, etc.). Therefore, this environment is currently not covered by EMC standards and product standards.

EXAMPLE 3 A protected zone can be a subassembly supplied by an additional AC/DC power supply installed within an EMC enclosure.



Key

HV	high voltage
LV	low voltage
SPD	surge protective device
CDM	complete drive module (variable speed drive)
Prox	proximity switch
M	motor

Figure 2 – Example of EMC environments

Residential and commercial EMC areas

Switchgear and controlgear, primarily intended for use in industry, may also be used in residential and commercial applications directly connected to a low-voltage power supply network. For these applications, no additional immunity tests are required because their product standards already require the minimum levels derived from the generic standards IEC 61000-6-1 or IEC 61000-6-2. But they shall comply with additional emission limits according to IEC 61000-6-3 and with radio-frequency emission limits according to Class B of CISPR 11. For installations with frequency converters, equipment with limits according to the category C2 of IEC 61800-3 may be used if installed by a professional. For further guidance, see IEC 61800-3.

Interconnection crossing different environments

When interconnections are declared suitable to cross different environments, information about additional measures (filtering or similar) shall be provided by the manufacturer of the equipment.

Assembly incorporating complete drive system

Where a complete drive system (CDM) is incorporated within assemblies, IEC 61800-3 provides information about additional measures to be managed in an EMC plan for power drive systems (PDS) exceeding the limits of CISPR 11, especially for those with device ratings equal to or above 400 A (category C4). This document also provides additional guidance about PDS related low frequency phenomena, reactive power compensation and the EMC analysis for PDS of category C4. The associated compatibility levels for the conducted disturbances below 9 kHz given in IEC 61000-2-4 with examples of typical industrial networks should be considered for establishing the EMC plan for PDS.

4.4 Low-voltage supply

4.4.1 Nominal voltages

Nominal voltages are based on the development of electrical supply systems throughout the world following some degree of harmonisation. IEC 60038 gives the preferential values for nominal voltages of electrical supply systems to be used as reference values for equipment and system design.

In addition, voltage drops may occur within the electrical installation in accordance with IEC 60364-5-52.

Most of the utility companies comply with a fluctuation of ±10 % in accordance with IEC 60038 but accept that, temporarily, voltages may vary outside this limit. IEC 61000-2-4:2002 defines a Class 3 of voltage fluctuation compatibility in the range −15 % to +10 % for a duration not longer than 60 s and 3 % of voltage unbalance.

4.4.2 Faults in power supply networks

In case of fault in the high voltage system, IEC 60364-4-44 provides the limits of permissible power-frequency overvoltage between line to earth or line to neutral of 1 200 V less than 5 s and 250 V more than 5 s. In case of loss of the neutral conductor in TN and TT systems or an earth fault in an IT system with distributed neutral, the temporary overvoltage can reach √3 the nominal line to earth or line to neutral voltage.

4.4.3 Nominal frequencies

Slow fluctuations around the nominal value of 50 Hz or 60 Hz are normally small. In Europe, EN 50160 specifies 50 Hz ± 1 % for 95 % of the week, and [+4 %, −6 %] in the event of major disturbances. These fluctuations may be far greater for autonomous networks, for example on an island.

4.4.4 Electromagnetic disturbances in power supply networks

The different earthing systems in accordance with IEC 60364-5-54 are presenting different EMC conditions and behaviours, mainly owing to the possible fault currents and the impedance between the phases and the earthing arrangement.

In TN-C systems, neutral (N) and protective conductor (PE) are combined together into only one conductor, the PEN conductor. In this case, the operational currents are divided between the neutral conductor and the grounding and equipotential bonding system, depending on the ratio of their impedances. As a result, common mode currents in the power cables as well as currents in the grounding arrangement occur with the consequential generation of power frequency magnetic fields due to the multiple loops of earthing.

From an EMC point of view, TN-S systems are preferred. In these systems, the neutral and protective earth conductors are strictly separated, except at one point where both are connected. In this case, the equipotential bonding system is free of operational currents and does not create significant low-frequency conducted and radiated phenomena.

