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Guidance on the Conventional Rail Energy TSI
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Guidance on the Conventional Rail Energy TSI

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This Rail Industry Guidance Note does not supersede any other Railway Group documents.

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Guidance on the Conventional Rail Energy TSI

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Part 1 Introduction

1.1 Purpose of this document

- 1.1.1 This document gives guidance on interpreting the technical requirements of the Conventional Rail Energy Technical Specification for Interoperability (CR ENE TSI) as they apply to the Great Britain (GB) mainline network (see definitions). This document does not provide guidance as to when the TSI is to be applied. The Contracting Entity Notified Bodies and Designated Bodies applying the TSI will have to satisfy themselves as to the particular requirements of the TSI. It does not constitute a recommended method of meeting any set of mandatory requirements. Existing lines are not required to be brought into conformity with this TSI unless undergoing renewal or upgrading (see definitions).
- 1.1.2 The CR ENE TSI is set out in the Annex to Commission Decision of 26 April 2011 concerning a TSI relating to the 'energy' subsystem of the trans-European conventional rail system (Decision 2011/274/EU).
- 1.1.3 Relevant requirements in the CR ENE TSI are reproduced in the sections that follow as boxed text.
- 1.1.4 Also reproduced are relevant requirements from:
 - a) The Conventional Rail Locomotives and Passenger Rolling Stock TSI (CR LOC & PAS TSI).
 - b) The Safety in Rail Tunnels TSI (SRT TSI).
- 1.1.5 The CR LOC & PAS TSI is set out in the Annex to Commission Decision of 26 April 2011 concerning a TSI relating to the rolling stock subsystem - 'Locomotives and passenger rolling stock' of the trans-European conventional rail system (Decision 2011/291/EU).
- 1.1.6 The SRT TSI is set out in the Annex to Commission Decision of 20 December 2007 concerning the technical specification of interoperability relating to 'safety in railway tunnels' in the trans-European conventional and high-speed rail system (Decision 2008/163/EC).
- 1.1.7 Guidance is provided as a series of sequentially numbered clauses prefixed 'GN' immediately below the boxed text to which it relates. Where there is no guidance given, this is stated.
- 1.1.8 The guidance in this document should be read in conjunction with the full text of the CR ENE TSI, as some information has been omitted for brevity and clarity.

1.2 Energy systems for the GB mainline network

- 1.2.1 The 25 kV AC system is the preferred system for the GB mainline network (see definitions).
- 1.2.2 The CR ENE TSI contains a 'specific case' for GB that permits, where appropriate, lines equipped with the electrification system operating at 600/750 V DC and utilising ground-level top-contact conductor rails in a three and/or four rail configuration to continue to be upgraded, renewed and extended where this is economically justified. In this case National Technical Rules (NTRs) will apply.
- 1.2.3 There is currently no plan to use any of the other systems permitted by the CR ENE TSI.

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1.3 Structure of the CR ENE TSI

- 1.3.1 The CR ENE TSI is divided into seven chapters. The first three chapters are informative and contain no mandatory requirements. Chapter 1, the Introduction, sets out the technical and geographical scope of the TSI, and describes its contents. Its geographical scope is the trans-European conventional rail system as described in Annex I, Chapter 1.1 to the Directive 2008/57/EC. Chapter 2 defines the energy subsystem and its interfaces with other subsystems. Chapter 3 sets out how the TSI has covered the 'essential requirements' for the subsystem defined in the Railway Interoperability Directive 2008/57/EC.
- 1.3.2 Chapter 4 sets out the main technical requirements in the TSI and is dealt with in detail in this Guidance Note.
- 1.3.3 Chapter 5 sets out the interoperability constituents (essentially components, sub-assemblies or complete assemblies of equipment intended to be incorporated into a subsystem). Guidance on these has been placed with the relevant requirements from Chapter 4.
- 1.3.4 Chapter 6 sets out the assessment of conformity of interoperability constituents and EC verification of the subsystem. Guidance on these has been placed with the relevant requirements from Chapter 4. The assessment modules to be used for assessment of conformity and EC verification are set out in Commission Decision 2010/713/EU of 9 November 2010.
- 1.3.5 Chapter 7 sets out the implementation of the TSI and specific cases. Guidance on these has been placed with the relevant requirements from Chapter 4.

1.4 References to other standards

- 1.4.1 The Railway Interoperability Directive 2008/57/EC permits TSIs to make reference to 'European or international standards or specifications or technical documents published by the [European Railway] Agency where this is strictly necessary' (Article 5(8)). The CR ENE TSI makes extensive references to other standards (mainly Euronorms) and in every case references a dated version (historic reference).
- 1.4.2 The Directive states that 'In such case, these standards or specifications (or the relevant parts) or technical documents shall be regarded as annexes to the TSI concerned and shall become mandatory from the moment the TSI is applicable' (Article 5(8)). Therefore, only the dated versions of the standards are to be used for assessment of conformity and EC verification. However, many of the documents being referenced are under revision, and it may be more appropriate to apply the latest version of the standard. In these cases care should be taken to ensure that the subsystem is also compliant with the dated version of the reference.

