

Design guidelines

Railway Energy: Part 4

Electromagnetic compatibility

19-03-2018



Co-financed by the European Union
Connecting Europe Facility

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1. Regulations, Codes, Standards, and Guidelines

The principal international codes, and standards employed for the design shall include, but not be limited to, the following:

1.1. European Standards:

- EN 50121 (IEC 62236) Railway applications. Electromagnetic compatibility. Rolling stock. Apparatus
- EN50122 Railway applications - Fixed installations - Electrical Safety, Earthing and the return circuit
- EN 50238-3 Railway applications – Compatibility between Rolling Stock and Train detection systems – Part 3 – Compatibility with axle counters
- EN 50343 Railway applications - Rolling stock - Rules for installation of cabling
- EN 50122-3 - Railway applications – Fixed installations – Electrical safety, earthing and the return circuit. Mutual Interaction of a.c. and d.c. traction systems (see Note 1)
- EN50126 Railway applications. The specification and demonstration of reliability, availability, maintainability and safety (RAMS). Basic requirements and generic process
- EN 50500 Measurement procedures of magnetic field levels generated by electronic and electrical apparatus in the railway environment with respect to human exposure.
- TR IEC 61000-5-6 EMC, part 5; Installation and mitigation guidelines, section 6; mitigations of external EM influences.
- IEC61000-5-2 Electromagnetic compatibility (EMC) - Part 5: Installation and mitigation guidelines - Section 2: Earthing and cabling
- IEC61000-5-1 Electromagnetic compatibility (EMC) - Part 5: Installation and mitigation guidelines - Section 1: General considerations - Basic EMC publication
- EN 61000-6-1 Electromagnetic compatibility (EMC) Part 6-1: Generic standards - Immunity for residential, commercial and light-industrial environments.
- EN 61000-6-2 Electromagnetic compatibility (EMC) Part 6-2: Generic standards - Immunity for industrial environments.
- EN 61000-6-3 Electromagnetic compatibility (EMC) Part 6-3: Generic standards – Emission for residential, commercial and light-industrial environments
- EN 61000-6-4 Electromagnetic compatibility (EMC) Part 6-4: Generic standards – Emission for industrial environments
- ICNIRP Guidelines, 1998 Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)
- ICNIRP Guidelines, 2009 Guidelines on limits of exposure to static magnetic fields
- ICNIRP Guidelines, 2010 Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz – 100 kHz)

Note 1: This standard shall be fulfilled when the Rail Baltica line lies in parallel with existing 1520mm gauge DC electrified railway in operation (cities approach for instance – chainages to be checked by the designer).

1.2. GOST standards

- ГОСТ Р 55176.1-2012 Совместимость технических средств электромагнитная. Системы и оборудование железнодорожного транспорта. Часть 1. Общие положения (Electromagnetic compatibility. Railway fixed installations, rolling stock and apparatus. Part 1: General) (see Note 2)
- ГОСТ Р 55176.2-2012 Совместимость технических средств электромагнитная. Системы и оборудование железнодорожного транспорта. Часть 2. Электромагнитные помехи от железнодорожных систем в целом во внешнюю окружающую среду. Требования и методы испытаний (Electromagnetic compatibility of technical equipment. Railway systems and equipment. Part 2. Emission of the whole railway systems to the outside world. Requirements and test methods) (see Note 2)
- ГОСТ Р 55176.3.1-2012 Совместимость технических средств электромагнитная. Системы и оборудование железнодорожного транспорта. Часть 3-1. Подвижной состав. Требования и методы испытаний (Electromagnetic compatibility of technical equipment. Railway systems and equipment. Part 3-1. Rolling stock. Requirements and test methods) (see Note 2)
- ГОСТ Р 55176.3.2-2012 Совместимость технических средств электромагнитная. Системы и оборудование железнодорожного транспорта. Часть 3-2. Подвижной состав. Аппаратура и оборудование. Требования и методы испытаний (Electromagnetic compatibility of technical equipment. Railway systems and equipment. Part 3-2 Rolling stock. Apparatus and equipment. Specifications and test methods) (see Note 2)
- ГОСТ Р 55176.4.1-2012 Совместимость технических средств электромагнитная. Системы и оборудование железнодорожного транспорта. Часть 4-1. Устройства и аппаратура железнодорожной автоматики и телемеханики. Требования и методы испытаний (Electromagnetic compatibility of technical equipment. Systems and equipment of railway transport. Part 4-1. Devices and equipment of railway automatics and telemechanics. Requirements and testing methods) (see Note 2)
- ГОСТ Р 55176.4.2-2012 Совместимость технических средств электромагнитная. Системы и оборудование железнодорожного транспорта. Часть 4-2. Электромагнитная эмиссия и помехоустойчивость аппаратуры электросвязи. Требования и методы испытаний (Electromagnetic compatibility of technical equipment. Railway systems and equipment. Part 4-2. Emission and immunity of telecommunication equipment. Requirements and test methods) (see Note 2)
- ГОСТ Р 55176.5-2012 Совместимость технических средств электромагнитная. Системы и оборудование железнодорожного транспорта. Часть 5. Электромагнитная эмиссия и помехоустойчивость стационарных установок и аппаратуры электроснабжения. Требования и методы испытаний (Electromagnetic compatibility of technical equipment. Railway systems and equipment. Part 5. Electromagnetic emission and immunity of fixed power supply installations and apparatus. Requirements and test methods) (see Note 2)