Detailed installation measures against electromagnetic influences related to each earthing system, including multiple-source power supplies, are given in IEC 60364-4-44.

4.5 EMC environment classification

Owing to the management of electromagnetic compatibility in electrical systems, the level of conducted disturbances is in general following proportionally the level of transient coupling observed in a given environment. The radiated disturbances have generally a similar decay owing to the shielding effect of the installation environment. Table 1 defines the reference of the compatibility level for each environment in industry based on the levels of transient coupling.

Table 1 – Typical environment levels

Environment	Maximum rated operational voltage (V RMS)	Transient coupling [a] (kV peak) [b]	Power frequency field [a] (A/m)	Immunity levels	Emission limits
E-I Protected	120 [e]	1	-	-	-
E-II Light-industrial	400	2	3	IEC 61000-6-1 [f] IEC 61000-6-7 [c]	CISPR 11 Class A group 1
E-III Industrial	690	4	30	IEC 61000-6-2 IEC 61000-6-7 [c]	CISPR 11 Class A group 1
E-IV Power distribution [d]	1 000	6	100 continuous 1 kA/m 1 s	IEC 61000-6-5 IEC 61000-6-7 [c]	CISPR 11 Class A group 1

[a] Typical levels of transient and power frequency field which are generally found in the different environments where switchgear and controlgear are operating at the maximum rated voltage (see also A.2 and Table A.1). For testing levels see Table 2.

[b] Power line to earth coupling limited by surge suppressors. Line to line coupling is generally half the value of the line to earth value. Higher transient overvoltages may occur, especially those from atmospheric origin.

[c] For safety function of safety-related systems according to IEC 61508 (all parts).

[d] Performance criterion A of IEC 61000-6-5 is recommended for protection function.

[e] Based on Zone A of IEC 61131-2.

[f] Based on Zone B of IEC 61131-2.

The environment E-III is the most typical environment for industrial power distribution and control. Control devices used for the automation of machinery are normally designed for environments E-II or E-III.

In the environments E-II, E-III and E-IV, non-periodic overvoltage peaks may appear on equipment power supply lines as a result of power interruptions to high-energy equipment (for example, blown fuse on one branch in a 3-phase system). Current interruption in an inductive power supply line creates a switching overvoltage, at around 2 x U_{peak} with about 1 ms duration.

The transient coupling levels of Table 1, mainly from atmospheric origin, are proportional and consistently classified like the overvoltage categories given in Table A.1.

4.6 Principle of compatibility

Compatibility levels are defined for the coordination of emission limits and immunity levels. Emissions from equipment should be limited in such a way that together with appropriate immunity levels, electromagnetic compatibility is achieved. As illustrated in Figure 3, the approach is to set the emission limits lower than the immunity levels for managing the tolerances of the potential coupling mechanisms and the equipment properties.

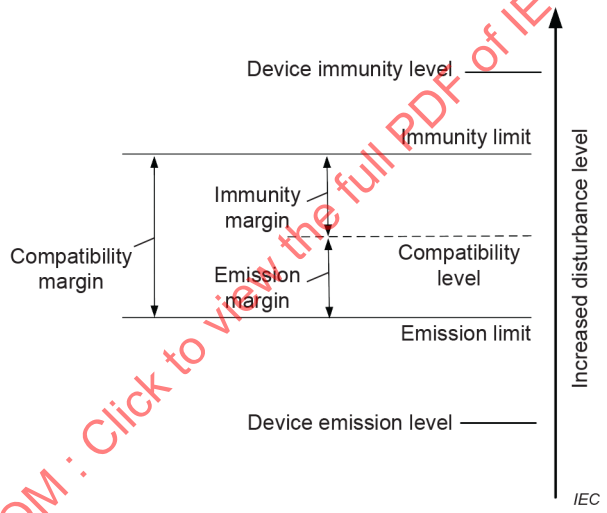


Figure 3 – Principle of EMC compatibility

Typical phenomena at the origin of electromagnetic disturbances are summarised in Annex B. Annex B also lists the corresponding testing standard covering the phenomena at different typical levels.

