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INTERNATIONAL STANDARD

colour inside

Railway applications – Electromagnetic compatibility –
Part 1: General

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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Part 1: General

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b) Introduction of subclause Abbreviated terms.
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INTRODUCTION

The railway system EMC ~~set~~ series of product-specific International Standards consists of five parts described at the end of this introduction.

The ~~set~~ series of standards provides both a framework for managing the EMC for railway~~s~~ systems and also specifies the limits for the electromagnetic (EM) emission of the railway system as a whole to the outside world and for the EM emission and immunity for equipment operating within the railway system. The latter ~~must~~ is intended to be compatible with the emission limits set for the railway system as a whole and also provides for establishing confidence in equipment being fit for purpose in the railway environment. There are different stationary emission limits set for trams/trolleybuses and for metro/mainline railway~~s~~ systems. The frequency covered by the standards is in the range from DC to 400 GHz. No measurements need to be performed at frequencies where no requirement is specified. The limits for EMC phenomena are set so that the railway system as a whole achieves electromagnetic compatibility with the outside world, and between the various parts of the railway system. Throughout the ~~set~~ series of standards, the immunity levels are chosen to ensure a reasonable level of EMC with other apparatus within the local railway environment and with emissions which enter the railway system from the outside world. Limits are also placed on EM emission by railway~~s~~ systems into the outside world.

The compatibility between railway system emissions and their external environment is based upon emission limits from the railway~~s~~ systems being set by considering the results from measurements. Given that the general compatibility between railway~~s~~ systems and their environment was satisfactory at the time these measurements were made and subsequent experience of applying the limits has confirmed their acceptability, compliance with this document has been judged to give satisfactory compatibility. The immunity and emission levels do not of themselves guarantee that the railway system will have satisfactory ~~compliance~~ EMC with its neighbours. In exceptional circumstances, for instance near a “special location” which has unusually high levels of EM interference, the railway system may require additional measures to be taken to ensure proper compatibility. Particular care should be taken when in proximity to equipment such as radio transmission equipment, military or medical installations. Attention is particularly drawn to any magnetic imaging equipment in hospitals that may be near to urban transport. In all these cases, compatibility ~~must~~ should be achieved with consultation and co-operation between the interested parties.

The immunity and emission levels do not of themselves guarantee that integration of the apparatus within the railway system will necessarily be satisfactory. The document cannot cover all the possible configurations of apparatus, but the test levels are sufficient to achieve satisfactory EMC in the majority of cases. In exceptional circumstances, for instance near a “special location” which has unusually high levels of EM interference, the system may require additional measures to be taken to ensure proper operation. The resolution of this is a matter for discussion between the equipment supplier and the project manager, infrastructure ~~controller~~ manager or equivalent.

The railway apparatus is assembled into large systems and installations, such as trains and signalling control centres. Details are given in annex A. It is not, therefore, possible to establish immunity tests and limits for these large assemblies. The immunity levels for the apparatus will normally ensure reliable operation, but it is necessary to prepare an EMC ~~management~~ plan to deal with complex situations or to deal with specific circumstances. For example, the passage of the railway line close to a high power radio transmitter which produces abnormally high field strengths. Special conditions may ~~have to~~ be applied for railway equipment which ~~has to~~ works near such a transmitter and these will be accepted as national conditions for the specification.

The series of standards IEC 62236, *Railway applications – Electromagnetic compatibility*, contains the following parts:

– *Part 1: General.* This part gives a description of the electromagnetic behaviour of a railway system; it specifies the performance criteria for the whole ~~set~~ series. A management process to achieve EMC at the interface between the railway infrastructure and trains is referenced.

– *Part 2: Emission of the whole railway system to the outside world.* This part sets the emission limits from the railway system to the outside world at radio frequencies. It defines the applied test methods and gives information on typical field strength values at traction and radio frequency (cartography).
– *Part 3-1: Rolling stock – Train and complete vehicle.* This part specifies the emission and immunity requirements for all types of rolling stock. It covers traction rolling stock and trainsets, as well as independent hauled rolling stock. The scope of this part of the series ends at the interface of the rolling stock with its respective energy inputs and outputs.
– *Part 3-2: Rolling stock – Apparatus.* This part applies to emission and immunity aspects of EMC for electrical and electronic apparatus intended for use on railway rolling stock. It is also used as a means of dealing with the impracticality of immunity testing a complete vehicle.
– *Part 4: Emission and immunity of the signalling and telecommunications apparatus.* This part specifies limits for electromagnetic emission and immunity for signalling and telecommunications apparatus installed within a railway system. The EMC plan states if this part is also applicable for railway operational equipment mounted trackside or at platforms.
– *Part 5: Emission and immunity of fixed power supply installations and apparatus.* This part applies to emission and immunity aspects of EMC for electrical and electronic apparatus and components intended for use in railway fixed installations associated with power supply.

RAILWAY APPLICATIONS – ELECTROMAGNETIC COMPATIBILITY –

Part 1: General

1 Scope

~~1.1~~ This Part 1 of IEC 62236 outlines the structure and the content of the whole series.

It specifies the performance criteria applicable to the whole standards series.

Clause 5 provides information about the management of EMC.

Annex A describes the characteristics of the railway system which affect electromagnetic compatibility (EMC) behaviour.

Phenomena excluded from the series are nuclear EM pulse, abnormal operating conditions (e.g. fault conditions) and the induction effects of direct lightning strike.

Emission limits at the railway system boundary do not apply to intentional transmitters within the railway system boundaries.

Safety considerations are not covered by this series of standards.

The biological effects of non-ionising radiation as well as apparatus for medical assistance, such as pacemakers, are not considered in this series.

