Rail Industry Standard
RIS-2715-RST
Issue: One **Draft:** 3
Date: December 2022

Rail Industry Standard on Rolling Stock Subsystem and Interfaces to AC Energy Subsystem

Synopsis

This document sets out interface requirements and guidance for the alternating current (ac) energy subsystem for all rolling stock operating over Great Britain (GB) mainline 25 kV ac electrified railway routes.

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Issue record

Issue	Date	Comments
One	04/12/2022	Original document. Created from the relevant non-NTR content of GMRT2111 issue two and associated content in GMGN2611.

Revisions have not been marked by a vertical black line in this issue because this is a new document.

Superseded documents

Superseded documents	Sections superseded	Date when sections are superseded
GMRT2111 Issue Two	2.1, 2.3, 3.5, 3.6, 3.7, 3.13, 3.14, 4.1, 4.7, 4.11, 4.13	04/03/2023
GMGN2611 Issue Two	G 2.1, G 2.3, G 3.5, G 3.6, G 3.7, G 3.13, G 3.14, G 4.1, G 4.7, G 4.11, G 4.13	04/03/2023

Supply

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Part 1 Purpose and introduction

1.1 Purpose

1.1.1 This document is applicable to rolling stock operating over the GB mainline 25 kV ac electrified railway and sets out the interface requirements for the ac energy subsystem that can be route specific.

1.1.2 This document details an industry agreed process to support technical compatibility between rolling stock and the ac energy subsystem at route level and for the provision of information related to this interface. Conformity with the requirements in this document can be used by railway undertakings (RUs) to help them discharge their legal obligations concerning compatibility between the rolling stock subsystem and ac energy subsystem.

1.1.3 This document provides guidance on requirements that define the interface and the need for cooperation between different categories of duty holder to manage risk safely.

1.1.4 This document can be adopted by RUs, rolling stock owners (ROSCOs) and original equipment manufacturers (OEM) under their respective safety/quality management system or when specifying products and services.

1.1.5 The requirements in the document are not applicable to the following types of vehicle:

a) Possession-only rail vehicles.
b) General Contract of Use (GCU) wagons.

1.2 Application of this document

1.2.1 Compliance requirements and dates have not been specified because these are the subject of internal procedures or contract conditions.

1.2.2 If you plan to do something that does not comply with a requirement in this RIS, you can ask a Standards Committee to comment on your proposed alternative. If you want a Standards Committee to do this, please submit your deviation application form to RSSB. You can find advice and guidance on using alternative requirements on RSSB's website www.rssb.co.uk.

1.3 Health and safety responsibilities

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1.4 Structure of this document

1.4.1 This document sets out a series of requirements that are sequentially numbered. This document also sets out the rationale for the requirement, explaining why the

requirement is needed and its purpose and, where relevant, guidance to support the requirement. The rationale and the guidance are prefixed by the letter 'G'.

1.4.2 Some subjects do not have specific requirements but the subject is addressed through guidance only and, where this is the case, it is distinguished under a heading of 'Guidance' and is prefixed by the letter 'G'.

1.5 Approval and authorisation of this document

1.5.1 The content of this document was approved by Rolling Stock Standards Committee on 04 November 2022.

1.5.2 This document will be authorised by RSSB on 01 December 2022.

Part 2 Requirements for all rail vehicles required to operate over 25 kV ac electrified lines

2.1 Short circuit fault protection

2.1.1 Vehicle bonding shall be fully rated for the fault current characteristics of the ac energy subsystem on the intended route.

Rationale

G 2.1.2 Fully rated bonding ensures touch voltages remain within the required limits and supports the rapid disconnection of faults.

G 2.1.3 Incorrect bonding can give rise to danger, such as electric shock, and also result in electrical fires, where the current capacity of the materials used may be exceeded under fault conditions.

Guidance

G 2.1.4 Back-up protection operates on infrequent occasions when faults on the power supply system are not cleared by the primary protection, and in most cases would imply a failure of the primary protection. Back-up protection is not typically considered in touch voltage calculations but, if included, will increase the likelihood of the bond remaining intact after a fault has cleared.

