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Guidance on Rolling Stock Subsystem and Interfaces to AC Energy Subsystem

Issue One: December 2014

Rail Industry Guidance Note for GM/RT2111



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Guidance on Rolling Stock Subsystem and Interfaces to AC Energy Subsystem

Issue record

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Superseded documents

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

Supply

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Guidance on Rolling Stock Subsystem and Interfaces to AC Energy Subsystem

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Part 1 Introduction

G 1.1 Purpose of this document

- G 1.1.1 This document gives guidance on interpreting the requirements of Railway Group Standard GM/RT2111 issue one Rolling Stock Subsystem and Interfaces to AC Energy Subsystem. It does not constitute a recommended method of meeting any set of mandatory requirements. It applies to both 25 kV electric rail vehicles and non-electric rail vehicles such as coaches and freight wagons.
- G 1.1.2 The rolling stock requirements in this document describe the compatibility requirements with all existing and future 25 kV electrified systems. As the existing 25 kV electrification system which predates GL/RT1210 is not TSI compliant, this has necessitated additional rolling stock requirements to fully define the interface with the energy subsystem.

G 1.2 The structure of this document

- G 1.2.1 All requirements from Railway Group Standard GM/RT2111 are reproduced with a grey background in this document.
- G 1.2.2 Guidance is provided as a series of sequentially numbered clauses prefixed 'G' immediately below the greyed text to which it relates.
- G 1.2.3 Specific responsibilities and compliance requirements are laid down in the Railway Group Standard itself.
- G 1.2.4 Part 2 sets out requirements that apply to all rail vehicles that operate over the 25 kV AC electrified network. It applies to both 25 kV electric rail vehicles and non-electric rail vehicles such as coaches and freight wagons.
- G 1.2.5 Parts 3 and 4 set out requirements for 25 kV and dual voltage 25 kV AC / 750 V DC electric rail vehicles.

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G 1.4 Approval and authorisation of this document

- G 1.4.1 The content of this document was approved by Rolling Stock (RST) Standards Committee on 20 June 2014.
- G 1.4.2 This document was authorised by RSSB on 03 November 2014.

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Part 2 Guidance on all Rail Vehicles Required to Operate over 25 kV AC Electrified Lines

G 2.1 Short circuit fault protection

Extract from GM/RT2111

2.1.1 Short circuit fault protection – provision of bonding

2.1.1.1 Bonding shall be provided on all rail vehicles that operate over the 25 kV AC system, except as set out in 2.1.1.2. The bonding shall be provided as set out in EN 50153:2002 clause 6.4.

2.1.1.2 It is permissible for rail vehicles that also operate over 750 V DC electrified lines to have only a single protective bonding path between the main body structure of the rail vehicle and the running rail.

G 2.1.1 Rationale: This requirement provides an impedance between the rail vehicle body and ground that is low enough to trip trackside feeders and to control touch voltage.

G 2.1.2 Rail vehicle traction load currents should be returned direct to the source of power through designated paths without passing through any parts of the rail vehicle structure, equipotential bonding paths or other components, not designated to carry such currents.

G 2.1.3 The relaxation permitting rail vehicles dedicated to DC electrified lines to be bonded between the rail vehicle main body structure and one bogie only, modifies the requirement of EN 50153:2002 clause 6.4.2. This relaxation is applicable to all rail vehicle types and is not limited to DC electric rail vehicles only.

G 2.1.4 Further guidance on the bonding of DC and dual voltage rail vehicles is set out in GM/GN2613.

Extract from GM/RT2111

2.1.1 Short circuit fault protection – provision of bonding

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

G 2.1.5 Rationale: Circulating currents under a train cause a longitudinal voltage which is incompatible with some signalling systems used.

G 2.1.6 Under normal conditions the return current for circuits supplied from within a train is not intended to flow in the running rails; but during fault conditions, circulating current under a train could be created, and this is considered during the assessment for compatibility with signalling systems.