Note 2: These standards shall be fulfilled when the Rail Baltica line lies in parallel with existing 1520mm gauge railway.

1.3. International Electro-Technical Commission (IEC) Standards

- IEC62236-2 Railway applications - Electromagnetic compatibility - Part 2: Emission of the whole railway system to the outside world
- IEC62236-3 Railway applications - Electromagnetic compatibility - Part 3-2: Rolling stock - Apparatus
- IEC62236-4 Railway applications – Electromagnetic compatibility – Part 4: Emission and immunity of the signalling and telecommunications apparatus
- IEC62236-5 Railway applications - Electromagnetic compatibility - Part 5: Emission and immunity of fixed power supply installations and apparatus
- IEC62305 Protection against lightning
- IEC61000-4-16 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
- IEC62128-1 Railway applications - Fixed installations - Electrical safety, earthing and the return circuit - Part 1: Protective provisions against electric shock

1.4. Institute of Electrical and Electronics Engineers (IEEE) Standards

- IEEE 80 – IEEE Guide for 1 Safety in AC Substation Grounding

2. Overview and General Design Criteria

2.1. Objective

The design shall ensure that the systems and components of the whole railway system are electromagnetically compatible with each other and electromagnetically compatible with systems in nearby environment.

All electrical and electronic equipment and apparatus supplied and/or installed under this scope of works to the railway project shall perform correctly in its intended environment. The intended environment shall include the railway (including, but not limited to, track areas, station areas, operation control centre(s), technical rooms, depots and terminals) as well as other systems in the environment along the alignment.

2.2. Definitions

Apparatus – Electrical or electronic product with an intrinsic function intended for implementation into a fixed railway installation, which can be placed on the market as a single unit.

Compatibility Level – the specified maximum electromagnetic disturbances.

Emission – The phenomenon by which electromagnetic energy emanates from a source

EMC (Electromagnetic Compatibility) – The ability of electronic and electrical equipment, systems and installations to function satisfactorily in its electromagnetic environment without introducing intolerable and/or excessive levels of electromagnetic disturbances that could degrade radio communications and other systems operating in that environment. Conversely electronic and electrical equipment, systems and installations forming the railway should be able to tolerate the levels of electromagnetic disturbances generated by other systems in that environment and should operate satisfactorily without degradation or loss of function.

EMI – Unwanted effects related to reception of electromagnetic energy introduced in an equipment, transmission channel or system

Electromagnetic Disturbance – Any electromagnetic phenomenon which may degrade the performance of a device, equipment or system, or adversely affect living or inert matter.

Emission – The phenomenon by which electromagnetic energy emanates from a source.

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

Limit of Disturbance – The maximum permissible electromagnetic disturbance level, as measured in a specified way

System – The railway as a whole includes different systems, such as: railway, signalling, power supply, telecommunication, MEP, PSD, etc...

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

2.3. General Design Requirements

Demonstration of equipment compliance to [IEC62236] (and other standards relevant for the type of product/equipment/installation and location of installation where applicable) shall be an element in demonstrating compatibility for a major part of the equipment. All the subsystems including basic apparatus from an EMC point of view shall be defined as compatible to each other.