G 2.1.5 The insulated copper cable cross-sectional area values in *Table 1* have been shown to sufficiently withstand fault currents as set out in RSSB research project T1001 (2014).

Bond type	For compatibility with an NTSN compliant 25 kV ac energy subsystem	For compatibility with a legacy 25 kV ac energy subsystem	
Single bond	120 mm^2	95 mm^2	each
Two parallel bonds	95 mm^2	35 mm^2	each
More than two parallel bonds	120 mm^2	-	equivalent

Table 1: Cable sizes for bonding paths

G 2.1.6 The effects of cable fatigue and corrosion can alter the properties of bonding conductors.

G 2.1.7 Maintenance exams typically include examinations for damage or wear of bonding conductors.

G 2.1.8 Where inter-vehicle bonds are fitted, these provide an additional parallel bonding path to be considered in evaluating the capacity of the vehicle bonding.

G 2.1.9 The provision of two bonding paths on a rail vehicle gives resilience in cases where vehicles operating on the railway infrastructure experience increased fault levels. This is with respect to a usual fault level of 6 kA protected by a single bond.

G 2.1.10 After a 25 kV fault has occurred on a vehicle, examination of the bonding conductors and earth brushes can give an indication of whether the bonding system remains sufficient, or whether damage caused requires the changing of components.

G 2.1.11 Additional bonding between vehicles in multiple units, where a vehicle's bonding capacity is lower than the capacity needed to operate on the intended target system, supports appropriate management of fault currents. This is considered good practice on vehicles other than those where a single bond arrangement is used.

G 2.1.12 Bonding path requirements and information on the maximum impedance between the vehicle body and running rail are set out in BS EN 50153:2014+A2:2020 clause 6.4.

G 2.1.13 BS EN 50153:2014+A2:2020 Annex A sets out a UK specific national condition that permits only a single protective bonding path to be in place between a vehicle body and the protective conductors of the fixed installation on vehicles that have to operate over the GB mainline 750 V direct current (dc) electrified railway. This permits rail vehicles which can operate over dc electrified lines to be bonded between the rail vehicle main body structure and one bogie only, and modifies the requirement of BS EN 50153:2002 clause 6.4.2. This UK specific national condition is applicable to all rail vehicle types required to operate over the GB mainline 750 V dc electrified railway, including ac electric rail vehicles that are dual-voltage.

G 2.1.14 Further guidance on the bonding of dc and dual-voltage rail vehicles is set out in GMGN2613.

2.2 Warning line

2.2.1 A continuous warning line 25-30 mm wide, located no higher than 3400 mm above rail level, shall be shown on all rail vehicles, except steam locomotives and wagons, operating over the GB mainline 25 kV ac electrified railway.

2.2.2 The line shall be continuous, except where this is prevented by physical features.

2.2.3 A 'Danger: electricity' warning sign as defined in The Health and Safety (Safety Signs and Signals) Regulations 1998 - Statutory Instruments, 1996 No. 341 (Schedule 1), with the supplementary text 'Overhead Live Wires', shall be fitted adjacent to any steps, ladders or other vehicle feature that when climbed on, could result in the user encroaching beyond the warning line.

Rationale

G 2.2.4 The clear indication of the upper limit on the bodywork of the rail vehicle identifies the line above which it is not safe to work on rolling stock in electrified areas without isolation and earthing of the overhead line. The warning line defines the cant rail for the purposes of GERT8000 Module AC section 4.2.

G 2.2.5 Rail vehicle features are often specific to the vehicle build style and can result in features being placed within, or overlapping the usual warning line position. Steam locomotives and wagons have irregular features which makes it impractical for a warning line to be applied to them.

G 2.2.6 Intrusion into a dangerous area where there is risk of electrocution may be aided by steps, ladders or other bodyshell design features that are easy to climb. A warning label to identify the risk of electrocution will highlight this hazard to anyone using these means of access.