1.5 Future developments

- 1.5.1 A suite of Railway Group Standards (RGSs) is in preparation that will cover the energy subsystem, setting out the requirements needed to maintain technical compatibility with those parts of the existing railway system that do not yet conform to TSIs. These RGSs will be aligned with the requirements of the Conventional Rail and High Speed TSIs and the specific cases for GB that they contain.
- 1.5.2 The European Railway Agency is drafting a revised Energy TSI that will combine the aspects of the High Speed and Conventional Rail systems, and extend the scope of the TSI to cover the whole of the mainline railway system, with publication expected in 2013.

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1.7 Approval and authorisation of this document

- 1.7.1 The content of this document was approved by Energy (ENE) Standards Committee on 19 January 2012.
- 1.7.2 This document was authorised by RSSB on 24 January 2012.

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Part 2 Technical Guidance on the ENE TSI

2.1 TSI technical requirement clauses (Chapter 4)

4. Characterisation of the subsystem

4.1 Introduction

The rail system, to which the Directive 2008/57/EC applies, and of which the subsystem is a part, is an integrated system whose consistency shall be verified. This consistency must be checked, in particular, with regard to the specifications of the subsystem, its interfaces vis-à-vis the system in which it is integrated, as well as the operating and maintenance rules.

The functional and technical specifications of the subsystem and its interfaces, described in chapters 4.2 and 4.3, do not impose the use of specific technologies or technical solutions, except where this is strictly necessary for the interoperability of the rail network. But innovative solutions for interoperability may require new specifications and/or new assessment methods. In order to allow technological innovation, these specifications and assessment methods shall be developed by the process described in chapters 6.1.3 and 6.2.3.

Taking account of all the applicable essential requirements, the energy subsystem is characterised by the specifications set out in clauses 4.2 to 4.7. A list of parameters relevant for the energy subsystem which shall be collected in the Register of Infrastructure is in Annex C to this TSI.

Procedures for the EC verification of the energy subsystem are indicated in clause 6.2.4 and Annex B, Table B.1, to this TSI.

For Specific Cases, see chapter 7.5;

Where reference is made to EN standards, any variations called 'national deviations' or 'special national conditions' in the EN do not apply.

- GN1 Chapter 4 sets out in detail the main technical requirements in the TSI.
- GN2 Only the main text of the referenced ENs applies to the TSI unless a national condition is referenced by a specific case in the TSI. The TSI also calls up a dated version of an EN, which is the issue / wording that the TSI Working Group has considered.
- GN3 The TSI does not have any specific technical requirements for the GB 600/750V DC system. These are covered (through the GB specific case in chapter 7 of the TSI) by NTRs. None of the technical requirements set out in the TSI for the 1.5 kV DC and 3 kV DC overhead line systems are applicable to the GB 600/750V DC system. The GB 600/750V DC system is permitted under a specific case (7.3.2.13) to the TSI if it is not economically justified to implement the 25 kV AC target system. NTRs apply to the DC system and assessment will be made by a designated body (DeBo).
- GN4 Aspects of the TSI other than the 'system characteristics and functionality' are still applicable, such as the provision of a Register of Infrastructure.
- GN5 The CR ENE TSI should be used in conjunction with relevant NTRs and company standards in order to fully characterise the subsystem. Most NTRs for the GB mainline network are RGSSs.

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4.2 Functional and technical specifications of the subsystem

4.2.1 General provisions

The performance to be achieved by the Energy subsystem shall correspond to the relevant performance of the rail system, with respect to:

- the maximum line speed, type of train, and
- the power demand of the trains at the pantographs.

GN6 This general clause is intended to reflect that the design of the electrification system should be appropriate for the type of traffic that the line is intended to handle. Consideration should be given to future traffic. There is no requirement to design a 'uniform' system if doing so will be uneconomic.

GN7 Where 4.2.1 and some later parts of the TSI such as 4.2.4 are concerned, a decision should be made as to whether the electrification subsystem is designed to the line speed of the line or designed to the maximum speed of electric stock expected to use the line. The TSI requires that the electrification system should be 'appropriate for the type of traffic that the line is intended to handle' and, at 4.2.4, the 'line speed for the planned services'. The Register of Infrastructure will define the parameters to which the line has been equipped. Differential speed limits for different types of rolling stock and environmental conditions (such as high wind) are a matter of technical compatibility and operational rules.

4.2.2. Basic parameters characterising the energy subsystem

The basic parameters characterising the energy subsystem are:

- Power supply:
 - Voltage and frequency (4.2.3)
 - Parameters relating to supply system performance (4.2.4)
 - Continuity of power supply in case of disturbances in tunnels (4.2.5)
 - Current capacity, DC systems, trains at standstill (4.2.6)
 - Regenerative braking (4.2.7)
 - Electrical protection coordination arrangements (4.2.8)
 - Harmonics and dynamic effects for AC systems (4.2.9)
 - Electric energy consumption measuring equipment (4.2.21)
- Geometry of the OCL and quality of current collection:
 - Geometry of the overhead contact line (4.2.13)
 - Pantograph gauge (4.2.14)
 - Mean contact force (4.2.15)
 - Dynamic behaviour and quality of current collection (4.2.16)
 - Pantograph spacing (4.2.17).
 - Contact wire material (4.2.18)
 - Phase separation sections (4.2.19)
 - System separation sections (4.2.20)

GN8 This section sets out the parameters that are elaborated further on in the document, and contains no mandatory requirements.