CISPR limits are mainly developed for protection of radiocommunications at a distance of 10 m or 30 m. They are not considering proximity fields. The emission limits for each environment are given in 8.1.

The minimum immunity levels are given in 8.2.

5 Drafting of EMC requirements

5.1 General

EMC is in constant evolution. The evolution of the EMC phenomena especially associated with new radiocommunication technologies (e.g. 5G cellular phones, near-field communication) can trigger the necessity to revise a product standard.

Electromagnetic compatibility assessment shall be developed or updated systematically when drafting a new product standard, or during the revision cycle of an existing product standard, using this document, IEC 60947-1 and IEC Guide 107 as references.

5.2 EMC assessment

The EMC assessment consists of:

- reviewing the relevant EMC environments from Table 1 to be considered depending on the intended applications and taking in account the evolution of the EMC phenomena;
- conducting an EMC impact analysis of the new provisions introduced in the revision of the product standard or, in the case of new product standard, a comparison analysis with a similar existing product standard.

The EMC impact analysis shall:

- evaluate possible new source of emissions from the equipment;
- identify the new functionality of the equipment and evaluate their acceptable criteria of performance in case of disturbances, taking into account the expectation of the user in term of safety, availability, including the performance of the radiocommunication means;
- identify all possible configurations of intended use, operating modes and assessing the configuration most likely to cause maximum emission and the configuration most likely to be susceptible to disturbances (worst case approach). These worst-case configurations shall be defined in the product standard;
- identify the electrical installation conditions taking into account IEC 60364-4-44.

5.3 Drafting of EMC requirements in product and assembly standards

Based on the EMC assessment, the EMC requirements shall be developed in the product standard or in the assembly standard by determining:

- the intended EMC environment(s) according to Table 1. A product may be classified for different EMC environments;
- the relevant corresponding emission limits according to CISPR 11 and CISPR 32;
- the relevant corresponding immunity requirements, including the performance criteria, depending on the expected phenomena from Table 2, referring to the EMC requirements of the relevant product family EMC standard: IEC 60947-1 or IEC 61439-1;
- the relevant information for the installation, mounting and maintenance, e.g. information about shielding, cable screening and routing, filters, shall be given in the manufacturer's documentation.

EMC of switchgear and controlgear shall be verified by type tests. See Clause 8.

When adding specific EMC requirement(s) not already provided in the general rules, typically from IEC 60947-1, references to EMC generic standards (IEC 61000-6 series), testing standards (IEC 61000-4 series) and emission limits (CISPR series) should be preferably undated (i.e. not referring to a specific subclause).

Testing requirements of product standards against emission limits should express the applicable limits selected from the appropriate CISPR standard with the dated references to the relevant clause or subclause of the testing method of this CISPR standard.

Assemblies are in most cases manufactured or assembled on a one-off basis, incorporating a wide range of components. It is therefore not practical to test every assembly manufactured. With respect to EMC, assemblies are treated as a system.

According to IEC 61439 series, no EMC immunity or emission tests are required on final assemblies if the following conditions are fulfilled:

a) the incorporated components are in compliance with the requirements for EMC for the stated environment as required by the relevant product or generic EMC standard;

b) the internal installation and wiring is carried out in accordance with the components manufacturer's instructions (arrangement with regard to mutual influences, cable, screening, earthing, etc.).

Mixing different EMC environments in one assembly is not recommended but this can be managed. If an assembly needs to host two different environments, they should be separated by appropriate shielding and feed through filtering, both connected to a common equipotential bonding of the assembly and preferably to the earth.

6 Radiocommunication

6.1 General

The EMC evaluation related to radiocommunication and radiodetermination (module, electronic components) integrated within switchgear and controlgear is necessary in order to ensure the efficient use of the radio spectrum and avoiding harmful interference.

This evaluation is based on a documented risk assessment realised by the working group in charge of the product standard.