Guidance

G 2.2.7 The height of the warning line can change in accordance with the risk present on the vehicle or to respond to other vehicle features, such as a lower warning line underneath the area of a vehicle where a pantograph is fitted. This considers the danger to staff associated with other components that may be energised to 25 kV ac and not just the OCL.

G 2.2.8 Historically, a minimum clearance of 600 mm has been provided to help personnel maintain a safe electrical clearance for working on the side of vehicles where this is permitted, when adjacent to live parts of a 25 kV ac OCL. This remains the case where the warning line is placed at a maximum height of 3440 mm and the minimum overhead contact wire height is 4040 mm.

G 2.2.9 Where the vehicle has a physical cant rail at an appropriate height, the warning line is placed at the cant rail level.

G 2.2.10 Guidance given in *Appendix A* includes details on how to provide adequate clearance to the overhead line above a non-electric vehicle.

G 2.2.11 *Appendix A* gives a method for positioning the warning line and how certain physical features can be addressed.

2.3 Shore supply

2.3.1 The shore supply shall incorporate a safety interlock circuit to prevent:

a) Disconnection or connection of a shore supply to and from vehicles while energised; and
b) Access to live parts of jumper plugs or receptacles; and
c) Connection of a fixed shore supply to the vehicle system while it is already powered from another source.

Rationale

G 2.3.2 Shore supply safety interlock circuits are designed to protect the user and vehicle from either harm or damage caused as a result of unintended contact with, or disconnection of, the live elements of the shore supply circuit.

Guidance

G 2.3.3 BS EN 50546:2020 sets out requirements and guidance for shore supply systems that can be applied for rolling stock.

2.4 Return current

2.4.1 The running rail(s) shall not be used to return ac currents between loads and their supply either within a single vehicle or between vehicles of a train set.

Rationale

G 2.4.2 Circulating ac currents under a vehicle cause longitudinal voltages to occur. These currents can affect the operation of signalling systems by interfering with track circuits. Returning currents between loads and their supply via the running rail can result in circulating currents.

Guidance

G 2.4.3 Under normal conditions, the return current for circuits supplied from within a train set is not intended to flow in the running rails. However, during fault conditions, circulating current under a train set could be created; this can be considered during the assessment for compatibility with signalling systems.

Part 3 Electrical requirements for 25 kV electric rail vehicles

3.1 Current regulation

3.1.1 For supply voltages above 12.5 kV and below 20 kV, current regulation is permissible so that the maximum allowable train current (ID_{max}) is reduced by the product of the maximum line current and line voltage divided by 20 kV, that is:

$$ID_{max} = \frac{(I_{max} \times V_{line}(kV))}{20\ kV}$$

Rationale

G 3.1.2 LOC&PAS NTSN clause 4.2.8.2.4 includes a note which permits less restrictive current limitation (a lower value of coefficient 'α' as set out in BS EN 50388-1:2022 clause 7.2) to be used on a network or route if agreed by the Infrastructure Manager (IM) for technical compatibility. Using the formula that is set out in *3.1.1* provides this lower value of 'α'.

Guidance

G 3.1.3 The settings for current regulation characteristics are recorded in the register of infrastructure (RINF).

3.2 Regenerative braking

3.2.1 Regeneration of power shall not be initiated or continue if the OCL voltage at the pantograph is at a predetermined value for the route within the range of 27.5 kV to 29 kV.

3.2.2 The upper voltage limit for regeneration shall be adjustable in a maximum of 500 V steps.

Rationale

G 3.2.3 Several different rolling stock classes can be expected to operate over the same route. Permitting adjustment of the maximum limits for regeneration allows for compatibility across the ac energy subsystem between rolling stock classes operating at the same time in the same area.

G 3.2.4 As regeneration to the contact line is permitted up to and including 29 kV (U_{max2}) in accordance with LOC&PAS NTSN clause 4.2.8.2.3, it is beneficial to have an adjustable inhibit threshold above 27.5 kV (U_{max1}). This is normally a maintenance setting in 500 V increments that facilitates tuning to suit the characteristics on different routes.