~~1.2 This part of IEC 62236 is supplemented by the following specific standards:~~

~~IEC 62236-2 *Railway applications – Electromagnetic compatibility – Part 2: Emission of the whole railway system to the outside world*~~

~~IEC 62236-3-1 *Railway applications – Electromagnetic compatibility – Part 3-1: Rolling stock – Train and complete vehicle*~~

~~IEC 62236-3-2 *Railway applications – Electromagnetic compatibility – Part 3-2: Rolling stock – Apparatus*~~

~~IEC 62236-4 *Railway applications – Electromagnetic compatibility – Part 4: Emission and immunity of the signalling and telecommunications apparatus*~~

~~IEC 62236-5 *Railway applications – Electromagnetic compatibility – Part 5: Emission and immunity of fixed power supply installations and apparatus*~~

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, *International Electrotechnical Vocabulary – Chapter 161: Electromagnetic compatibility* ~~*(EMC)*~~

IEC 61000 (all parts), *Electromagnetic compatibility (EMC)*

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

~~IEC 62427, *Railway applications – Compatibility between rolling stock and train detection systems*~~

3 Terms, definitions and abbreviated terms

For the purposes of this document, the terms and definitions ~~related to EMC and to relevant phenomena~~ 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 Terms and definitions

3.1.1
intentional transmitter
transmitting equipment dedicated to radiate electromagnetic energy, such as radio, television, communication

3.2 Abbreviated terms

AC	Alternating current
DC	Direct current
E	Electric (field)
EM	Electromagnetic
EMC	Electromagnetic compatibility
GTO	Gate turnoff (thyristor)
H	Magnetic (field)
IGBT	Insulated gate bipolar transistor
MVA	Megavoltampere
RF	Radio frequency

4 Performance criteria

NOTE This clause is based on IEC 61000-6-2:2016.

The variety and the diversity of the apparatus within the scope of this ~~series~~ set of standards makes it difficult to define precise criteria for the evaluation of the immunity test results.

~~If, as a result of the application of the tests defined in this series of standards, the apparatus becomes dangerous or unsafe, the apparatus shall be deemed to have failed the test.~~

A functional description and a definition of performance criteria, during or as a consequence of the EMC testing, shall be provided by the manufacturer and noted in the test report, based on the following criteria:

a) Performance criterion A

The apparatus shall continue to operate as intended during and after the test. No degradation of performance or loss of function is allowed below a performance level specified by the manufacturer, when the apparatus is used as intended. The performance level may be replaced by a permissible loss of performance. If the minimum performance level or the permissible performance loss is not specified by the manufacturer, either of these may be derived from the product description and documentation, and from what the user may reasonably expect from the apparatus if used as intended.

b) Performance criterion B

The apparatus shall continue to operate as intended after the test. No degradation of performance or loss of function is allowed below a performance level specified by the manufacturer, when the apparatus is used as intended. The performance level may be replaced by a permissible loss of performance. During the test, degradation of performance is however allowed. No change of actual operating state or stored data is allowed. If the minimum performance level or the permissible performance loss is not specified by the manufacturer, either of these may be derived from the product description and documentation, and from what the user may reasonably expect from the apparatus if used as intended.

c) Performance criterion C

Temporary loss of function is allowed, provided the function is self-recoverable or can be restored by the operation of the controls.

5 Management of EMC

The railway system is a complex installation with moving sources of electromagnetic energy and the application of the EMC standards in the IEC 62236 series is not a guarantee of satisfactory performance. There may be cases where apparatus has to be positioned in restricted spaces or added to an existing assembly, with the possible creation of environments of unusual severity. All cases shall be considered with respect to ~~a formal~~ an EMC plan ~~for the management of EMC~~. This plan should be established at as early a stage of the project as is possible.

~~Refer to IEC 62427 for the management process to achieve EMC between rolling stock and train detection systems.~~

For any new subsystem introduced within the railway systems boundary, potential sources and victims as well the coupling mechanisms between these sources and victims shall be considered.

The EMC plan shall make reference to the basic EMC phenomena described in the IEC 61000 series as applicable.

Annex A
(informative)

The railway system

A.1 General

For operating purposes, railway~~s~~ systems use electrical systems that require very high outputs (up to several MVA) and power electronic systems that are characterised by their non-linearity (producing harmonics).

In an electric railway system, the trains ~~must be~~ are supplied ~~via~~ by means of sliding contacts from a power supply line, called the ~~catenary or~~ overhead contact line, or a trackside conductor rail, which is installed along the track. The current generally returns to the substation via the rails, a separate return conductor or via the earth. The railway system is an integrated system in which electricity has many ~~other~~ uses in addition to train propulsion including:

- heating, air conditioning, catering and lighting of passenger coaches with converters on the vehicles. This power is fed along the train by separate conductors;
- signalling and telecommunication systems along the track and between control centres, concerned with the movement of trains;
- computer installations in control centres, linked via trackside routes;
- passenger information systems on vehicles, stations and depots;
- traction within diesel-electric locomotives and multiple units;
- battery traction vehicles.

Hence, problems of EMC arise not only within the ~~locomotive~~ traction unit and the power supply but also in these associated systems and their subsystems. Non-electrified traction such as diesel electric traction may also be a source of EM ~~noise~~ disturbances.

The normal and disturbed working of these systems may be a source of electromagnetic ~~noise~~ disturbance which can ~~affect~~ influence all other systems.

A.2 General coupling mechanisms

The coupling between systems is by the well known physical phenomena and limits are expressed in terms of these phenomena.

Five modes of coupling are distinguished:

- electrostatic coupling, in which a charged body is discharged to a victim circuit;
- capacitive coupling, in which the varying voltage in one circuit produces voltage changes in a victim circuit via mutual capacitance;
- inductive coupling, in which a varying magnetic field produced by a current in one circuit, links with a victim circuit, inducing a voltage via mutual inductance;
- conductive coupling, in which the source and victim circuits share a common conduction path;
- electric (E) and magnetic (H) radiation, in which the circuit structures act as antennas transmitting and receiving energy.

A.3 Principal electromagnetic phenomena for immunity

A.3.1 Conducted low frequency phenomena

Slow variations of the supply voltage including dips, surges, fluctuations, unbalance, harmonics, intermodulation products, data transfer carried on the power supply, power frequency variations, induced low frequency voltages and DC in AC networks.

A.3.2 Radiated low frequency field phenomena

Magnetic fields, both steady and transient. Electric fields.

A.3.3 Conducted high frequency phenomena

Unidirectional and oscillatory transients, as single events or repetitive bursts. Induced currents. Electrostatic discharge.

A.3.4 Radiated high frequency phenomena

Magnetic fields. Electric fields. Radio frequency radiated waves.

A.4 Principal electromagnetic phenomena for emission

In principle, the same phenomena exist as are listed for immunity, but limits have only been applied to the following:

– magnetic fields produced by power frequency and harmonic frequency currents~~, up to 9 kHz~~;
– voltage fluctuations produced by power frequency and harmonic currents;
– radio frequency fields produced by trains.