In order to minimise the EMC risks, the design shall also consider all coupling mechanisms that could occur between the systems and subsystems with respect to EMC so that could occur between the systems and subsystems with respect to EMC so that appropriate EMC mitigation and control measures can be implemented at the early stages of the project.

The design shall consider all EMC interactions (Intra, Inter and Extra) including the EMC coupling mechanisms that are applicable to each system.

Note:

- Intra-system coupling: a coupling between two equipment of a single system, e.g. between two SIG equipment.
- Inter-system coupling: a coupling between two equipment in different systems' scope of supply, e.g. between a rolling stock equipment and a SIG equipment.
- Extra-system coupling: a coupling between one (or more) equipment in any Partner scope of supply and an external stakeholder's equipment or system

The design shall consider all (but not limited to) the following systems from EMC point of view:

- Rail systems;
- Signaling;
- Telecom;
- Civil work including the integrated electrical systems in stations, depots, sidings;
- Rolling stock and all associated on-board electrical, electronic and control systems;
- Power systems including but not limited to substations TPSS, traction power systems;
- Third party systems including interfaces internally and externally to the rail environment;
- Systems upgrades and maintenance.

The frequency license/authorisation for use of new radio device for the construction and operation of the railway from national frequency agency shall be required.

All electrical and electronics equipment supplied to, and/or installed under this scope of works, and performing safety functions and/or safety related functions, shall have adequate electromagnetic immunity to electromagnetic disturbances.

Emphasis is required on the cross-discipline and independent nature of the EMC Specialists, showing that they can effectively influence the design when EMC aspects are at variance with other constraints.

2.4. EMC zoning

The rail environment shall be characterized into three different categories. This characterization reflects the reduction in EM levels of radiated and conducted emissions with increasing distance from the center of the running rails and is in line with the railway standards [IEC62236]:

1. Railway environment (for equipment location < 3 m from the center of the track line): this EM zone is defined as the railway zone, railway EMC standards [IEC62236-3], [IEC62236-4], [IEC62236-5] shall be applied to equipment in this zone. The test levels are defined by the standards.
2. Industrial Environment (for equipment locations >3m and <10m from the center of the track line): this EM zone is defined as the industrial zone, the generic industrial standards [IEC61000-6-2] and [IEC61000-6-4] for emissions and immunity shall be applied to equipment in this zone. The test levels are defined by the standards. Any safety critical equipment located within this zone shall be required to comply with the generic industrial standards including any additional requirements as minimum.
3. Commercial and light industrial environment (for equipment locations >10m from the center of the track line): this EM zone is defined as the commercial and light industrial zone, the generic light industrial standards [IEC61000-6-1] and [IEC61000-6-3] for emissions and immunity shall be applied to equipment in this zone including any additional requirements. The test levels are defined by standards

2.5. EMC environment characterisation

The design shall consider the existing EM environment and define a baseline levels prior to the procurement, installation and construction of the systems.

The assessment shall be based on quantitative desktop study and where high levels identified by the study this shall be validated by EM site survey measurements.

The following process may be used to carry out the EM environment assessment:

- Identification of geographical areas for the application of EM environmental assessment;
- Carry out EM environment desktop study;
- Visual inspection and background measurements;
- Validation: EM site survey at defined locations.

2.5.1. EM environment desktop study

EM environment desktop study shall be based on, but not limited to, information and databases available from national and local authorities, existing project documentation, maps of proposed alignments, satellite images, civil site visit reports etc.

The EM site survey report shall indicate the key EM characteristics (frequency range, immunity levels, signal levels, etc..) of those systems in the nearby environment.

The EM environment desktop report shall identify all intentional and non-intentional sources and victims located within the vicinity of railways environment and specifically analyses all overhead High Voltage cable until 3 km from the alignment.

The EM environment desktop study report shall include the phenomena of human beings (possible with mobile communication devices and/or medical devices (peacemakers, hearing aids and similar) in the Rail Baltica railway environment.

2.5.2. EM Site Survey

EM site survey shall be carried out to validate the EMI flagged by the previous desktop study. This study shall allow for further investigation and control measures to be implemented at early design stages where necessary.

The EM site survey report shall consist of a visual inspection of the alignment, dynamic and static measurements of the possible EMI identify and follow up actions (collecting relevant data from 3rd parties, where applicable).