Guidance

G 3.2.5 Manual control of regenerative braking, such as its isolation by a circuit breaker, can be useful for operational staff if circumstances require immediate isolation of this capability. The control does not need to be operated by a driver whilst driving the train set and can be located in a cupboard that is accessible when the train set is in service.

G 3.2.6 Where the use of regenerative braking is not possible on certain sections of line, this is recorded in RINF.

G 3.2.7 RSSB research report T1001 (2014) gives information on rolling stock that can affect, or be affected by, regenerative braking.

3.3 Control of the in-feed circuit breaker, pantograph and associated interlocks

3.3.1 Each pantograph shall only be raised from its stowed position when its associated in-feed circuit breaker is in the open state.

3.3.2 The in-feed circuit breaker associated with a pantograph shall not close until the associated pantograph is in contact with the live OCL.

Rationale

G 3.3.3 A controlled method for connecting the vehicle to the ac supply prevents arcing from occuring between the pantograph and OCL, which would cause damage to both sides of the interface.

G 3.3.4 Closing the in-feed circuit breaker before a pantograph is in contact with a live OCL can result in damage to onboard and signalling equipment.

Guidance

G 3.3.5 Due to the installation of existing signalling systems, the ac transformer inrush might need to be considered as part of route compatibility. BS EN 50388–1:2022 clause 11.4 also sets out requirements for the maximum inrush current of an ac traction unit.

G 3.3.6 The in-feed circuit breaker may be triggered to operate by systems such as pantograph raise/lower, automatic drop detection (ADD), automatic power control (APC) and automatic power change over (APCO).

G 3.3.7 BS EN 50388-1:2022 clause 11.3 sets out requirements for in-feed circuit breakers to trip automatically within 3 seconds after loss of line voltage and to not reclose within 4 seconds of the line being re-energised to allow for testing of the line for a persistent short-circuit. It also refers to BS EN 50163:2004 clause 4.1, Note 2, which recommends that, through a UK special national condition, undervoltage relays are set from 85 % to 95 % of U_{min2}. GB historical practice for undervoltage relays has been to set them to 10 kV, which is lower than 85 % of U_{min2}.

3.4 Power frequency harmonics

Guidance

G 3.4.1 For compatibility with the ac energy subsystem, the rms harmonic current generated by a train set as a percentage of the rms fundamental current at any frequency typically does not exceed the values set out in *Table 2*.

Harmonic	Harmonic current as a percentage of current at the fundamental frequency
1	100 %
3	15.5 %
5	7.6 %
7	3.5 %
9	1.4 %
11	0.7 %
13	0.5 %
15	0.33 %
17	0.3 %
19	0.2 %
21	0.15 %
> 21	0.1 %

Table 2: Harmonic current as a percentage of current at the fundamental frequency

G 3.4.2 Exceeding the values in *Table 2* may result in excessive interference current from the train set which presents a risk to the safe operation of the ac energy subsystem. When the switching frequency does not match the power harmonic frequencies, the most stringent requirement of the two adjacent values in *Table 2* is considered the most appropriate measure to reduce the impact to the infrastructure.

G 3.4.3 Vehicle switching frequency related harmonics are given in *Table 3*.

Switching frequency related harmonics	Harmonic current as a percentage of maximum current demand
Below 300 Hz	15.5 %
300 Hz to 450 Hz	1.5 %
Above 450 Hz	1 %

Table 3: Harmonic current at switching frequency

G 3.4.4 Harmonic current increases the rms current in an electrical supply circuit and reduces the quality of the supply voltage. Equipment can malfunction or be damaged as a result of poor harmonic current control. This can impose risk for the safe operation of the railway.

G 3.4.5 It is considered good practice to, where possible, minimise any switching frequency, particularly at values in excess of 900 Hz, which have a potential to excite electrical resonance of the overhead line.