Generally, switchgear and controlgear equipped with radiocommunication means are tested according to EMC requirements given in their product standards with the following additions:

- it is assumed that the radiocommunication means (module or electronic component, antenna) has been pre-evaluated against its technology standard and is integrated according to the instructions of its manufacturer;
- for immunity, where the radio and the non-radio functions have been tested separately, an additional set of radiated immunity tests shall be performed within these functions operating simultaneously;
- no evaluation is necessary if the radiocommunication means cannot be used at the same time as the non-radio function;
- the configuration and operation during the EMC tests should be defined in the product standard with both non-radio and radio functions operating at the same time which is the worst case of emissions and susceptibility.

6.2 Radiated emissions

EMC evaluation of radiated emissions limits of switchgear and controlgear with radiocommunication means is preferably to be performed in receive mode only (no emitting function). Otherwise, If the emitting function cannot be disabled, the radiocommunication spectrum band shall be excluded from the evaluation.

6.3 Conducted emissions

For switchgear and controlgear with integrated radiocommunication means the radiocommunication spectrum band shall be excluded from the conducted emission limits.

Where the equipment has a port intended for the connection of an external antenna via coaxial cable, the Class A requirements of CISPR 32 for antenna ports applies.

6.4 Immunity

6.4.1 General

The performance of the radiocommunications function(s) shall comply with the requirements performance criteria of the particular technology standard(s).

Where the radio link is defined by the manufacturer as a service or configuration link only and not intended for permanent use, the radio link may be disturbed temporarily at levels higher than those defined in the particular technology standard.

6.4.2 Radiated immunity

The radiated immunity test of the product standard shall cover 80 MHz to 6 GHz (or higher depending on the available radiocommunication technology).

6.4.3 Radio frequency (common mode)

The radio frequency common mode test of the product standard shall cover up to 80 MHz.

6.5 Typical radiocommunication standards

Example of radiocommunication are defined by the following standards:

– Wi-Fi IEEE 802.11;
– DECT IMT-2000 FDMA/TDMA;
– Bluetooth Core Version 5.0;
– Zigbee IEEE 802.15.4;
– RFID e.g. ISO/IEC 18000-3;
– NFC e.g. ISO/IEC 14443 (all parts).

7 EMC related information

7.1 Information on the product environment

The intended EMC environment(s) of the equipment shall be given in the manufacturer's literature available before ordering and provided with the equipment in accordance with 4.3. This can be expressed as the following example.

EXAMPLE EMC environment E-III: industrial and EMC environment E-II: light-industrial.

The type and reference of the necessary EMC accessory for complying with the compatibility levels of the declared EMC environment shall be mentioned in the manufacturer's catalogue.

7.2 Information related to emission limits

The emission levels of the equipment may exceed Class B limits of CISPR standards. In such case, they are only suitable for use in all locations other than those allocated in residential environments. Consequently, in accordance with CISPR 11, the manufacturer shall provide the following notice with the equipment:

CAUTION

This equipment is not intended for use in residential environments and may not provide adequate protection to radio reception in such environments.

7.3 Instruction for use

EMC accessories such as interconnecting shielded cables, filters, surge suppressors and shielding used to pass the EMC tests shall be specified in the instruction manual.

The mounting instruction of the EMC accessory and the necessary EMC related interconnections such as special cable types and maximum lengths, circuit separations, grounding, earthing and functional earthing, type of auxiliary supply shall be given in the instruction provided with the equipment. If the product with its accessories can be used in different EMC environments, specific installation instructions shall also be given.

7.4 Good wiring practices

Good installation practices may be relevant in the instruction for use. The following list gives the essential principles:

Separation:

- mains conductors should be separately routed from control and signal conductors with a distance of 10 cm or more. Unavoidable crossing should be at right angles;
- field wiring should be separated from internal I/O cabling and from communication bus lines. Care shall be taken not to compromise isolated circuits;
- input and output cables should be separated.