A.5 Description of the different electric traction systems

Direct current and alternating current sources are used.

DC systems include:

High voltage:	3 000 V
Medium voltage:	1 500 V
Low voltage:	from 600 V to 1 400 V, including ~~more~~ particularly urban transit systems.

AC systems include:

Industrial frequency:	50/60 Hz at 20/25 kV or Autotransformer System 50/25 kV or Booster Transformer System 20/25 kV or Autotransformer System 30/15 kV
Low frequency:	16,7 Hz at 15 kV.

Isolated three phase lines exist with two overhead conductors.

A.6 Components of electric traction systems

Traction power is generally supplied from the high voltage national or railway grid systems at voltages up to 400 kV. Connection points, known as substations, perform the following functions:

– protection (circuit breakers) for both public and railway system interests;
– adaptation of voltage level by transformer;
– possible rectification to provide DC supply or frequency conversion to give low frequency supply.

The power obtained by this means is transmitted to the traction vehicle via a system of flexible-suspension contact lines (known as the overhead ~~catenary~~ contact line) with which a ~~locomotive~~ traction unit-mounted articulated device (known as the pantograph) is brought into contact. On low voltage lines, a trackside conductor rail may be provided from which power is collected by a sliding contact (known as the collector shoe).

On the traction vehicle, the traction power is regulated and supplied to ~~electric~~ traction motors to control the movement of the train. Auxiliary power is also regulated and, although of lower power than that supplied to the ~~electric~~ traction motors, can still be a significant source of electromagnetic ~~noise~~ disturbance.

On AC lines, circuit components may be added to the traction power supply lines (e.g. auto-transformers or booster transformers) to reduce the magnetic field and hence the induced voltage in telecommunication circuits.

A.7 Internal sources of electromagnetic ~~noise~~ disturbance

A.7.1 General

There are several rail-specific components which produce electromagnetic ~~noise~~ disturbance. These include:

A.7.2 ~~Static~~ Fixed elements

The overhead line of the railway system and the high voltage line feeding the substation can be the source of high or low frequency ~~noise~~ disturbance.

Among the phenomena which are involved in RF emission are:

– the corona effect, where ionisation of neutral molecules in the electric field close to the conductors produces RF ~~noise~~ disturbance. This can exist along the whole alignment;
– brush discharges in zones of high voltage gradient on the surface of insulators;
– discharge type micro-arcs at bad contacts between energised metallic parts. These effects are local and attenuate rapidly with distance;
– partial flashovers across dry bands of polluted insulator surfaces.

Railway overhead systems differ from most high voltage overhead lines by being closer to the ground, having more insulators and having less natural cleaning of the insulators.

Low frequency ~~noise~~ disturbance can be significant within a wide zone, up to 3 km (or more if the ground resistivity is high). It is produced transiently at substations when high voltage switching takes place, is distributed along the overhead line when it is energised, is enhanced when non-linear traction loads such as rectifiers are supplied, and is stimulated locally when flashover takes place. If a DC traction system is used, low frequency harmonics are produced by the rectifier substation.

A.7.3 Mobile elements

Motive power units (electric ~~locomotives~~ traction units or multiple unit coaches) are a source of electromagnetic ~~noise~~ disturbance during routine working, primarily controlled by the following equipment:

– power control systems using controlled semiconductors such as thyristors, GTOs and IGBTs. These produce energy, which gives either direct radiation from the vehicle components or indirect radiation via the power supply lines. An overhead line can act as an antenna;

– auxiliary apparatus on traction vehicles may have relatively high power rating and ~~must be considered as~~ are a source of ~~noise~~ disturbance;

– the sliding contact between the line and the pantograph (or shoe and rail). This collection is via a series of short arcs which act as radio sources;

– special case arcing and transients which are produced when the pantograph is raised or lowered, or the vehicle circuit breaker is closed or opened.

Diesel-electric ~~locomotives~~ traction units should be included since they can contain semiconductor power control which can generate ~~noise~~ disturbance. Such ~~locomotives~~ traction units also contain auxiliary systems which may be sources.

A.7.4 Onboard auxiliary power converters

Coaching rolling stock air conditioning, catering and similar systems may be supplied via a semiconductor static converter and these may be sources of ~~noise~~ disturbance. These converters may be on several coaches in a train and the summation of their ~~noise must be considered~~ disturbance is relevant.

A.7.5 Train line

The ~~locomotive~~ traction unit supplies power, generally at voltages less than or equal to 1 500 V, sometimes at 3 000 V, at powers up to 800 kW, to the electric systems of the train for lighting, heating, air-conditioning, battery charging, and converters through a conductor (termed “train line”). This current, which can be 800 A, is a source of ~~noise~~ disturbance to adjacent equipment.

This auxiliary current may return to the ~~locomotive~~ traction unit via the rails and hence have an influence on apparatus on the track. Train lengths of several hundred metres are not unusual.

A.7.6 Traction return current with respect to track circuits

An electrical supply (continuous, alternating or pulse) is connected across the running rails, in what is known as a track circuit. A track circuit is a system using the rails as transmission path between emitter and receiver with the aim to detect the presence of railway vehicles. When a train travels on the track, its axles short-circuit a detector ~~of~~ from this electrical supply and the presence of the train ~~is~~ will be detected. Electrical ~~noise~~ disturbance may energise the detector although the train is present, giving a false indication of clear track. Track circuits take many forms with some having frequency and time coding to reduce the risk of false energisation.

Since the power supply may contain voltage components at track circuit frequencies, the input impedance of the train may have to be greater than a specified value. This prevents the passage of currents at track circuit frequencies in the running rails. The traction and auxiliary equipment on the vehicle and the substations should not be allowed to generate currents at track circuit frequencies which exceed specified values. Limits are applied for particular cases. These effects are entirely internal to the railway system and many different cases can exist.

A.7.7 Trackside equipment

Electricity is used in trackside ~~cabinets~~ equipment to ~~drive~~ supply switch motors, heating and train pre-heating as well as other apparatus. Although of relatively low power, these elements are close to the line and may affect other railway apparatus.