G 3.4.6 The values given in *Table 2* and *Table 3* are average figures that can be exceeded transiently. It is understood that these values are broadly out of date and may no longer be entirely accurate, but have been included where alternative values are not available.

G 3.4.7 The values in *Table 2* are for harmonics generated by the vehicles and assume a sinusoidal line voltage.

G 3.4.8 The limits given can be used to give an indication of compatibility with the ac energy subsystem. Lower limits at the given frequencies and limits at other frequencies can be used to understand compatibility with signalling and other infrastructure systems.

3.5 High frequencies (overhead contact line resonance)

Guidance

G 3.5.1 LOC&PAS NTSN clause 4.2.8.2.7 requires an assessment to be undertaken to demonstrate that harmonics and dynamic effects do not cause unacceptable overvoltages in accordance with the process set out in BS EN 50388:2012 part 10. BS EN 50388-1:2022 part 10 and annex I set out updated requirements and guidance for this assessment process.

G 3.5.2 The models and methodology developed in RSSB research project T1225 (2022) as described in report 'Assessing Electrical Resonance Compatibility— Voltage Resonance Model Guidance' supports the assessment referred to in *G 3.5.1*.

G 3.5.3 If the models and methodology developed in RSSB research project T1225 (2022) are not used, a worst case (maximum open circuit) OCL impedance of 15 kΩ, at frequencies between 2 kHz and 20 kHz, is a historical value that has been assumed for operation over all routes.

G 3.5.4 RSSB research project OTH-RES (2020) contains information that supports the models and methodology set out in RSSB research project T1225 (2022).

G 3.5.5 The full report from RSSB research project T1225 (2022), and the models and methodology for assessing electrical resonance compatibility are available on SPARK on the RSSB website.

G 3.5.6 Train borne EMC monitoring allows for the measurements of harmonic currents and voltage at the primary side of the main transformer(s). EMC monitoring facilities can include voltage transducers and provisions for connecting EMC test equipment, such as power sockets and connection points.

Part 4 Mechanical and pantograph bonding requirements for 25 kV electric rail vehicles

4.1 Pantograph disconnection and bonding

4.1.1 Rail vehicles shall have an earthing switch to discharge any residual electrical charge in the vehicles high voltage electrical equipment.

4.1.2 Rail vehicle parts intended for connection to the OCL shall have the means to be bonded to running rail potential.

Rationale

G 4.1.3 Prior to personnel approaching rail vehicle live parts intended for connection to the 25 kV ac energy subsystem, protection can be given by bonding the equipment to running rail potential which reduces the risk of touch voltages and flashovers.

G 4.1.4 Bonding high voltage electrical equipment to running rail potential reduces the risk of electric shock during system maintenance.

Guidance

G 4.1.5 To facilitate safe working on the high voltage electrical equipment on rail vehicles that can be supplied from an OCL, system protection has traditionally been provided by an isolating cock and mechanically interlocked earthing switch. Such systems were put in place mainly to protect depot staff when working on the roof equipment.

G 4.1.6 A manual isolating cock can remove the air supply from the pantograph up valve and prevents the pantograph from being raised. When the device is operated, this isolates the air supply from the pantograph up valve and makes it impossible to raise the pantograph.

G 4.1.7 An earthing switch can bond all high voltage equipment and when it is placed in the closed (earthed) position, it bonds both:

a) The pantograph, roof connections and any other equipment on the supply side of the in-feed circuit breaker to the rail vehicle main body structure; and
b) The roof input bushing, high voltage cable and any other primary circuit equipment on the load side of the in-feed circuit breaker, to the rail vehicle main body structure.

4.2 Pantograph location on rail vehicles

4.2.1 The distance between multiple operating pantographs in contact with the OCL and their position relative to the front of the leading vehicle in any combination shall be recorded in the technical file for the vehicle.

Rationale

G 4.2.2 The distance between multiple operating pantographs on a vehicle is made available in the technical file as it is used to check technical compatibility with the OCL during route compatibility assessments, taking into account signal position and section insulator or booster overlaps, and prevents vehicles from bridging sections.