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4.2.3. Voltage and frequency

Locomotives and traction units need standardisation of voltage and frequency. The values and limits of the voltage and frequency at the terminals of the substation and at the pantograph shall comply with EN50163:2004, clause 4.

The AC 25 kV 50 Hz system is to be the target supply system, for reasons of compatibility with the electrical generation and distribution systems and standardisation of substation equipment.

However, due to the high investment costs needed to migrate from other system voltages to the 25 kV system and the possibility of using multi-system traction units, the use of the following systems for new, upgraded or renewed subsystems is permitted:

- AC 15 kV 16.7 Hz
- DC 3 kV, and
- DC 1.5 kV

Nominal voltage and frequency shall be listed in the Register of Infrastructure (see Annex C).

- GN9 Great Britain (GB) will generally select the 25 kV AC 'target system' of electrification, and meet the appropriate voltage parameters defined in EN 50163:2004, clause 4. Although the use of a DC overhead line system is also permitted by the TSI, the 15 kV 16.7 Hz AC is unsuitable for application in GB.
- GN10 Throughout Europe, the wide spread of existing electrification and the fact that multiple traction vehicles are available makes the migration to one system not economically viable. Therefore, the CR ENE TSI permits the application of single phase 15 kV 16.7 Hz AC and 1.5 kV and 3 kV DC systems for new, upgraded or renewed subsystems.
- GN11 The Tyne and Wear metro system utilises the 1.5 kV DC system (including parts where there is interworking over Network Rail infrastructure) but is assumed to be out of scope of the TSI as a local or metro railway.
- GN12 The TSI seeks to limit the number of systems across Europe. To support interoperability each of these systems has been standardised in EN 50163.
- GN13 Details of the system selected will be set out in the Register of Infrastructure for the line section concerned (see Annex C). The GB special conditions in EN 50163 are not included as special conditions to the TSI, and so do not apply to a new electrification project.
- GN14 A GB specific case states that, where appropriate, lines equipped with the electrification system operating at 600/750 V DC and utilising ground-level top-contact conductor rails in a three and/or four rail configuration can continue to be upgraded, renewed and extended where this is economically justified. In this case NTRs will apply.

Specific case 7.5.2.7.4. 600/750 V DC Electrified Railway using ground level conductor rails

Lines equipped with the electrification system operating at 600/750 V DC and utilising ground level top-contact conductor rails in a three and/or four rail configuration shall continue to be upgraded, renewed and extended where this is economically justified. National technical rules shall apply.

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- GN15 This specific case allows the DC railway to continue to be maintained and operated, and maintains compatibility with existing rolling stock in accordance with NTRs.
- GN16 There are some 4,500 single-track km of GB mainline railway that are equipped with ground-level top-contact conductor rails in a three and/or four rail configuration. The use of this type of electrification on the mainline railway, rather than metro style railways, is unique to GB. Retaining the existing system avoids the cost of changing the system of electrification when existing lines are renewed or upgraded.

CR LOC & PAS TSI 4.2.8.2.1 General

Requirements applicable to rolling stock, and which interface with the Energy subsystem are dealt with in this clause. Therefore, this clause 4.2.8.2 applies to Electric units.

The CR Energy TSI defines the AC 25 kV 50 Hz system as a target system, and allows the use of the AC 15 kV 16.7 Hz system and of the DC 3 kV or 1.5 kV systems. As a consequence, requirements defined below are related to these 4 systems only, and references to standards are valid for these 4 systems only.

The CR Energy TSI allows the use of catenary systems compatible with pantograph heads geometry of lengths 1600 mm or 1950 mm (see clause 4.2.8.2.9.2).

CR LOC & PAS TSI 4.2.8.2.2 Operation within range of voltages and frequencies

Electric units shall be able to operate within the range of at least one of the systems 'voltage and frequency' defined in the CR Energy TSI, clause 4.2.3.

The actual value of the line voltage shall be available in the driver cab in driving configuration.

The systems 'voltage and frequency' for which the rolling stock is designed shall be recorded in the rolling stock register defined in clause 4.8 of this TSI.

- GN17 For the infrastructure, GB adopts the 25 kV target system with a pantograph head length of 1600 mm.
- GN18 GB requires vehicles that can operate on at least the 25 kV target system with pantograph heads of lengths 1600 mm, or the 600/750 V DC system with ground-level conductor rails. Other systems may also be fitted, if appropriate.
- GN19 Historically, electric trains used in GB have been specified to operate (but at a reduced performance) at a pantograph voltage between 12.5 kV and 17.5 kV. In implementing the use of EN 50163, GB is moving to a position where voltages below 17.5 kV will no longer be seen on lines provided with new electrification systems. On legacy infrastructure, voltages below 17.5 kV may occasionally be present. Any trains required to operate on legacy infrastructure may still need to be capable of operating in this range.