A.8 Summary of main characteristics of railways systems

The essential differences between electric railways systems and other large electric networks are:

– a very wide variety of power supply configurations;
– a very wide variety of power use and control systems and sub-systems;
– the use of sliding contacts to convey high powers to the moving trains;
– the high speed of some trains;
– the presence of several moving sources within the same zone of influence;
– a fluctuating and imprecise system of current flow to and from the train, including the passage of current via the ground;
– high single phase loads which may cause imbalance in the three phase system;
– the possibility of simultaneous generation of disturbance from several sources;
– generation of EM ~~noise~~ disturbance over a wide frequency spectrum;
– the interaction of supply and vehicles to enhance or diminish the effect at any given frequency.

A.9 External sources of disturbance

The railway system is distributed through the public domain and is exposed to various sources of EM ~~noise~~ disturbance at various places.

These include:

– neighbouring railway systems;
– ~~trackside radio stations (e.g. GSM-R system), sometimes operating at high powers;~~
– ~~portable~~ radio transmitters including portable telephones;
– adjacent overhead power lines from which power frequency induction may be experienced;
– radar sets at airports, on aircraft, in military use;
– industrial plants which disturb the electricity supply network.

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IEC 61000-6-2:2016, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity standard for industrial environments*

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**Applications ferroviaires – Compatibilité électromagnétique –
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- amended.

INTRODUCTION

The railway system EMC series of product-specific International Standards consists of five parts described at the end of this introduction.

The series of standards provides both a framework for managing the EMC for railway systems and also specifies the limits for the electromagnetic (EM) emission of the railway system as a whole to the outside world and for the EM emission and immunity for equipment operating within the railway system. The latter is intended to be compatible with the emission limits set for the railway system as a whole and also provides for establishing confidence in equipment being fit for purpose in the railway environment. There are different stationary emission limits set for trams/trolleybuses and for metro/mainline railway systems. The frequency covered by the standards is in the range from DC to 400 GHz. No measurements need to be performed at frequencies where no requirement is specified. The limits for EMC phenomena are set so that the railway system as a whole achieves electromagnetic compatibility with the outside world, and between the various parts of the railway system. Throughout the series of standards, the immunity levels are chosen to ensure a reasonable level of EMC with other apparatus within the local railway environment and with emissions which enter the railway system from the outside world. Limits are also placed on EM emission by railway systems into the outside world.

The compatibility between railway system emissions and their external environment is based upon emission limits from the railway systems being set by considering the results from measurements. Given that the general compatibility between railway systems and their environment was satisfactory at the time these measurements were made and subsequent experience of applying the limits has confirmed their acceptability, compliance with this document has been judged to give satisfactory compatibility. The immunity and emission levels do not of themselves guarantee that the railway system will have satisfactory EMC with its neighbours. In exceptional circumstances, for instance near a “special location” which has unusually high levels of EM interference, the railway system may require additional measures to be taken to ensure proper compatibility. Particular care should be taken when in proximity to equipment such as radio transmission equipment, military or medical installations. Attention is particularly drawn to any magnetic imaging equipment in hospitals that may be near to urban transport. In all these cases, compatibility should be achieved with consultation and co-operation between the interested parties.

The immunity and emission levels do not of themselves guarantee that integration of the apparatus within the railway system will necessarily be satisfactory. The document cannot cover all the possible configurations of apparatus, but the test levels are sufficient to achieve satisfactory EMC in the majority of cases. In exceptional circumstances, for instance near a “special location” which has unusually high levels of EM interference, the system may require additional measures to be taken to ensure proper operation. The resolution of this is a matter for discussion between the equipment supplier and the project manager, infrastructure manager or equivalent.

The railway apparatus is assembled into large systems and installations, such as trains and signalling control centres. Details are given in annex A. It is not, therefore, possible to establish immunity tests and limits for these large assemblies. The immunity levels for the apparatus will normally ensure reliable operation, but it is necessary to prepare an EMC plan to deal with complex situations or to deal with specific circumstances. For example, the passage of the railway line close to a high power radio transmitter which produces abnormally high field strengths. Special conditions may be applied for railway equipment which works near such a transmitter and these will be accepted as national conditions for the specification.

The series of standards IEC 62236, *Railway applications – Electromagnetic compatibility*, contains the following parts:

– *Part 1: General.* This part gives a description of the electromagnetic behaviour of a railway system; it specifies the performance criteria for the whole series. A management process to achieve EMC at the interface between the railway infrastructure and trains is referenced.

– *Part 2: Emission of the whole railway system to the outside world.* This part sets the emission limits from the railway system to the outside world at radio frequencies. It defines the applied test methods and gives information on typical field strength values at traction and radio frequency (cartography).
– *Part 3-1: Rolling stock – Train and complete vehicle.* This part specifies the emission and immunity requirements for all types of rolling stock. It covers traction rolling stock and trainsets, as well as independent hauled rolling stock. The scope of this part of the series ends at the interface of the rolling stock with its respective energy inputs and outputs.
– *Part 3-2: Rolling stock – Apparatus.* This part applies to emission and immunity aspects of EMC for electrical and electronic apparatus intended for use on railway rolling stock. It is also used as a means of dealing with the impracticality of immunity testing a complete vehicle.
– *Part 4: Emission and immunity of the signalling and telecommunications apparatus.* This part specifies limits for electromagnetic emission and immunity for signalling and telecommunications apparatus installed within a railway system. The EMC plan states if this part is also applicable for railway operational equipment mounted trackside or at platforms.
– *Part 5: Emission and immunity of fixed power supply installations and apparatus.* This part applies to emission and immunity aspects of EMC for electrical and electronic apparatus and components intended for use in railway fixed installations associated with power supply.

RAILWAY APPLICATIONS – ELECTROMAGNETIC COMPATIBILITY –

Part 1: General

1 Scope

This Part 1 of IEC 62236 outlines the structure and the content of the whole series.

It specifies the performance criteria applicable to the whole standards series.

Clause 5 provides information about the management of EMC.

Annex A describes the characteristics of the railway system which affect electromagnetic compatibility (EMC) behaviour.

Phenomena excluded from the series are nuclear EM pulse, abnormal operating conditions (e.g. fault conditions) and the induction effects of direct lightning strike.

Emission limits at the railway system boundary do not apply to intentional transmitters within the railway system boundaries.

Safety considerations are not covered by this series of standards.

The biological effects of non-ionising radiation as well as apparatus for medical assistance, such as pacemakers, are not considered in this series.