Guidance

G 4.2.3 The distance between pantographs depends on the relative orientation of fixed configuration units and the orientation of the vehicle with the pantograph fitted to it within the unit.

G 4.2.4 Pantographs are usually located above a bogie to minimise relative lateral displacement on curves.

4.3 Pantograph lowering

4.3.1 It shall be possible for the driver to isolate the ADD after activation.

Rationale

G 4.3.2 A failure or spurious operation of the ADD may result in the pantograph dropping unnecessarily during vehicle operation. This requirement permits a driver to isolate the ADD, preventing the pantograph from dropping unnecessarily, so that the vehicle may move to a position for inspection as set out in GERT8000 Module AC section 12.8 without the requirement for support from other rail vehicles or to maintain its hotel supplies whilst stationary and awaiting recovery.

Guidance

G 4.3.3 Another pantograph can be used if available, rather than isolating the ADD.

G 4.3.4 If the vehicle is multi-mode, alternative means of power can be used instead of isolating the ADD.

G 4.3.5 RSSB research project T1060 (2016) gives information on improvements to pantographs to control failures in addition to the implementation of an ADD system.

G 4.3.6 RSSB research project T1161 (2020) gives information on improvements that can be made to the ADD system.

4.4 Pantograph camera

Guidance

G 4.4.1 The pantograph to OCL interface is monitored by both on-train and fixed cameras.

G 4.4.2 On-train cameras are installed on each train set as appropriate and can monitor the full route that the train set runs on, whereas fixed cameras are in static locations but can monitor all trains that pass through that location.

G 4.4.3 Cameras are used to monitor the interface between the pantograph head and the contact line. Cameras are installed in the pantograph well and positioned to show the raised position of the pantograph and the interaction at the head.

G 4.4.4 The video images are captured on a recorder and requirements and guidance for on-train camera monitoring systems are set out in RIS-2712-RST.

G 4.4.5 The performance or condition of the interface is determined by back-office analysis of downloaded data or by automated image recognition tools that can indicate and provide alerts for points of concern.

G 4.4.6 The data can also be used for post incident investigation when the breakdown of the interface has resulted in damage to the pantograph, OCL system or other parts of the infrastructure.

G 4.4.7 Cameras and other optical sensors are installed at specific locations to assess the condition of the interface and in particular, the pantograph head. These automated image recognition systems can detect abnormal conditions such as damage and excessive wear and can provide immediate alerts through the use of automatic vehicle identification. These sites have readers that take data from vehicle-mounted RFID tags that identify the vehicle. Requirements and guidance for these vehicle-mounted tags are set out in RIS-0796-CCS.

G 4.4.8 RSSB research project COF-UOH-58 (2021) gives information on electrification system monitoring using on-train equipment, which includes cameras.

Appendices

Appendix A Warning Line (Previously Known as Cant Rail Warning Line)

A.1 Warning line

Guidance

G A.1.1 This appendix gives information on the warning line which provides a clear indication of the upper limit above which it is not safe to work on rail vehicles in overhead electrified areas without isolation of the OCL.

A.2 Application to rail vehicles

Guidance

G A.2.1 The warning line is applied to vehicles required to operate over 25 kV ac electrified lines, except steam locomotives and wagons.

A.3 Distinction of warning line

Guidance

G A.3.1 Historically, the target colour of the warning line has been light orange (BS 381C: 1996 Reference No. 557). Orange is the typically recognised colour of the warning line on rail vehicles that has been used in all cases unless there was a problem of visibility of the warning line, or of recognising it as a warning line.

G A.3.2 Distinction against other vehicle features, such as livery colours and joins in bodywork, are factors that can help to determine the specification for a warning line.