Filtering:

- mains filters including transient suppressors should be used at the entrance of an assembly or sub-assembly, e.g. for a control system;
- shielded cables with low-inductance cable shields and twisted-pair should be used for low-level signals. The shielding should be connected to functional earth or protective earth via a low-impedance RF connection;
- wiring of circuits switching inductive loads should be designed with specific attention for limiting overvoltage;
- cable length should be minimised.

8 Test levels of switchgear and controlgear

8.1 Emission limits and test methods

For EMC environments E-II, E-III and E-IV, the corresponding limits and testing methods for conducted and radiated emission on AC and DC power ports are given by CISPR 11, group 1 (not intentionally generating radio frequencies) and Class A (non-residential). As an example, Figure 4 illustrates the Class A limits (quasi peak) for conducted and radiated emission at 10 m. Wired network ports are tested according to CISPR 32 Class A.

NOTE Figure 4 does not illustrate the new valid test method given in CISPR 11:2015, CISPR 11:2015/AMD1:2016 using a fully anechoic room (FAR).

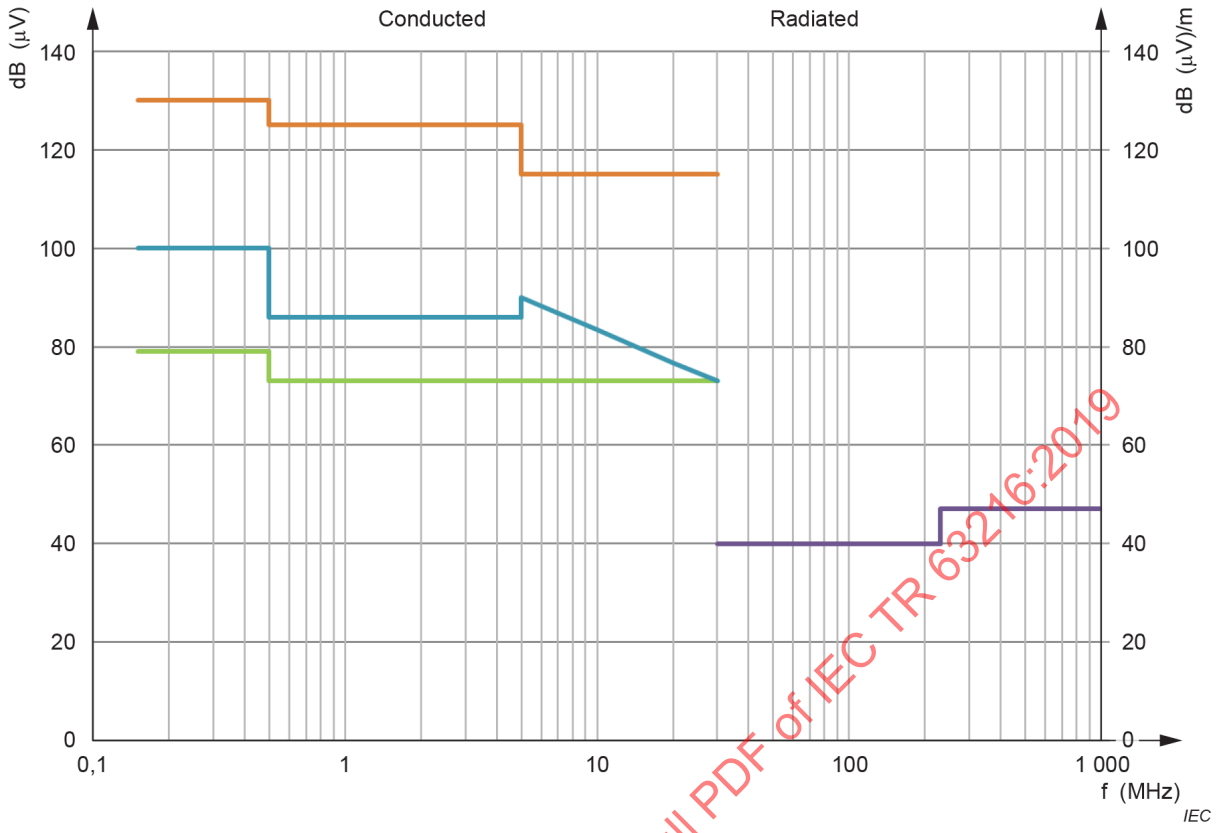


Figure 4 – CISPR 11:2015, Class A limits (quasi peak) for conducted and radiated emission at 10 m