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, *International Electrotechnical Vocabulary. Chapter 161: Electromagnetic compatibility*

IEC 61000 (all parts), *Electromagnetic compatibility (EMC)*

3 Terms, definitions and abbreviated terms

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 Terms and definitions

3.1.1
intentional transmitter
transmitting equipment dedicated to radiate electromagnetic energy, such as radio, television, communication

3.2 Abbreviated terms

AC	Alternating current
DC	Direct current
E	Electric (field)
EM	Electromagnetic
EMC	Electromagnetic compatibility
GTO	Gate turnoff (thyristor)
H	Magnetic (field)
IGBT	Insulated gate bipolar transistor
MVA	Megavoltampere
RF	Radio frequency

4 Performance criteria

NOTE This clause is based on IEC 61000-6-2:2016.

The variety and the diversity of the apparatus within the scope of this set of standards makes it difficult to define precise criteria for the evaluation of the immunity test results.

A functional description and a definition of performance criteria, during or as a consequence of the EMC testing, shall be provided by the manufacturer and noted in the test report, based on the following criteria:

a) Performance criterion A

The apparatus shall continue to operate as intended during and after the test. No degradation of performance or loss of function is allowed below a performance level specified by the manufacturer, when the apparatus is used as intended. The performance level may be replaced by a permissible loss of performance. If the minimum performance level or the permissible performance loss is not specified by the manufacturer, either of these may be derived from the product description and documentation, and from what the user may reasonably expect from the apparatus if used as intended.

b) Performance criterion B

The apparatus shall continue to operate as intended after the test. No degradation of performance or loss of function is allowed below a performance level specified by the manufacturer, when the apparatus is used as intended. The performance level may be replaced by a permissible loss of performance. During the test, degradation of performance is however allowed. No change of actual operating state or stored data is allowed. If the minimum performance level or the permissible performance loss is not specified by the manufacturer, either of these may be derived from the product description and documentation, and from what the user may reasonably expect from the apparatus if used as intended.

c) Performance criterion C

Temporary loss of function is allowed, provided the function is self-recoverable or can be restored by the operation of the controls.

5 Management of EMC

The railway system is a complex installation with moving sources of electromagnetic energy and the application of the EMC standards in the IEC 62236 series is not a guarantee of satisfactory performance. There may be cases where apparatus has to be positioned in restricted spaces or added to an existing assembly, with the possible creation of environments of unusual severity. All cases shall be considered with respect to an EMC plan. This plan should be established at as early a stage of the project as is possible.

For any new subsystem introduced within the railway systems boundary, potential sources and victims as well the coupling mechanisms between these sources and victims shall be considered.

The EMC plan shall make reference to the basic EMC phenomena described in the IEC 61000 series as applicable.

Annex A
(informative)

The railway system

A.1 General

For operating purposes, railway systems use electrical systems that require very high outputs (up to several MVA) and power electronic systems that are characterised by their non-linearity (producing harmonics).

In an electric railway system, the trains are supplied by means of sliding contacts from a power supply line, called the overhead contact line, or a trackside conductor rail, which is installed along the track. The current generally returns to the substation via the rails, a separate return conductor or via the earth. The railway system is an integrated system in which electricity has many uses in addition to train propulsion including:

– heating, air conditioning, catering and lighting of passenger coaches with converters on the vehicles. This power is fed along the train by separate conductors;
– signalling and telecommunication systems along the track and between control centres, concerned with the movement of trains;
– computer installations in control centres, linked via trackside routes;
– passenger information systems on vehicles, stations and depots;
– traction within diesel-electric locomotives and multiple units;
– battery traction vehicles.

Hence, problems of EMC arise not only within the traction unit and the power supply but also in these associated systems and their subsystems. Non-electrified traction such as diesel electric traction may also be a source of EM disturbances.

The normal and disturbed working of these systems may be a source of electromagnetic disturbance which can influence all other systems.

A.2 General coupling mechanisms

The coupling between systems is by the well known physical phenomena and limits are expressed in terms of these phenomena.

Five modes of coupling are distinguished:

– electrostatic coupling, in which a charged body is discharged to a victim circuit;
– capacitive coupling, in which the varying voltage in one circuit produces voltage changes in a victim circuit via mutual capacitance;
– inductive coupling, in which a varying magnetic field produced by a current in one circuit, links with a victim circuit, inducing a voltage via mutual inductance;
– conductive coupling, in which the source and victim circuits share a common conduction path;
– electric (E) and magnetic (H) radiation, in which the circuit structures act as antennas transmitting and receiving energy.

A.3 Principal electromagnetic phenomena for immunity

A.3.1 Conducted low frequency phenomena

Slow variations of the supply voltage including dips, surges, fluctuations, unbalance, harmonics, intermodulation products, data transfer carried on the power supply, power frequency variations, induced low frequency voltages and DC in AC networks.

A.3.2 Radiated low frequency field phenomena

Magnetic fields, both steady and transient. Electric fields.

A.3.3 Conducted high frequency phenomena

Unidirectional and oscillatory transients, as single events or repetitive bursts. Induced currents. Electrostatic discharge.

A.3.4 Radiated high frequency phenomena

Magnetic fields. Electric fields. Radio frequency radiated waves.

A.4 Principal electromagnetic phenomena for emission

In principle, the same phenomena exist as are listed for immunity, but limits have only been applied to the following:

– magnetic fields produced by power frequency and harmonic frequency currents;
– voltage fluctuations produced by power frequency and harmonic currents;
– radio frequency fields produced by trains.

A.5 Description of the different electric traction systems

Direct current and alternating current sources are used.

DC systems include:

High voltage:	3 000 V
Medium voltage:	1 500 V
Low voltage:	from 600 V to 1 400 V, including particularly urban transit systems.

AC systems include:

Industrial frequency:	50/60 Hz at 20/25 kV or Autotransformer System 50/25 kV or Booster Transformer System 20/25 kV or Autotransformer System 30/15 kV
Low frequency:	16,7 Hz at 15 kV.

Isolated three phase lines exist with two overhead conductors.

A.6 Components of electric traction systems

Traction power is generally supplied from the high voltage national or railway grid systems at voltages up to 400 kV. Connection points, known as substations, perform the following functions:

– protection (circuit breakers) for both public and railway system interests;

– adaptation of voltage level by transformer;
– possible rectification to provide DC supply or frequency conversion to give low frequency supply.