The output from this EMC activity shall provide to all parties involved in the project that there are no significant and excessive levels of EM emissions in the vicinity of the rail environment which could exceed the EMC susceptibility limits of the railway systems.

As a minimum (but not limited to) the following intentional EM sources should be covered by the EM site survey report:

- Airport systems (e.g. ground and approach radars, VOR transmitters, aircraft weather radars, military airport, etc.);
- GSM base stations;
- Wi-Fi, short range devices;
- Public emergency services (e.g. Police and ambulance radios operating on roads/ bridges in the vicinity to the LRT lines) ranging broadly from 150 MHz – 3 GHz;
- Local national radio and TV transmitter tower.

As a minimum (but not limited to) the following non-intentional EM sources should be covered by the EM site survey report

- Industrial scientific and medical band (e.g. arching from welding machines in industrial areas, medical systems inside adjacent or crossing the proposed alignment);
- Overhead power lines and;
- non-railway substations.

As a minimum (but not limited to) the following susceptible victims should be covered by the EM site survey report:

- Navigation systems of airport;
- Various industrial installations nearby alignment;
- Sensitive medical and monitoring equipment in hospitals and clinics;
- Sensitive scientific research equipment;
- Non-medical research facilities or equipment such as Electron Microscope (EM) or transmission electron microscopes (TEM);
- Parallel run to the motor way, with possibly cables in parallel;

The EM site survey report shall indicate the key EM characteristics (frequency range, immunity, signal levels) of those systems in the nearby environment.

In addition, the impact of electromagnetic pulses due to lightning strikes and people carrying mobile communication devices shall be considered as “systems” in the environment.

Lightning protection measures as per [IEC62305] will typically be covered by the earthing and bonding requirements.

Note: It shall be noted that people may possess medical devices, such as implants, hearing aids and similar (for the purpose of analysis, the immunity for those devices may be assumed to typically in compliance with [EN45502-2-1] and [EN60118-4]).

With respect to livestock, livestock shall be considered as a potential victim (to exposure levels and/or touch potentials).

In general, the investigations of systems/objects in the environment shall be coordinated with earthing & bonding specialists, as the E&B works may overlap with EMC activities.

2.6. EMI hazard analysis

EMI Hazard analysis shall cover the systems and components in the scope of works and those systems in the nearby environment (as identified during the site survey).

The hazard analysis shall be based on EMC control plan (with respect to sources and victims in the railway environment) and the site survey report (with respect to sources and victims in the railway environment).

The hazard analysis for the systems in the environment shall indicate how those systems could be affected by the railway emissions.

EMI interference between existing and future railways system should be considered in EMI hazard analysis.

2.6.1. EMI coupling / risk analysis

During design phase, to insure a good design, a coupling / risk analysis report shall be write by the contractor and contain as a minimum the following topics:

- An EMI zone allocation, indicating the type of zones (refer to paragraph 2.4) ;
- A coupling / risk analysis for railway systems via each of the coupling modes (galvanic, capacitive, inductive, electromagnetic coupling), being able to reach the system under consideration;
- A coupling / risk analysis of systems in close proximity to the railway indicating how those systems might be impact by the electromagnetic emission propagated from the railway (typically 50Hz magnetic fields, 50Hz currents via the soil and broadband electromagnetic fields due to radiation);
- A Signalling Compatibility Analysis demonstrating compatibility, under normal and credible failure conditions, between the Rolling Stock and Wayside Signalling systems, in particular Train Detector Systems. Refer to [EN 50238] for guidance;
- A coupling / risk analysis between GSM, UMTS, WIFI emitter and railway equipment;
- A three-party coupling / risk analysis, which shall demonstrate that the interface between power supply, rolling stock and signalling (all using the running rails for their function) will be compatible;
- A coupling / risk analysis between external HV line, catenary and sensitive cable (such as signaling or telecommunication cables) shall be performed in order to estimate safety risk in case of maintenance;
- An analysis of the earthing system in order to prevent any longitudinal voltage, which could cause a hazard to staff and/or passengers or other personnel in and/or near the railway. Limits as per [IEC62128-1] shall be considered;
- EMC requirements for equipment (final set of applicable standards (after execution of coupling / risk analysis) for the equipment within the scope of supply), of which compliance needs to be proven. This set of requirements is to be established before any equipment will be procured;
- EMC requirements for installation (final set of applicable installation measures (after execution of coupling / risk analysis) for the equipment within the scope of supply), of which compliance on implementation on site is to be proven. This set of requirements is to be established before any (installation) works on site will start;
- An analysis of human being exposure levels. This analysis shall demonstrate that for typical areas (such as stations, on-board of trains and trackside areas) the exposure levels for human beings (both passengers and

staff) are in compliance with [ICNIRP] and will not cause problems to people with medical implants and/or hearing devices and similar.