8.2 Immunity test levels

Table 2 gives the minimum immunity test level for each EMC environment based on the requirement of the generic standard IEC 61000-6-1 (environment E-II), IEC 61000-6-2 (environment E-III) and IEC 61000-6-5 (environment E-IV). Key functions of the equipment may require a higher level of robustness and consequently higher test levels. Advice for the selection of the relevant test levels can be found in each testing standard given in Table 2.

Table 2 – Minimum immunity test levels

Phenomenon	Environment E-II: Light industrial	Perf. crit.	Environment E-III: Industrial	Perf. crit.	Environment E-IV: Power distribution	Perf. crit.
Enclosure ports						
Electrostatic discharge IEC 61000-4-2 [a]	8 kV / air 4 kV / contact	B	8 kV / air 4 kV / contact	B	8 kV / air 4 kV / contact	B
Power frequency magnetic field 50/60 Hz [b] IEC 61000-4-8	3 A/m	A	30 A/m	A	100 A/m	A
Radiated radiofrequency 80 MHz to 1 GHz IEC 61000-4-3	3 V/m	A	10 V/m	A	10 V/m	A

Phenomenon	Environment E-II: Light industrial	Perf. crit.	Environment E-III: Industrial	Perf. crit.	Environment E-IV: Power distribution	Perf. crit.
Radiated radiofrequency 1,4 GHz to 6 GHz IEC 61000-4-3	1 V/m	A	3 V/m	A	3 V/m	A
Signal/control/DC power ports						
Radiofrequency common mode [c] 150 kHz to 80 MHz IEC 61000-4-6	3 V	A	10 V	A	10 V	A
Surge [d, h] 1,2/50 µs – 8/20 µs IEC 61000-4-5	±1 kV line-to-earth ±0,5 kV line-to-line for DC power ports	B	±1 kV line-to-earth ±0,5 kV line-to-line for DC power ports	B	±2 kV line-to-earth ±1 kV line-to-line for DC power ports	B
Fast transients/burst [c] 5/50 ns, 100 kHz IEC 61000-4-4	±0,5 kV	B	±1 kV	B	±2 kV	A
AC power ports						
Radiofrequency common mode 150 kHz to 80 MHz IEC 61000-4-6	3 V	A	10 V	A	10 V	A
Damped oscillatory wave IEC 61000-4-18	No requirement		No requirement		1 kV 1 MHz CM 0,5 kV 1 MHz DM 0,5 kV 10 MHz DM	A
Voltage dips Residual voltage IEC 61000-4-11	0 % during 0,5 cycle	B	0 % during 1 cycle	B	40 % during 50 cycles	B [e]
	0 % during 1 cycle	B	40 % during 10/12 cycles	C	70 % during 1 cycle	B [e]
	70 % during 25/30 cycles	C	70 % during 25/30 cycles	C	-	-
Short interruptions Residual voltage IEC 61000-4-11	0 % during 250/300 cycles	C	0 % during 250/300 cycles	C	0 % during 5 cycles 0 % during 50 cycles	B [e]
Current dips and interruptions for overcurrent protection function [f]	No requirement		0 % during 0,5, 1, 5, 25 and 50 cycles	B	0 % during 0,5, 1, 5, 25 and 50 cycles	B
			0,4 I_r during 10, 25 and 50 cycles	B	0,4 I_r during 10, 25 and 50 cycles	B
			0,7 I_r during 10, 25 and 50 cycles	B	0,7 I_r during 10, 25 and 50 cycles	B
Surge 1,2/50 µs – 8/20 µs IEC 61000-4-5	±2 kV line-to-earth ±1 kV line-to-line	B	±2 kV line to earth ±1 kV line to line	B	±4 kV line to earth ±2 kV line to line	B
Fast transients/burst 5/50 ns, 100 kHz IEC 61000-4-4	±1 kV	B	±2 kV	B	±4 kV	A
Immunity to harmonics in the supply IEC 61000-4-13	To be defined by the product standard if needed		To be defined by the product standard if needed		No requirement	
Immunity to differential mode disturbances 2 kHz to 150 kHz [g] IEC 61000-4-19	Level 3	A	Level 4	A	Level 4	A
Immunity to common mode disturbances 0 Hz to 150 kHz [g] IEC 61000-4-16	Level 3	A	Level 4	A	Level 4	A
Current harmonics (test waveform) for overcurrent	No requirement		72 %<h3<88 % Peak factor 2	A	72 %<h3<88 % Peak factor 2	A