The power obtained by this means is transmitted to the traction vehicle via a system of flexible-suspension contact lines (known as the overhead contact line) with which a traction unit-mounted articulated device (known as the pantograph) is brought into contact. On low voltage lines, a trackside conductor rail may be provided from which power is collected by a sliding contact (known as the collector shoe).

On the traction vehicle, the traction power is regulated and supplied to traction motors to control the movement of the train. Auxiliary power is also regulated and, although of lower power than that supplied to the traction motors, can still be a significant source of electromagnetic disturbance.

On AC lines, circuit components may be added to the traction power supply lines (e.g. auto-transformers or booster transformers) to reduce the magnetic field and hence the induced voltage in telecommunication circuits.

A.7 Internal sources of electromagnetic disturbance

A.7.1 General

There are several rail-specific components which produce electromagnetic disturbance. These include:

A.7.2 Fixed elements

The overhead line of the railway system and the high voltage line feeding the substation can be the source of high or low frequency disturbance.

Among the phenomena which are involved in RF emission are:

– the corona effect, where ionisation of neutral molecules in the electric field close to the conductors produces RF disturbance. This can exist along the whole alignment;
– brush discharges in zones of high voltage gradient on the surface of insulators;
– discharge type micro-arcs at bad contacts between energised metallic parts. These effects are local and attenuate rapidly with distance;
– partial flashovers across dry bands of polluted insulator surfaces.

Railway overhead systems differ from most high voltage overhead lines by being closer to the ground, having more insulators and having less natural cleaning of the insulators.

Low frequency disturbance can be significant within a wide zone, up to 3 km (or more if the ground resistivity is high). It is produced transiently at substations when high voltage switching takes place, is distributed along the overhead line when it is energised, is enhanced when non-linear traction loads such as rectifiers are supplied, and is stimulated locally when flashover takes place. If a DC traction system is used, low frequency harmonics are produced by the rectifier substation.

A.7.3 Mobile elements

Motive power units (electric traction units or multiple unit coaches) are a source of electromagnetic disturbance during routine working, primarily controlled by the following equipment:

– power control systems using controlled semiconductors such as thyristors, GTOs and IGBTs. These produce energy, which gives either direct radiation from the vehicle components or indirect radiation via the power supply lines. An overhead line can act as an antenna;

- auxiliary apparatus on traction vehicles may have relatively high power rating and are a source of disturbance;
- the sliding contact between the line and the pantograph (or shoe and rail). This collection is via a series of short arcs which act as radio sources;
- special case arcing and transients which are produced when the pantograph is raised or lowered, or the vehicle circuit breaker is closed or opened.

Diesel-electric traction units should be included since they can contain semiconductor power control which can generate disturbance. Such traction units also contain auxiliary systems which may be sources.

A.7.4 Onboard auxiliary power converters

Coaching rolling stock air conditioning, catering and similar systems may be supplied via a semiconductor static converter and these may be sources of disturbance. These converters may be on several coaches in a train and the summation of their disturbance is relevant.

A.7.5 Train line

The traction unit supplies power, generally at voltages less than or equal to 1 500 V, sometimes at 3 000 V, at powers up to 800 kW, to the electric systems of the train for lighting, heating, air-conditioning, battery charging, and converters through a conductor (termed “train line”). This current, which can be 800 A, is a source of disturbance to adjacent equipment.

This auxiliary current may return to the traction unit via the rails and hence have an influence on apparatus on the track. Train lengths of several hundred metres are not unusual.

A.7.6 Traction return current with respect to track circuits

An electrical supply (continuous, alternating or pulse) is connected across the running rails, in what is known as a track circuit. A track circuit is a system using the rails as transmission path between emitter and receiver with the aim to detect the presence of railway vehicles. When a train travels on the track, its axles short-circuit a detector from this electrical supply and the presence of the train will be detected. Electrical disturbance may energise the detector although the train is present, giving a false indication of clear track. Track circuits take many forms with some having frequency and time coding to reduce the risk of false energisation.

Since the power supply may contain voltage components at track circuit frequencies, the input impedance of the train may have to be greater than a specified value. This prevents the passage of currents at track circuit frequencies in the running rails. The traction and auxiliary equipment on the vehicle and the substations should not be allowed to generate currents at track circuit frequencies which exceed specified values. Limits are applied for particular cases. These effects are entirely internal to the railway system and many different cases can exist.

A.7.7 Trackside equipment

Electricity is used in trackside equipment to supply switch motors, heating and train pre-heating as well as other apparatus. Although of relatively low power, these elements are close to the line and may affect other railway apparatus.

A.8 Summary of main characteristics of railway systems

The essential differences between electric railway systems and other large electric networks are:

– a very wide variety of power supply configurations;
– a very wide variety of power use and control systems and sub-systems;
– the use of sliding contacts to convey high powers to the moving trains;
– the high speed of some trains;
– the presence of several moving sources within the same zone of influence;
– a fluctuating and imprecise system of current flow to and from the train, including the passage of current via the ground;
– high single phase loads which may cause imbalance in the three phase system;
– the possibility of simultaneous generation of disturbance from several sources;
– generation of EM disturbance over a wide frequency spectrum;
– the interaction of supply and vehicles to enhance or diminish the effect at any given frequency.

A.9 External sources of disturbance

The railway system is distributed through the public domain and is exposed to various sources of EM disturbance at various places.

These include:

– neighbouring railway systems;
– radio transmitters including portable telephones;
– adjacent overhead power lines from which power frequency induction may be experienced;
– radar sets at airports, on aircraft, in military use;
– industrial plants which disturb the electricity supply network.