CR LOC & PAS TSI Specific case 7.3.2.13 Power supply – general (4.2.8.2.1)

It is permissible to continue to procure rolling stock to operate on and be compatible with, lines equipped with the electrification system operating at 600/750 V DC and utilising ground level conductor rails in a three and/or four rail configuration. Notified National Technical Rules shall apply.

- GN20 This specific case allows for the continued operation of the 600/750 V DC systems. This also allows continued procurement, as a 750 V DC-only train is still TSI compliant. These systems would still be subject to the TSI approvals process, but assessment of conformity with the NTRs would be undertaken by a DeBo.

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4.2.4. Parameters relating to supply system performance

The design of the energy subsystem is determined by the line speed for the planned services and the topography.

Therefore the following parameters have to be taken in consideration:

- the maximum train current,
- the power factor of trains, and
- the mean useful voltage.

- GN21 Though target values for conventional lines in the reference to different supply systems are set out in EN 50388:2005 (Table 7.1), the parameters that affect the maximum train current are more complex, including types of traffic, rolling stock, relief of the line, headway etc. To give one target value for all conventional lines would lead to oversizing of the supply system and unnecessary costs in fixed installations.
- GN22 In the TSI it is stressed that the power supply system has to be designed according to real needs, and the maximum train current is indicated in the Register of Infrastructure (see Annex C). In designing the power supply system the maximum train current automatic regulation characteristic (EN 50388:2005 clause 7.2) of the trains and planned services (timetable) are factors to be considered.
- GN23 To avoid unnecessary rolling stock costs, the system should allow trains up to 2 MW without current limiting devices (see EN 50388:2005 clause 7.3).

4.2.4.1 Maximum train current

The Infrastructure Manager shall declare the maximum train current in the Register of Infrastructure (see Annex C).

The energy subsystem design shall ensure the ability of the power supply to achieve the specified performance and permit the operation of trains with a power less than 2 MW without current limitation as described in clause 7.3 of EN 50388:2005.

CR LOC & PAS TSI 4.2.8.2.4 Maximum power and current from the overhead contact line

Electric units with power higher than 2 MW (including the declared fixed and predefined formations) shall be equipped with current limitation function as required in clause 7.3 of EN 50388:2005.

Electric units shall be equipped with automatic regulation of the current within abnormal operation condition regarding voltage as required in clause 7.2 of EN 50388:2005.

The maximum current assessed here above (rated current) shall be recorded in RST register defined in clause 4.8 of this TSI.

CR LOC & PAS TSI 4.2.8.2.9.3 Pantograph Current Capacity (IC Level)

Pantographs shall be designed for the rated current (as defined in clause 4.2.8.2.4) to be transmitted to the Electric unit.

An analysis shall demonstrate that the pantograph is able to carry the rated current; this analysis shall include the verification of the requirements of clause 6.13 of EN 50206-1:1998.

Pantographs for DC systems shall be designed for the maximum current at standstill (as defined in clause 4.2.8.2.5 of this TSI).

- GN24 These clauses are written on the assumption that trains are generally locomotive-hauled or have a single pantograph. However, in GB, multiple units may have more than one pantograph. The maximum train current limit applies to the whole train, not a single unit.

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GN25 The last requirement of CR LOC & PAS TSI 4.2.8.2.9.3 does not apply to the GB mainline railway infrastructure.

4.2.4.2 Power factor of trains

The power factor of trains shall be in accordance with requirements in Annex G and EN 50388:2005 clause 6.3.

CR LOC & PAS TSI 4.2.8.2.6 Power factor

The power factor design data shall be as set out in Annex G of the CR Energy TSI.

Annex G Power factor

This Annex deals only with inductive power factor and power consumption over the range of voltage from U_{min1} to U_{max1} defined in EN 50163.

[Full text not reproduced]

GN26 The power factor is a requirement for the rolling stock, but it is very important for the performance and design of the energy subsystem. The values are set out in Annex G of the TSI, which clarifies the existing wording in EN 50388:2005 (clause 6.2). This new text is part of the revision of EN 50388, expected to be published in 2012.

GN27 For trains with power lower than 2 MW, the condition of the power factor set out in the TSI and EN 50388:2005 has to be fulfilled over a complete journey. To avoid the provision of an uneconomical and oversized power supply at marshalling yards and depots, some restrictions are placed upon the power factor of hotel (heating, cooling, lighting and catering) and other auxiliary loads for stabled rolling stock.

4.2.4.3 Mean useful voltage

The calculated mean useful voltage 'at the pantograph' shall comply with EN 50388:2005, clauses 8.3 and 8.4, using the design data for the power factor according to Annex G.