Phenomenon	Environment E-II: Light industrial	Perf. crit.	Environment E-III: Industrial	Perf. crit.	Environment E-IV: Power distribution	Perf. crit.
protection function [f]			45 %<h5<55 % Peak factor 1,9		45 %<h5<55 % Peak factor 1,9	

[a] See 8.3 of IEC 61000-4-2:2008.

[b] Applicable to equipment containing magnetic sensing devices used typically for current detection.

[c] Applicable only to ports interfacing with cables whose total length according to the manufacturer's functional specification may exceed 3 m.

[d] Applicable only to ports interfacing with cables longer than 30 m or outdoor, which is not usually the case for switchgear and controlgear.

[e] See IEC 61000-6-5.

[f] I_r is the minimum setting of the over-current tripping device unless otherwise indicated by the manufacturer. The tolerance on the peak factor is ±10 %.

[g] Applicable to equipment with powerline communication ability.

[h] DC ports intended to be supplied by DC power supplies (≤ 60 V), isolated from the AC mains supply and not subject to transient over-voltages (i.e. reliably grounded, capacitively filtered) are not regarded as DC power ports.

8.3 Type tests

Switchgear and controlgear generally have limited emission sources with limited spectrum and energy because of the low complexity of their electronics. Criteria of their immunity are precisely defined in their product standards according to their intended use.

EMC is verified by performing a type test on a representative switchgear or controlgear sample of the production series. The manufacturer ensures by means of his quality system that the EMC of the equipment is maintained with an appropriate margin covering the variations of the EMC-related characteristics.

The test report and the instruction manual shall include any special measures that have been taken to achieve compliance, for example the use of shielded or special cables. If auxiliary equipment is used in order to comply with immunity or emission requirements, it shall be included in the report and the instruction manual.

Annex A
(informative)

Rationale of the electromagnetic compatibility based on the electric network topology

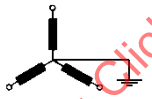
A.1 General

The required impulse withstand voltage of equipment installed in an electrical installation is given by IEC 60364-4-44 where surge protective devices are installed in accordance with IEC 60364-5-53. The levels of overvoltage in the different zones of the topology of the electrical installation can be used as the maximum surge coupling, which can be found in each zone.

A.2 Overvoltage levels in the installation

Table A.1 gives the maximum levels of overvoltage for the relevant ranges of nominal voltage to earth in each zone of the electrical installation. These levels of overvoltage per zone, depicted in Table A.1 as grouped coloured cells, can be correlated to the relevant EMC environments in consistency with the overvoltage category.

Table A.1 – Relation between surge coupling and overvoltage category

Maximum value of rated operational voltage to earth	**Nominal voltage** [a]	**Maximum surge coupling** (kV)			
		Overvoltage category			
		OC-IV	**OC-III**	**OC-II**	**OC-I**
AC RMS or DC (V)	 **AC RMS** (V)	**Origin of installation (service entrance) level**	**Distribution circuit level**	**Load (appliance, equipment) level**	**Specially protected level**
50	-				0,33
150	120/208 127/220			1,5	0,8
300	220/380, 230/400 240/415, 260/440 277/480		4	2,5	
600	347/600, 380/660 400/690, 415/720 480/830	8	6		
1 000		12			

[a] According to IEC 60038.