A coupling analysis on frequencies not covered in the EMC standards shall be performed in order to demonstrate that those phenomena will not result in EMC problems, or in case they would result in EMC problems, implement measures such that the final design will not result in compatibility problems in those out-of-standard frequencies.

Note that a result of an initial coupling analysis can be that for certain equipment, for certain locations compatibility may not be reached and additional measures (higher than normal immunity levels and/or additional installation measures) will be required.

Where the output from the quantitative analysis shows that the identified risks are still high and exceed the EMC susceptibility limits, EMC control measures shall be designed, installed and tested. All the design modifications and tests results shall be documented.

2.6.2. EMC risks log

During all project phases, an EMC risk log shall be developed by the contractor and shall include all EMI identified by the contractors, subcontractors, equipment suppliers and third-party owners.

EMC risks once identified by the EMC coupling analyses process shall then be categorised into whether the risk will have any safety implications. EMC risks that are safety related shall also be transferred and logged into the safety hazard log together with any additional information relevant to the management of the hazard and shall follow the risk evaluation process.

2.7. EMI rules

The design shall ensure that all cable runs associated with the systems installation adequately protected against external interference.

The design shall follow EMC best practices design guidelines during the design and construction of all cabling networks and all associated terminating equipment.

The design shall that the cable routing strategy respects cable segregation rules (as per e.g. [IEC61000-5-1] and [IEC61000-5-2]) are incorporated into the design

The following recommended basic rules should be considered:

- Main cables, including power feeds and lighting circuits or any cables in this same category should not be grouped with sensitive cables (e.g. data, signal, coms);
- All cabling runs should avoid any proximity to intentional radio, transmitters operating in the vicinity;
- Long parallel runs of cables should be avoided and if not practicable, enclose either/both the noisy or/and the sensitive cables in fully enclosed metallic conduits/trunking
- The systems and its cabling shall be adequately protected from the effects of the magnetic field generated by HV power cables, HV power lines, rolling stock and traction power supplies;
- Cable sheaths shall be earthed in such a manner as to provide maximum protection from any inducing field;
- The earthing system shall prevent any longitudinal voltage, which could cause a hazard to staff and/or passengers or other personnel in and/or near the railway. Limits as per [IEC62128-1] shall be adhered to;
- The earthing system shall be designed to limit values at the terminals of equipment connected to the cables to the values specified in [IEC61000-4-16]. The equipment itself shall be immune to [IEC61000-4-16].

3. Specific design requirements about EMC

3.1. Electromagnetic Compatibility of the Communication System

The Communication System and the related electrical and electronic apparatus shall comply with the European Directive about Electromagnetic Compatibility (2014/30/EU) about the CE marking process, as far as applicable.

The Communication Systems and the related electrical and electronic apparatus shall be designed with the following objectives:

- a. to reduce the electromagnetic emission which may affect the correct operation of the other subsystems of the transportation System, in particular Vehicle and Signalling system
- b. to reduce the electromagnetic emission which may disturb the sensitive equipment of the outside world (radio apparatus, adjacent railways, etc.)
- c. to be immune to disturbances coming from the other subsystems of the transportation System, in particular from the Vehicle and Signalling system
- d. to be immune from disturbances coming from the outside world (mobile phones, radio equipment, adjacent railways, etc.)