A.4 Warning line height

Guidance

G A.4.1 The following can be included when assessing the position of the warning line height above rail level:

a) Visibility when viewed from standing at rail level;
b) The top of the warning line not being any closer than 600 mm to the nearest train-mounted, exposed live electrical equipment, as good practice. All parts of insulators can be considered live for such assessments;
c) The warning line being placed within the range normally reached by carriage washing machines (not higher than 3300 mm above rail level) with the rail vehicle in tare condition with new wheels; and
d) Where placing the warning line at or below 3300 mm prevents it from being carried over the top of areas which cannot be liveried, being at a value less than the absolute maximum.

G A.4.2 Except under the conditions set out in *G A.4.3*, it is good practice to provide a continuous warning line that is positioned so that it is not less than 3100 mm above rail level, when the rail vehicle is in tare condition with new wheels and the suspension is in the service condition.

G A.4.3 Where there are glazed areas, ventilators, grilles, rubber elements or other parts of the rail vehicle that cannot be liveried and which are of such a height that the guidance given in *G A.4.2* cannot be met, then one of either the following conditions can be applied:

a) Carrying of the warning line below 3100 mm in cases where it can be positioned sufficiently high for it to be readily recognisable as a warning line; or
b) The warning line terminated immediately either side of the obstruction and requirements for signage as set out *2.2.3* followed. It is considered good practice to fit the signage within 200 mm of each termination of the warning line, where practicable, on the rail vehicle end and at the same level as the warning line.

G A.4.4 The warning line can be placed above body side doors and windows, rail vehicle end doors and windows, horns and destination and route indicators.

Appendix B Speed conversions

B.1 Conversion table

Note: The content of this appendix is for guidance.

B.1.1 Where there is a reference in any BS EN or NTSN to a speed in km/h, it is good practice to use the conversions to mph in *Table 4.*

Infrastructure subsystem (INF), Rolling Stock subsystem (RST) and Energy subsystem (ENE) speed conversions	
km/h	**mph**
2	1
3	1
5	3
10	5
15	10
20	10
30	20
40	25
50	30
60	40
80	50
100	60
120	75
140	90
150	95
160	100
170	105
180	110
190	120
200	125
220	135
225	140
230	145
250	155

Infrastructure subsystem (INF), Rolling Stock subsystem (RST) and Energy subsystem (ENE) speed conversions	
km/h	**mph**
280	175
300	190
320	200
350	220
360	225

Table 4: INF, RST and ENE speed conversions

Definitions

automatic dropping device (ADD)	device that lowers the pantograph in the event of pantograph head failure or damage of the pantograph head. Source: *BS EN 50206-1:2010*
ID_{max}	Maximum allowable train current.
I_{max}	Maximum line current.
inrush current	Transient current associated with energizing of transformers, cables, reactors, etc. Source: *IEV 448-11-30*
overhead contact line (OCL)	Contact line placed above (or beside) the upper limit of the rail vehicle gauge and supplying vehicles with electric energy through roof-mounted current collection equipment. Sources: *IEV 811-33-02, ENE NTSN* **Note:** Where this includes, in addition to all current-collecting conductors, the following elements: reinforcing feeders; cross-track feeders; disconnectors; section insulators; overvoltage protection devices; supports that are not insulated from the conductors; insulators connected to live parts; along-track feeders; conductors connected permanently to the contact line for supply of other electrical equipment; earth wires and return conductors.
Radio Frequency Identification (RFID)	A method of storing and retrieving data via electromagnetic transmission to a radio-frequency-compatible integrated circuit.
register of infrastructure (RINF)	A register that shall be maintained in accordance with regulation 35 of the Railways (Interoperability) Regulations 2011 (as amended).
route	The physical path of a journey to be undertaken by a vehicle or a collection of vehicles, where the path is comprised of a number of track sections, each of which has individually defined characteristics.
switching frequency	The maximum number of switching (on/off) operations of a device or system per second. Given in Hz.
train set	Combination of vehicles coupled together, including banking locomotives. *BS EN 50388-1:2022*
U_n	Nominal voltage. Designated value for a system. Source: *BS EN 50163:2004+A2:2020*
U_{max1}	Highest permanent voltage. Maximum value of the voltage likely to be present indefinitely. Source: *BS EN 50163:2004+A2:2020*
U_{max2}	Highest permanent voltage. Maximum value of the voltage likely to be present as highest non permanent voltage for a limited period of time. Source: *BS EN 50163:2004+A2:2020*

U_{min2}	Lowest permanent voltage. Minimum value of the voltage likely to be present for a limited period of time. Source: *BS EN 50163:2004+A2:2020*
V_{line}	Voltage at the overhead contact line.