Annex B
(informative)

Electromagnetic phenomena

B.1 EMC phenomena

B.1.1 General

Three basic categories of phenomena, conducted and radiated, have been identified: electrostatic discharge, low-frequency phenomena and high-frequency phenomena (see Table 2).

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.

Radiated disturbances occur in the medium surrounding the equipment, while conducted disturbances occur in various metallic media.

B.1.2 Voltage dips and short interruptions

Networks are disturbed not only by load fluctuations in normal operation, but also and above all by random phenomena of accidental origin, for example short-circuits. Voltage dips last in most cases for less than 1 s. 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.

Typical examples can be described as follows:

Disturbances due to operation of HV and MV networks

Energisation of large transformers causes developing voltage dips due to inrush current. Phenomena such as equipment insulation fault, lightning strike, damage to an underground cable, earthing of an overhead conductor, cause short-circuits that generate high voltage drops in an area around the origin of the fault, prior to disconnection of the faulty device by the protection devices.

Disturbances due to operation of LV networks

The voltage dips observed on LV networks, due to their operation, are caused by activation of capacitors or direct-on-line starting of large motors.

Disturbances due to faults on LV networks

Short-circuits on the main LV distribution, between two live conductors or between a live conductor and a frame in the TN earthing system are also responsible for voltage dips and interruptions.

B.1.3 Overvoltages

Transient overvoltages due to lightning strikes in proximity to the supply networks have the higher amplitude. Transient overvoltages due to operation of switches and fuses are longer in duration and higher in energy. Switching of capacitor banks is a usual cause of propagating transients along a line.

When lightning strikes the MV line, it causes arcing in the spark-gap or surge arrester, which lets through part of the impulse wave, that may be amplified by the wave reflection phenomenon. Ferro-resonance may occur on no-load and slightly loaded networks, particularly in high voltage, as well as behind small transformers and in the presence of filters.

B.1.4 Sine wave disturbances

Harmonics and interharmonics can be generated by generators' "noise", inverters, transformer saturation, rectifier, switch mode power supply, induction furnace, signalling, amplitudes of harmonics.

Continuous or randomly repeated and relatively rapid fluctuations at a frequency ranging from 25 times per second to one time per minute cause flickering of incandescent lamps and generate 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.

Power supply networks can also be used for the transmission of information by mains signalling systems with signals up to 5 % of U_{n}, such as ripple control systems generally below 500 Hz power-line carrier systems in the range of 3 kHz to 95 kHz and signalling systems in the range of 95 kHz to 500 kHz.

B.1.5 Three-phase system disturbances

The currents absorbed by three-phase loads can be different amplitudes, which results in voltage unbalances. These voltage unbalances generate negative sequence components that mainly lead to unwanted braking torques and temperature rises in AC motors. The operation of phase-controlled thyristor devices may be disturbed in this instance.

The common mode voltage, equal to the neutral line voltage in polyphase systems, 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. This can be the case with power drive systems connected to the power system without a transformer.

B.1.6 Electromagnetic disturbances

A device placed near a conductor conveying a large alternating current will collect an electromotive force by inductive coupling. This is true for all circuits placed in the magnetic field. Devices placed near HV networks may be subjected to induced voltages, a phenomenon of conductors placed in an electric field. In fact, all electromagnetic fields are characterised by the simultaneous presence of electrical and magnetic fields.

Electronic circuits are the main victims of electromagnetic disturbances since they process very low-voltage signals and have large impedances (they consume less and less). Interference occurs on the "victim", mainly through the cables entering and leaving the box (by coupling in common mode – differential mode – common impedance – crosstalk). Also, the paths of printed circuits and components can and shall be determined to ensure minimum electromagnetic susceptibility. To avoid the risk of crosstalk to signal cables, especially for common mode harmonic coupling from power converters, the installation instructions should either recommend that the power cable be segregated from signal cables or state alternative mitigation methods.

Low-frequency currents in cables can 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.

DC voltage in AC networks is caused primarily by geomagnetic storms that may induce high levels of 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