Bibliography

IEC 61000-6-2:2016, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity standard for industrial environments*

SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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APPLICATIONS FERROVIAIRES – COMPATIBILITÉ ÉLECTROMAGNÉTIQUE –

Partie 1: Généralités

AVANT-PROPOS

1) La Commission Electrotechnique Internationale (IEC) est une organisation mondiale de normalisation composée de l'ensemble des comités électrotechniques nationaux (Comités nationaux de l'IEC). L'IEC a pour objet de favoriser la coopération internationale pour toutes les questions de normalisation dans les domaines de l'électricité et de l'électronique. A cet effet, l'IEC – entre autres activités – publie des Normes internationales, des Spécifications techniques, des Rapports techniques, des Spécifications accessibles au public (PAS) et des Guides (ci-après dénommés "Publication(s) de l'IEC"). Leur élaboration est confiée à des comités d'études, aux travaux desquels tout Comité national intéressé par le sujet traité peut participer. Les organisations internationales, gouvernementales et non gouvernementales, en liaison avec l'IEC, participent également aux travaux. L'IEC collabore étroitement avec l'Organisation Internationale de Normalisation (ISO), selon des conditions fixées par accord entre les deux organisations.
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La Norme internationale IEC 62236-1 a été établie par le comité d'études 9 de l'IEC: Matériels et systèmes électriques ferroviaires.

Cette troisième édition annule et remplace la deuxième édition publiée en 2008. Elle constitue une révision technique et a été développée sur la base de EN 50121-1:2015.

Cette édition inclut les changements techniques significatifs suivants par rapport à l'édition précédente:

a) Clarification du domaine d'application.
b) Introduction du paragraphe Termes abrégés.
c) La gestion de l'EMC se base dorénavant sur la série IEC 61000, car la référence précédente n'est pas adéquate.

Le texte de cette Norme internationale est issu des documents suivants:

FDIS	Rapport de vote
9/2335/FDIS	9/2365/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette norme.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2.

Une liste de toutes les parties de la série IEC 62236, publiées sous le titre général *Applications ferroviaires – Compatibilité électromagnétique*, peut être consultée sur le site web de l'IEC.

Le comité a décidé que le contenu de ce document ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous "http://webstore.iec.ch" dans les données relatives au document recherché. A cette date, le document sera

- reconduit,
- supprimé,
- remplacé par une édition révisée, ou
- amendé.

INTRODUCTION

Cette série de Normes internationales de produits comprend cinq parties qui sont décrites à la fin de cette introduction.

Cette série de normes fournit à la fois un cadre pour la gestion de la CEM à l'intérieur du domaine ferroviaire et spécifie également les limites d'émission électromagnétique (EM) du système ferroviaire dans son ensemble vers le monde extérieur ainsi que les limites d'émission et d'immunité EM des équipements qui fonctionnent dans le système ferroviaire. Ces dernières sont destinées à être compatibles avec les limites d'émission définies pour le système ferroviaire dans son ensemble et également apporter l'assurance que les équipements sont adaptés pour l'environnement ferroviaire. En statique, des limites d'émission différentes sont définies pour les trams/trolleybus et les métros/grandes lignes. La fréquence couverte par ces normes va du courant continu à 400 GHz. Aucun mesurage n'est nécessaire aux fréquences pour lesquelles aucune exigence n'est spécifiée. Les limites pour les phénomènes de CEM sont fixées de manière à ce que le système ferroviaire pris dans son ensemble obtient la compatibilité électromagnétique avec le monde extérieur, et entre les différents éléments du système ferroviaire. Dans cette série de normes, les niveaux d'immunité sont choisis pour assurer un niveau raisonnable de CEM avec les autres appareils dans l'environnement ferroviaire local et avec les émissions qui pénètrent le système ferroviaire et qui proviennent du monde extérieur. Sont également fixées des limites pour les émissions EM produites par les systèmes ferroviaires et affectant le monde extérieur.

La compatibilité entre les émissions des chemins de fer et l'environnement extérieur est basée sur les limites d'émission ferroviaires établies en tenant compte des résultats de mesures effectuées. Étant donné que la compatibilité générale entre les chemins de fer et leur environnement était satisfaisante au moment où les mesures ont été réalisées et que l'expérience tirée de l'application des limites a confirmé leur acceptabilité, il a été jugé que la conformité au présent document donnait une CEM satisfaisante. Les niveaux d'émission et d'immunité ne garantissent pas par eux-mêmes une conformité satisfaisante du système ferroviaire à celui de ses voisins. Dans des circonstances exceptionnelles, par exemple à proximité d'un "emplacement spécial" qui a des niveaux d'interférences EM exceptionnellement élevés, le système ferroviaire peut requérir de prendre des mesures complémentaires pour assurer une compatibilité convenable. Il convient d'apporter un soin particulier à proximité d'équipements, tels que les appareils de transmission radio, les installations médicales ou militaires. Une attention toute particulière est portée aux équipements à imagerie magnétique dans les hôpitaux qui peuvent être près des transports urbains. Dans tous ces cas, il convient que la compatibilité soit atteinte après consultation et coopération entre les parties intéressées.

Les niveaux d'immunité et d'émission ne garantissent pas par eux-mêmes que l'intégration des appareils à l'intérieur du système ferroviaire est nécessairement satisfaisante. Le présent document ne peut pas couvrir toutes les configurations possibles d'appareils mais les niveaux d'essai sont suffisants pour obtenir une CEM satisfaisante dans la majorité des cas. Dans des circonstances exceptionnelles, par exemple à proximité d'un "emplacement spécial" qui a des niveaux d'interférences EM exceptionnellement élevés, le système peut requérir de prendre des mesures complémentaires pour assurer un fonctionnement correct. Une telle décision fait l'objet d'une discussion entre le fournisseur de l'équipement et le chef de projet, le responsable d'infrastructure ou une personne de responsabilité équivalente.

Les appareils ferroviaires sont assemblés dans de grands systèmes et installations, tels que les trains et les centres de commande de la signalisation. Des informations plus précises sont données à l'Annexe A. Il n'est donc pas possible d'établir des essais et des limites d'immunité pour ces ensembles de grande taille. Les niveaux d'immunité pour les appareils assurent normalement un fonctionnement fiable mais il est nécessaire de préparer un plan de CEM pour traiter les situations complexes ou les circonstances particulières. Par exemple, le passage d'une ligne de chemin de fer à proximité d'un émetteur radiofréquence de grande puissance qui produit des champs anormalement élevés. Des conditions spéciales peuvent s'appliquer pour les équipements ferroviaires qui fonctionnent à proximité d'un tel émetteur et celles-ci sont acceptées comme conditions nationales pour la spécification.