The Communication system and the related electric and electronic apparatus shall be designed according to the applicable standards, in particular:

- a. 2014/30/EU: Electromagnetic Compatibility (EMC) Directive
- b. EN 50121-3-2: Railway applications - Electromagnetic compatibility - Rolling stock -Part 3.2: Rolling Stock Apparatus
- c. EN 50121-4: Railway applications - Electromagnetic compatibility - Part 4: Emission and immunity of the Signalling and Telecommunications Apparatus (09/2000)
- d. EN 50121-5: Railway applications - Electromagnetic compatibility - Part 5: Emission and immunity of railway fixed power supply installations

The electrical and electronic apparatus intended for use in the Communication Systems shall be designed in compliance with the approach of the subsystem's supplier to EMC aspects and with the electromagnetic emission and immunity requirements which will be defined in the subsystem document Communication Systems EMI/EMC Control Plan; this document shall be split into the following points, related to the equipment of supply:

- a. analysis of the electromagnetic environment stressing the installation when it is working in normal, transient, degraded and failure conditions
- b. identification of the interference sources and related frequencies of operation
- c. identification of the victims or of the possible circuits sensitive to the interference and related frequencies
- d. identification of the propagation medium or of the interference mechanism
- e. methodology to solve the problems
- f. determination of the emission and immunity limits for all electric and electronics apparatus, identified as source or victims, covering the interference mechanisms identified in the bullet point above, taking the existing standards, if they are applicable, into account

- g. definition of the necessary actions to obtain immunity of the equipment with respect to the above-mentioned interference mechanisms (examples of possible actions are installation of protection devices, shielding of equipment, filtering, grounding, bonding, shielding and/or armouring of cables, cable segregation criteria).

The tests of the electrical and electronic apparatus intended for use in the Communication Systems, if necessary, shall be performed in compliance with the specifications about performance of tests which will be defined in the subsystem documents EMI/EMC Test Specification; these documents shall be split into the following points, related to the equipment of supply:

- a. to be written based on the Control Plan and with the contribution of the reference standards
- b. to locate the tests to be done on the railway System, on the various subsystems and/or their components for compliance with the emission and susceptibility criteria
- c. to be inclusive of procedures, measurement methods, limits, detailed list of test equipment, expected accuracy of measurement and external influencing conditions, description of modes of operation of the test samples
- d. to show how the test results will have to be documented (diagrams, photographs, tables, etc.)
- e. to indicate the testing program.

The results of performed tests on electric and electronic apparatus and related certification shall be collected in the subsystems documents EMC Dossier, in accordance to the related subsystem documents EMI/EMC Test Specification; these documents shall include all the test reports of the apparatus and the certificates and/or Declarations of Conformity with the European Directive 2014/30/EU about Electromagnetic Compatibility.

3.2. Electromagnetic Compatibility of the Signalling system

The Signalling System and the related electrical and electronic apparatus shall comply with the European Directive about Electromagnetic Compatibility (2014/30/EU:) about the CE marking process, as far as applicable.

The Signalling System and the related electrical and electronic apparatus shall be designed with the following objectives:

- a. to reduce the electromagnetic emission which may affect the correct operation of the other subsystems of the transportation System, in particular Vehicle and Communication systems
- b. to reduce the electromagnetic emission which may disturb the sensitive equipment of the outside world (radio apparatus, adjacent railways, etc.)
- c. to be immune to disturbances coming from the other subsystems of the transportation System, in particular from the Vehicle and Traction Power system
- d. to be immune from disturbances coming from the outside world (mobile phones, radio equipment, adjacent railways, etc.)

The Signalling system and the related electric and electronic apparatus shall be designed according to the applicable standards, in particular:

- a. 2014/30/EU: Electromagnetic Compatibility (EMC) Directive
- b. EN 50121-3-2: Railway applications - Electromagnetic compatibility - Rolling stock -Part 3.2: Rolling Stock Apparatus
- c. EN 50121-4: Railway applications - Electromagnetic compatibility - Part 4: Emission and immunity of the Signalling and Telecommunications Apparatus (09/2000)

- d. EN 50121-5: Railway applications - Electromagnetic compatibility - Part 5: Emission and immunity of railway fixed power supply installations

The electrical and electronic apparatus intended for use in the Signalling System shall be designed in compliance with the approach of the subsystem's supplier to EMC aspects and with the electromagnetic emission and immunity requirements which will be defined in the subsystem document Signalling EMI/EMC Control Plan; this document shall be split into the following points, related to the equipment of supply:

- a. analysis of the electromagnetic environment stressing the installation when it is working in normal, transient, degraded and failure conditions
- b. identification of the interference sources and related frequencies of operation
- c. identification of the victims or of the possible circuits sensitive to the interference and related frequencies
- d. identification of the propagation medium or of the interference mechanism
- e. methodology to solve the problems
- f. determination of the emission and immunity limits for all electric and electronics apparatus, identified as source or victims, covering the interference mechanisms identified in the bullet point above, taking the existing standards, if they are applicable, into account
- g. definition of the necessary actions to obtain immunity of the equipment with respect to the above-mentioned interference mechanisms (examples of possible actions are installation of protection devices, shielding of equipment, filtering, grounding, bonding, shielding and/or armouring of cables, cable segregation criteria).