Abbreviations

ac	Alternating current.
ADD	Automatic dropping device.
APC	Automatic power control.
dc	Direct current.
ENE	Energy subsystem.
IM	Infrastructure manager.
LOC&PAS	Locomotive and passenger carriages. Part of the rolling stock subsystem.
NTSN	National technical specification notice.
OCL	Overhead contact line.
RINF	Register of infrastructure.
rms	Root mean squared.
RST	Rolling stock subsystem.

References

The Standards catalogue gives the current issue number and status of documents published by RSSB: http://www.rssb.co.uk/railway-group-standards.

RGSC 01	Railway Group Standards Code
RGSC 02	Standards Manual

Documents referenced in the text

Railway Group Standards

GMRT2111	Rolling Stock Subsystem and Interfaces to AC Energy Subsystem
GERT8000-AC	AC Electrified Lines

RSSB documents

GMGN2613	Guidance on Rolling Stock Subsystem and Interfaces to DC Conductor Rail Energy Subsystem
RIS-0796-CCS	Train to Infrastructure RFID Compatibility
RIS-2712-RST	On-train Camera Monitoring Systems
RIS-2713-RST	System Requirements for the Introduction and Operation of Multi-Mode Rolling Stock

Other references

BS EN 50153:2002	Railway applications — Rolling stock — Protective provisions relating to electrical hazards
BS EN 50153:2014+A2:2020	Railway applications - Rolling stock - Protective provisions relating to electrical hazards
BS EN 50163:2004	Railway applications — Supply voltages of traction systems
BS EN 50388:2012	Railway applications – Fixed installations – Electrical supply and earthing systems for public transport equipment and ancillary apparatus (Fixed installations)
BS EN 50388-1:2022	Railway applications – Fixed installations – Electrical supply and earthing systems for public transport equipment and ancillary apparatus (Fixed installations)
BS EN 50546:2020	Railway applications — Rolling Stock — Three-phase shore (external) supply system for rail vehicles and its connectors
ENE NTSN	Energy National Technical Specification Notice (ENE NTSN). Published by the Secretary of State on 1 January 2021 pursuant to regulation 3B of the Railways (Interoperability) Regulations 2011. This Notice replaces and substantially reproduces the provisions of Commission Regulation (EU) 1301/2014 of 18 November 2014

	(the ENE TSI) and includes relevant amendments made by Corrigendum of 20 January 2015, Commission Implementing Regulation (EU) 2018/868 of 13 June 2018, and Commission Regulation (EU) 2019/776 which came into force in June 2019
LOC&PAS NTSN	Locomotive and Passenger National Technical Specification Notice (LOC&PAS NTSN). Published by the Secretary of State on 1 January 2021 pursuant to regulation 3B of the Railways (Interoperability) Regulations 2011. This NTSN replaces and substantially reproduces the provisions of Commission Regulation (EU) 1302/2014 (the LOC&PAS TSI), and includes relevant amendments made by Commission Implementing Regulation (EU) 2019/776 which came into force in June 2019
SI 1996 No.341 (Schedule 1)	Health and Safety (Safety Signs and Signals) Regulations 1998
T1001 (2014)	Review of existing rolling stock against new and upgraded electrification compliant with the Energy TSI
T1225 (2022)	Develop rolling stock and infrastructure models to improve electrical resonance compatibility

Other relevant documents

Railway Group Standards

GLRT1210	AC Energy Subsystem and Interfaces to Rolling Stock Subsystem

RSSB documents

RIS-1853-ENE	Rail Industry Standard on AC Energy Subsystem and Interfaces to Rolling Stock Subsystem