6.2.4.1 Assessment of mean useful voltage

The assessment shall be carried out in accordance with EN 50388:2005, clauses 14.4.1, 14.4.2 (simulation only) and 14.4.3.

GN28 Mean useful voltage is a quality parameter of the power supply system that shows the ability of the power supply system to deliver to trains the required performance in normal and degraded conditions. The mean useful voltage is a parameter that cannot be directly measured. It is calculated during simulation of the capacity of the supply system for the geographical zone during peak hours of a design timetable and for the train with the lowest voltage (referred to as the 'dimensioning train'). A detailed description of the process of calculation is set out in EN 50388:2005, Annex B.

GN29 This general clause is intended to reflect that the design of the electrification system should be appropriate for the type of traffic that the line is intended to handle (including anticipated future traffic). There is no requirement to design a 'standard system' if doing so will be uneconomic. Details of the maximum current that can be received by an individual train will be set out in the Register of Infrastructure (see Annex C). It can be assumed that the minimum power of each train will be 2 MW, but that above this value the train will be provided with a system to limit the power demand to a specific value advised by the infrastructure manager in the Register of Infrastructure.

GN30 The historic norm in GB is a default maximum train current of 300 Amps, but a different value can be defined in the Register of Infrastructure, although the minimum value of maximum train current will be about 80 Amps (2 MW at 25 kV), as below that value a train is not required to be provided with a system to limit the power demand.

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4.2.5. Continuity of power supply in case of disturbances in tunnels

The power supply and the overhead contact line system shall be designed to enable continuity of operation in case of disturbances in tunnels. This shall be achieved by sectioning overhead contact line in accordance with clause 4.2.3.1 of the SRT TSI.

SRT TSI 4.2.3 Subsystem Energy

This section applies to the infrastructure part of the subsystem Energy.

SRT TSI 4.2.3.1 Segmentation of overhead line or conductor rails

This specification applies to tunnels of more than 5 km in length.

The traction energy supply system in tunnels shall be divided up into sections, each not exceeding 5 km. This specification applies only if the signalling system permits the presence of more than one train in the tunnel on each track simultaneously.

The location of the switches shall be arranged in accordance with the requirements of the tunnel emergency plan, and so that the number of switches in the tunnel is minimised.

Remote control and switching of each 'switching section' shall be provided.

A means of communication means and lighting shall be provided at the switching location to enable safe manual operation and maintenance of the switching equipment.

GN31 Clause 4.2.5 is linked with the SRT TSI clause 4.2.3.1 and the requirement to ensure the continuity of power supply to enable a train to leave the endangered zone by sectionalising the power supply into sections of not more than 5 km. This requirement will apply whenever the ENE TSI applies, whether or not the full SRT TSI applies as well.

GN32 In the High Speed TSI (HS TSI) this heading was of a more general nature, and covered the continuing operation of the system in the event that the system became degraded. Sustained objections to this clause on the grounds that this would require excessive redundancy being needed, led to this clause covering only long tunnels through a reference to the SRT TSI, clause 4.2.3.1 – 'Segmentation of overhead line or conductor rails'.

GN33 The location of the switches should be arranged in accordance with the requirements of the tunnel emergency plan, so that the number of switches in the tunnel is minimised. The intention is that the power supply can be maintained to 'healthy' trains to enable them to leave the tunnel, but disconnected from a faulty train or defective part of the tunnel. In designing the switching facility, consideration should be given to communications, local control lighting and maintenance of the equipment. Remote control of each 'switching section' should be provided and is expected to be the normal condition. The switching equipment may need to be capable of load-breaking. The sectioning may be used in conjunction with additional facilities for providing emergency isolation such as remotely controlled earthing of the overhead line so as to facilitate entry / access into the tunnel to deal with an incident.

4.2.6. Current capacity, DC systems, trains at standstill

The overhead contact line of DC systems shall be designed to sustain 300 A (for a 1.5 kV supply system) and 200 A (for a 3 kV supply system), per pantograph when the train is at standstill.

This shall be achieved using a static contact force as defined in clause 7.1 of EN 50367:2006.

Where the overhead contact line has been designed to sustain higher values for maximum current at standstill, this shall be declared by the Infrastructure Manager in the Register of Infrastructure (see Annex C).

The OCL shall be designed taking into account the temperature limits in accordance with EN 50119:2009 clause 5.1.2.

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CR LOC & PAS TSI 4.2.8.2.5 Maximum current at standstill for DC systems

For DC systems, the maximum current at standstill per pantograph shall be calculated and verified by measurement.

Limit values are specified in clause 4.2.6 of the CR Energy TSI; higher values than those limits shall be recorded in the rolling stock register defined in clause 4.8 of this TSI.

GN34 These clauses have no relevance to the target 25 kV AC electrification system.

4.2.7. Regenerative braking

AC power supply systems shall be designed to permit the use of regenerative braking as a service brake, able to exchange power seamlessly either with other trains or by any other means.

DC power supply systems shall be designed to permit the use of regenerative braking as a service brake at least by exchanging power with other trains.