The tests of the electrical and electronic apparatus intended for use in the Signalling System, if necessary, shall be performed in compliance with the specifications about performance of tests which will be defined in the subsystem documents Signalling EMI/EMC Test Specification; this document shall be split into the following points, related to the equipment of supply:

- a. to be written on the basis of the Control Plan and with the contribution of the reference standards
- b. to locate the tests to be done on the railway System, on the various subsystems and/or their components for compliance with the emission and susceptibility criteria
- c. to be inclusive of procedures, measurement methods, limits, detailed list of test equipment, expected accuracy of measurement and external influencing conditions, description of modes of operation of the test samples
- d. to show how the test results will have to be documented (diagrams, photographs, tables, etc.)
- e. to indicate the testing program.

The results of performed tests on electric and electronic apparatus and related certification shall be collected in the subsystem documents EMC Dossier, in accordance with the related subsystem documents EMI/EMC Test Specification; these documents shall include all the test reports of the apparatus and the certificates and/or Declarations of Conformity with the European Directive 2014/30/EU about Electromagnetic Compatibility.

3.3. Electromagnetic Compatibility of the Traction Power

The Traction Power electrical and electronic apparatus shall comply with the European Directive about Electromagnetic Compatibility (2014/30/EU) about the CE marking process, as far as applicable.

The Traction Power electrical and electronic apparatus shall be designed with the following objectives:

- a. to reduce the electromagnetic emission which may affect the correct operation of the other subsystems of the transportation System, Signalling system
- b. to reduce the electromagnetic emission which may disturb the sensitive equipment of the outside world (radio apparatus, adjacent railways, etc.)
- c. to be immune to disturbances coming from the other apparatus of the Traction Power and from the other subsystems of the transportation System
- d. to be immune from disturbances coming from the outside world (mobile phones, radio equipment, adjacent railways, etc.)

The Traction Power electric and electronic apparatus shall be designed according to the applicable standards, in particular:

- a. 2014/30/EU: Electromagnetic Compatibility (EMC) Directive
- b. EN 50121-5: Railway applications - Electromagnetic compatibility - Part 5: Emission and immunity of railway fixed power supply installations
- c. EN 61000-6-2: Electromagnetic compatibility (EMC) Part 6-2: Generic standards - Immunity for industrial environments (10/2001) and EN 61000-6-4: Electromagnetic compatibility (EMC) Part 6-4: Generic standards – Emission for industrial environments or specific product standards (e.g. EN 50091-2 about UPS) applicable to apparatus not covered by the above-mentioned railway standard.

The tests of the electrical and electronic apparatus intended for use in the Traction Power, if necessary, shall be performed in compliance with the specifications about performance of tests which will be defined in the subsystem documents Traction Power EMI/EMC Test Specification; this document shall be split into the following points, related to the equipment of supply:

- a. to be written on the basis of the applicable reference standards
- b. to locate the tests to be done on the railways System, on the various subsystems and/or their components for compliance with the emission and susceptibility criteria
- c. to be inclusive of procedures, measurement methods, limits, detailed list of test equipment, expected accuracy of measurement and external influencing conditions, description of modes of operation of the test samples
- d. to show how the test results will have to be documented (diagrams, photographs, tables, etc.)
- e. to indicate the testing program.

The results of performed tests on electric and electronic apparatus and related certification shall be collected in the subsystem documents EMC Dossier, in accordance with the related subsystem documents EMI/EMC Test Specification; these documents shall include all the test reports of the apparatus and the certificates and/or Declarations of Conformity with the European Directive 2014/30/EU about Electromagnetic Compatibility.

3.4. Particular maintenance requirements

The design shall consider that the maintenance activities will not be degraded EMC characteristics when any equipment or systems is modified and/or upgraded.