La série de Normes IEC 62236, *Applications ferroviaires – Compatibilité électromagnétique* se compose des parties suivantes:

– *Partie 1: Généralités.* Cette partie donne une description du comportement électromagnétique du système ferroviaire. Elle spécifie les critères d'aptitude à la fonction pour l'ensemble de la série. Un processus de gestion pour obtenir la compatibilité électromagnétique à l'interface de l'infrastructure ferroviaire et des trains est mentionné.

– *Partie 2: Émission du système ferroviaire dans son ensemble vers le monde extérieur.* Cette partie définit les limites d'émission du système ferroviaire vers le monde extérieur aux radiofréquences. Elle définit les méthodes d'essai appliquées et donne des informations sur les valeurs typiques des champs aux fréquences de traction et en radiofréquence (cartographie).

– *Partie 3-1: Matériel roulant – Trains et véhicules complets.* Cette partie spécifie les exigences d'émission et d'immunité pour tous les types de matériels roulants. Elle couvre le matériel de traction et les rames, ainsi que le matériel tracté. Le domaine d'application de cette partie de la série s'arrête à l'interface du matériel et de ses entrées et sorties d'énergie respectives.

– *Partie 3-2: Matériel roulant – Appareils.* Cette partie s'applique aux aspects d'émission et d'immunité de la CEM pour les appareils électriques et électroniques destinés à être utilisés à bord du matériel roulant ferroviaire. Elle est également utilisée comme moyen de traiter l'impossibilité de faire des essais d'immunité sur le véhicule en totalité.

– *Partie 4: Émission et immunité des appareils de signalisation et de télécommunication.* Cette partie spécifie les limites d'émission électromagnétique et d'immunité pour les appareils de signalisation et de télécommunication installés à l'intérieur d'un système ferroviaire. Le plan CEM énonce si cette partie s'applique également aux équipements opérationnels ferroviaires installés le long de la voie ou sur des quais.

– *Partie 5: Émission et immunité des installations fixes d'alimentation de puissance et des équipements associés.* Cette partie s'applique aux aspects d'émission et d'immunité de la CEM pour les appareils et les composants électriques et électroniques destinés à être utilisés dans les installations ferroviaires fixes associées à l'alimentation.

APPLICATIONS FERROVIAIRES – COMPATIBILITÉ ÉLECTROMAGNÉTIQUE –

Partie 1: Généralités

1 Domaine d'application

La présente Partie 1 de la série IEC 62236 donne la structure et le contenu de l'ensemble de la série.

Elle spécifie les critères d'aptitude à la fonction applicables à l'ensemble de la série de normes.

L'Article 5 donne des informations relatives à la gestion de la CEM.

L'Annexe A décrit les caractéristiques du système ferroviaire qui affectent la compatibilité électromagnétique (CEM).

Les phénomènes exclus de cette série de normes sont l'impulsion électromagnétique nucléaire, les conditions anormales de fonctionnement (conditions de défaut, par exemple) et les effets d'induction dus à un choc direct de la foudre.

Les limites d'émission à la limite du système ferroviaire ne s'appliquent pas aux émetteurs intentionnels dans les limites du système ferroviaire.

Les aspects relatifs à la sécurité ne sont pas couverts par cette série de normes.

Les effets biologiques des rayonnements non ionisants ainsi que les appareils d'assistance médicale, tels que les stimulateurs cardiaques, ne sont pas traités dans cette série.

2 Références normatives

Les documents suivants cités dans le texte constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60050-161, *Vocabulaire Electrotechnique International. Chapitre 161: Compatibilité électromagnétique*

IEC 61000 (toutes les parties), *Compatibilité électromagnétique (CEM)*

3 Termes, définitions et termes abrégés

Pour les besoins du présent document, les termes et définitions donnés dans l'IEC 60050-161 ainsi que les suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse http://www.electropedia.org/

- ISO Online browsing platform: disponible à l'adresse http://www.iso.org/obp

3.1 Termes et définitions

3.1.1
émetteur intentionnel
équipement de transmission dédié à rayonner de l'énergie électromagnétique, par exemple une radio, une télévision, une communication

3.2 Termes abrégés

CA	courant alternatif
CC	courant continu
E	(champ) électrique
EM	électromagnétique
CEM	compatibilité électromagnétique
GTO	gate turnoff (transistor) (thyristor blocable)
H	(champ) magnétique
IGBT	insulated gate bipolar transistor (transistor bipolaire à grille isolée)
MVA	mégavolt ampère
RF	radiofréquence

4 Critères d'aptitude à la fonction

NOTE Cet article est fondé sur l'IEC 61000-6-2:2016.

La variété et la diversité des appareils couverts par le domaine d'application de la présente série de normes rendent difficile la définition de critères précis pour l'évaluation des résultats des essais d'immunité.

Une description fonctionnelle et une définition des critères d'aptitude à la fonction, pendant ou après les essais de CEM, doivent être fournies par le fabricant et notées dans le rapport d'essai sur la base des critères d'aptitude à la fonction suivants:

a) Critères d'aptitude à la fonction A

L'appareil doit continuer à fonctionner comme prévu pendant et après l'essai. Aucune dégradation du fonctionnement ou perte de fonction n'est autorisée au-dessous du niveau d'aptitude spécifié par le fabricant lorsque l'appareil est utilisé comme prévu. Le niveau d'aptitude peut être remplacé par une perte d'aptitude admissible. Si le niveau minimal d'aptitude ou la perte d'aptitude admissible n'est pas spécifié par le fabricant, ils peuvent être déduits de la description et de la documentation du produit et de ce que l'utilisateur est raisonnablement en droit d'attendre de l'appareil s'il est utilisé comme prévu.

b) Critères d'aptitude à la fonction B

L'appareil doit continuer à fonctionner comme prévu après l'essai. Aucune dégradation du fonctionnement ou perte de fonction n'est autorisée au-dessous du niveau d'aptitude spécifié par le fabricant lorsque l'appareil est utilisé comme prévu. Le niveau d'aptitude peut être remplacé par une perte d'aptitude admissible. Pendant l'essai, une dégradation de fonctionnement est toutefois autorisée. Aucune modification du mode de fonctionnement en cours ou des données mémorisées n'est autorisée. Si le niveau minimal d'aptitude ou la perte d'aptitude admissible n'est pas spécifié par le fabricant, ils peuvent être déduits de la description et de la documentation du produit et de ce que l'utilisateur est raisonnablement en droit d'attendre de l'appareil s'il est utilisé comme prévu.