Information about possibility of the use of regenerative braking shall be provided in the Register of Infrastructure (see Annex C).

6.2.4.2. Assessment of regenerative braking

The assessment for AC power supply fixed installations shall be carried out according to EN 50388:2005, clause 14.7.2.

The assessment for DC power supply shall be carried out by a design review.

CR LOC & PAS TSI 4.2.8.2.3 Regenerative brake with energy to the overhead contact line

Electric units which return electrical energy to the overhead contact line in regenerative braking mode shall comply with the clause 12.1.1 of EN 50388:2005.

It shall be possible to prevent the use of the regenerative brake.

- GN35 Facilities to permit the use of regenerative braking are expected for economic and environmental reasons. Regenerative braking for both AC and DC systems is widely used in modern rolling stock. Existing technologies allow energy to be produced for AC and DC systems during regenerative mode with low harmonic content, which would otherwise impact on the quality of energy delivered by the supplier to other consumers.
- GN36 For AC systems, the supply system can be designed to feed energy back to the supply grid. It is supposed that any power supplier will accept the feedback of energy.
- GN37 For DC systems, current technology generally allows exchange between trains, but it is also permitted to use energy storage systems at the substations, or converters to feed back energy to the supply grid.
- GN38 The intention of this clause is to encourage the use of regenerative braking. As a matter of course, any 25 kV AC energy subsystem constructed under the TSI should be capable of accepting regenerative braking. Similarly, any 750 V DC systems constructed using clause 7 of the TSI should allow regenerative braking (see clause 7.5.2.7.4) in accordance with the Notified NTRs.
- GN39 The statement that 'It shall be possible to prevent the use of regenerative braking' in the CR LOC & PAS TSI applies to both 25 kV AC and 600/750 V DC operations. On some designs of rolling stock, a small reverse current may be exported to the line when using the rheostatic brake. The infrastructure manager should consider this when limiting the use of regenerative braking.

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4.2.8. Electrical protection coordination arrangements

Electrical protection coordination design of the energy subsystem shall comply with the requirements detailed in EN 50388:2005, clause 11 except Table 8 which is replaced by Annex H of this TSI.

CR LOC & PAS TSI 4.2.8.2.10 Electrical protection of the train

Electric units shall be protected against internal short-circuits (from inside the unit).

The location of the main circuit breaker shall be such as to protect the on-board high voltage circuits, including any high voltage connections between vehicles. The pantograph, the main circuit breaker, and the high voltage connection between them shall be located on the same vehicle.

In order to prevent electric hazards, any unintentional energisation shall be avoided; the control of the main circuit breaker is a safety related function; the safety level required is an open point.

Electric units shall protect themselves against short over-voltages, temporary over-voltages and maximum fault current. To meet this requirement, electrical protection coordination design shall comply with the requirements defined in the standard EN 50388:2005, clause 11 'coordination of protection'; Table 8 of this clause shall be replaced by the Annex H of the CR Energy TSI.

6.2.4.3 Assessment of electrical protection coordination arrangements

The assessment shall be carried out for design and operation of substations in accordance with EN 50388:2005 clause 14.6.

GN40 The principle that is being addressed here is that an appropriate power system protection system is required that will detect and remove system faults as soon as possible, but with minimum disruption to the power supply to the railway. Where possible, protection on the traction units should operate first for a fault within the traction unit. It is recognised that this may not always be achieved. The reference to Annex H is to text included in a revised, but unpublished revision of EN 50388, expected to be published in 2012.

4.2.9. Harmonics and dynamic effects for AC systems

The CR energy subsystem and rolling stock must be able to work together without interference problems, such as over-voltages and other phenomena described in EN 50388:2005 clause 10.

6.2.4.4. Assessment of harmonic and dynamic effects for AC systems

The assessment, based on a compatibility study, shall be conducted according to EN 50388:2005 clause 10.3 taking into account over-voltages given in EN 50388:2005 clause 10.4.

CR LOC & PAS TSI 4.2.8.2.7 System Energy Disturbances for AC Systems

An Electric unit shall not cause unacceptable overvoltage and other phenomena described in EN 50388:2005 clause 10.1 (harmonics and dynamic effects) on the overhead contact line.

A compatibility assessment shall be done in accordance with the methodology defined in the clause 10.3 of EN 50388:2005. the steps and hypothesis described in table 6 of EN 50388:2005 have to be defined by the applicant (column 3 not applicable), taking into consideration input data given in Annex D of the same standard; the acceptance criteria shall be as defined in clause 10.4 of EN 50388:2005.

All hypothesis and data considered for this compatibility study shall be recorded in the technical documentation (see clause 4.2.12.2).

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- GN41 These phenomena are related to the harmonic characteristics of power supply fixed installation and rolling stock, which can create over-voltages and other instability phenomena in the power supply system. Particular attention should be paid when introducing a new element – either a piece of rolling stock or infrastructure equipment – into an existing stable electric environment. The TSIs require a compatibility study to be carried out in this case, to assess the consequences made to the system by the new element. The compatibility study is set out in detail in EN 50388:2005 to which the TSI makes reference. Technical studies are being undertaken by CENELEC in order to find common compatibility criteria.
- GN42 Rolling stock (both new and existing) and the electrification infrastructure may interact to cause interference problems, such as over-voltages and other phenomena. This topic is dealt with extensively in EN 50388:2005, clause 10, which contains a process for undertaking a compatibility assessment. It is advisable that this process is undertaken as early as possible in the life cycle of the equipment, as resolution of the problems that the compatibility assessment identifies may only be possible by the introduction of additional hardware, either on the train or on the infrastructure.
- GN43 This assessment will be an input to the process set out in RGS GE/RT8270.
- GN44 Several countries have experienced serious problems, due to unpredicted instability phenomena, and it is recognised at European level that more work is needed to define clear, simple and safe acceptance criteria for 'new elements' (rolling stock, or infrastructure subsystems). The process for assessment of compatibility has been identified as one where more work is required, and CENELEC committee SC9XC, working group WGC11 is considering the issue.
- GN45 Equivalent requirements apply to the conformity assessment of rolling stock, in order for the certificate of compliance to be issued. However, for rolling stock, it is not necessary, for TSI purposes, for a new compatibility study to be carried out every time the rolling stock is introduced on a new line. This means that a TSI-compliant train being introduced on a new line might not work with a TSI-compliant power supply, due to phenomena that have not been predicted by the compatibility study. EN 50388 proposes a methodology for analysing this issue. On the GB main line the compatibility assessment standard GE/RT8270 is applicable.

4.2.10. Harmonic emissions towards the power utility

Harmonic emissions towards the power utility shall be dealt with by the Infrastructure Manager taking into account European or national standards and the requirements of the power utility.

No conformity assessment is required within this TSI.

- GN46 This is a matter for the infrastructure manager to address under the contract with the supply authorities. This will be part of the compatibility assessment process for changes to the timetable and rolling stock operation in a particular supply area. Data on the harmonic behaviour of rolling stock will be required by the infrastructure manager in order to address this point. As far as the TSI is concerned there are no additional requirements or anything to be assessed.

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4.2.11. External electromagnetic compatibility

External electromagnetic compatibility is not a specific characteristic of the rail network. Energy supply installations shall comply with the Essential Requirements of the EMC Directive 2004/108/EC.

No conformity assessment is required within this TSI.

- GN47 This is a matter for the infrastructure manager to address. This will be part of the compatibility assessment process for changes to the timetable and rolling stock operation on a particular supply area. Data on the harmonic behaviour of rolling stock will be required by the infrastructure manager in order to address this point. As far as the TSI is concerned, there are neither additional requirements nor anything to be assessed. It is considered that the essential requirements referring to environmental protection (see Annex III (1.4) to Directive 2008/57/EC) are fulfilled by the current general European legislation and agreements and national regulations.
- GN48 Railway Group Standard GE/RT8015 and EN 50121 provide further guidance on complying with the essential requirements of the EMC Directive 2004/108/EC.

4.2.12. Protection of the environment

Protection of the environment is covered by other European legislation concerning the assessment of the effects of certain projects on the environment.

No conformity assessment is required within this TSI.

- GN49 This is a matter for the infrastructure manager to address. As far as the TSI is concerned, there are neither additional requirements nor anything to be assessed. It is considered that the essential requirements referring to environmental protection (see Annex III (1.4) to Directive 2008/57/EC) are fulfilled by the current general European legislation and agreements and national regulations.

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4.2.13. Geometry of the overhead contact line

Overhead contact line shall be designed for use by pantographs with the head geometry specified in the CR LOC&PAS TSI clause 4.2.8.2.9.2.

The contact wire height, gradient of the contact wire in relation to the track and the lateral deviation of the contact wire under the action of a cross-wind all govern the interoperability of the rail network.

CR LOC & PAS TSI 4.2.8.2.9.2 Pantograph Head Geometry (IC Level)

At least one of the pantograph(s) to be installed on an Electric unit shall have a head geometry type compliant with one of the two specifications given in the clauses below.

The type(s) of pantograph head geometry that an Electric unit is equipped with shall be recorded in the rolling stock register defined in clause 4.8 of this TSI.

Pantograph heads fitted with contact strips having independent suspensions shall remain compliant to the overall profile with a static contact force of 70N applied to the middle of the head. The permissible value for pantograph head skew is defined in EN 50367:2006 clause 5.2.

Contact between contact wire and pantograph head is permitted outside the contact strips and within the whole conducting range over limited line sections under adverse conditions, e.g. coincidence of vehicle swaying and high winds.

CR LOC & PAS TSI 7.3.2.16 Pantograph head geometry (4.2.8.2.9.2)

For rolling stock required to operate on AC 25 kV 50Hz sub-system that has not been upgraded in accordance with the CR ENE TSI, the following requirement shall apply:

In order to maintain compatibility with the existing infrastructure the profile of the pantograph head shall be as depicted in EN 50367:2006, Annex B.7.

In order to maintain compatibility with requirements for running through phase or system separation sections, pantograph heads shall have a maximum along track width of 250 mm, unless permitted by arrangements set out in the Infrastructure Register.

CR LOC & PAS TSI 4.2.8.2.9.2.1 Pantograph Head Geometry Type 1600 mm

The profile of the pantograph head shall be as depicted in EN 50367:2006, Annex A.2, Figure A.7.

- GN50 The profile of the pantograph head defined in EN 50367:2006, Annex A.2, Figure A.7, is the 'Euro-pantograph' profile and has insulated horns that are not generally compatible with existing GB lines.
- GN51 To ensure compatibility with existing lines in GB, a specific case is included in both the TSI and the CR LOC&PAS TSI for the fitting of the pantograph designed for conventional GB infrastructure, with metallic horns, and limits to the along track dimension to ensure compatibility with the practical designs of 'short' neutral section insulators. Single carbon-strip pantographs may also not be compatible with some designs of section insulators.
- GN52 Generally, GB overhead line systems should be designed to allow for the passage of the 1600 mm pantograph designed for conventional GB infrastructure (as depicted in EN 50367:2006, Annex B.7) to be compatible with existing rolling stock (unless the OLE design or pantograph gauge is not compatible with the existing GB pantograph head). No GB lines will be compatible with 1950 mm pantograph heads.
- GN53 On certain lines that are on the migration path towards increased compatibility with the target European pantograph, as depicted in EN 50367:2006, Annex A.2 Figure A.7, there may be an advantage in designing the equipment to allow operation of trains equipped with the pantograph head profiles, as depicted in EN 50367:2006, Annex B.7 and EN 50367:2006, Annex A.2, Figure A.7. Permitted arrangements will be set out in the Register of Infrastructure (see Annex C).

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- GN54 Applying the specific cases will mean that, generally, 'the Euro-pantograph' (EN 50367:2006, Annex A.2, Figure A.7) will not be compatible with GB infrastructure unless this is specifically incorporated in the design of the overhead line. The lateral deviation of the contact wire set out in the specific case is such that the wire will regularly run on the horn insulation. The 'Euro-pantograph' is incompatible with unmodified existing infrastructure. As an example, the class 395 pantograph is a 'Euro-pantograph' design, and HS1 is compatible with that pantograph, as will any future line designed to be compatible with Class 395.

4.2.13.1. Contact wire height

The nominal contact wire height shall be in the range of 5.00 - 5.75 m. For the relation between the contact wire heights and pantograph working heights see EN 50119:2009 figure 1.

The contact wire height may be lower in cases related to gauge (like bridges, tunnels). The minimum contact wire height shall be calculated in accordance with EN 50119:2009 clause 5.10.4.

The contact wire may be higher in cases e.g. level crossings, loading areas, etc. In these cases the maximum design contact wire height shall not be greater than 6.20 m.

Taking into account tolerances and uplift in accordance with EN 50119:2009 figure 1, the maximum contact wire height shall not be greater than 6.50 m.

The nominal contact wire height shall be listed in the Register of Infrastructure (see Annex C).

Specific case 7.5.2.7.1 Contact wire height (4.2.13.1)

In Great Britain, for upgrade or renewal of the existing energy subsystem, or the construction of new energy subsystems on existing infrastructure, the nominal contact wire height adopted shall not be less than 4700 mm.

CR LOC & PAS TSI 4.2.8.2.9.1.1 Height of interaction with contact wires (RST level)

The installation of a pantograph on an Electric unit shall allow mechanical contact from at least one of the contact wires at heights between:

- 4800 mm and 6500 mm above rail level for tracks designed in accordance with the gauge GC.
- 4500 mm and 6500 mm above rail level for tracks designed in accordance with the gauge GA/GB.

CR LOC & PAS TSI 4.2.8.2.9.1.2 Working range in height of pantograph (IC level)

Pantographs shall have a working range of at least 2000 mm. The characteristics to be verified shall be in accordance with the requirements of clauses 4.2 and 6.2.3 of EN 50206-1:2010.

CR LOC & PAS TSI 7.3.2.15 Working range in height of pantograph (4.2.8.2.9.1)

All rolling stock required to operate on UK AC 25 kV 50Hz sub-system that has not been upgraded in accordance with the CR ENE TSI, the following requirement shall apply:

Pantographs shall have a working range of 2100 mm. When mounted on an Electric unit, the pantograph shall operate between 4140 mm (the lower operating position, ref. EN 50206-1, 3.2.13) and 6240 mm (the upper operating position, ref. EN 50206-1, 3.2.13) above rail level.

In exceptional topographical circumstances where electrical clearances are limited by physical restrictions, and a reduced maximum rolling stock (static) height of 3775 mm applies, pantographs on these vehicles shall have a working range of 2315 mm. When mounted on an Electric unit, the pantograph shall operate between 3925 mm (the lower operating position, ref. EN 50206-1, 3.2.13) and 6240 mm (the upper operating position, ref. EN 50206-1, 3.2.13) above rail level.