Extract from GM/RT2111

2.1.2 Short circuit fault protection – bonding capacity

2.1.2.1 Bonding of all rail vehicles shall be compatible with an energy subsystem having the parameters for the maximum fault current and maximum fault durations, as set out in Table 1.

Maximum rms fault current [EN50388:2012, clause 11.2]	Maximum fault duration with back-up protection	Maximum fault duration with main protection operating	Maximum number of reclosures permitted	Maximum cumulative fault duration with main protection operating and maximum number of reclosures
15 kA	1 s	200 ms	2	600 ms

Table 1 Fault current characteristics – target system

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- G 2.1.7 Rationale: This requirement specifies the maximum fault conditions for design, such that bonding capacity can be provided that is fully rated and compatible with the target system.
- G 2.1.8 The figures in Table 1 represent the target system, and therefore by providing bonding capacity compatible with this target system it will provide compatibility for all 25 kV electrified lines in the future.
- G 2.1.9 The maximum impedance between the vehicle body and running rail should be minimised, and should not exceed 40 mΩ in order that the touch voltage remains acceptable. For touch voltage calculations, the impedance between the wheel and running rail can be assumed to be insignificant.
- G 2.1.10 All bonding paths to an axle should use an earth brush arrangement, with an impedance in the order of 1 mΩ, and not rely on the bearing as an earth path.
- G 2.1.11 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 considered in touch voltage calculations.
- G 2.1.12 Where insulated copper cables are used, the body to bogie and bogie to axle bonds should each be of a minimum size of 95 mm² where two parallel copper bonds are used.
- G 2.1.13 Where insulated copper cables are used and where more than two parallel bonding paths are provided, the body to bogie and bogie to axle bonds should have a minimum capacity equivalent to a single bond of 120 mm².
- G 2.1.14 Where insulated copper cables are used with a single bond, the body to bogie and bogie to axle bonds should be of a minimum size of 120 mm².
- G 2.1.15 Where materials other than insulated copper cables are used, then the vehicle bonding should be fully rated for the faults set out in 2.1.2.1.

2.1.2.2 It is permissible for the bonding of rail vehicles that are not intended to operate on lines provided with an energy subsystem having the parameters as set out in Table 1, to be compatible with an energy subsystem having the parameters for the maximum fault current and maximum fault durations as set out in Table 2.

Maximum rms fault current	Maximum fault duration with back-up protection	Maximum fault duration with main protection operating	Maximum number of reclosures permitted	Maximum cumulative fault duration with main protection operating and maximum number of reclosures
6 kA	1 s	250 ms	2	750 ms
12 kA	1 s	250 ms	1	500 ms
15 kA	0.65 s	150 ms	1	300 ms

Table 2 Fault current characteristics for compatibility with existing rail vehicles

- G 2.1.16 Rationale: This requirement specifies the maximum fault conditions for design, so that bonding remains intact on a rail vehicle after clearance of a fault and is compatible with all vehicles presently operating on the 25 kV network.
- G 2.1.17 Body to bogie and bogie to axle bonds should each be of a minimum size of 35 mm² where two parallel copper bonds are used. This provides adequate capacity to be compatible with the values set out in Table 2.

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- G 2.1.18 Body to bogie and bogie to axle bonds should be of a minimum size of 95 mm² where a single bond is used. This provides adequate capacity to be compatible with the values set out in Table 2.
- G 2.1.19 Where inter-vehicle bonds are fitted, these provide an additional parallel bonding path that should be considered in evaluating the capacity of the vehicle bonding.
- G 2.1.20 Vehicles operating on the existing railway infrastructure with a 6 kA fault level are protected by a single 35 mm² bond, but when the fault level is increased to 12 kA or 15 kA with the timings specified in Table 2, then at least two bonds should be intact at all times.
- G 2.1.21 Where a vehicle's bonding capacity is lower than the capacity needed to meet the requirements set out in 2.1.2.1, then the bonding and earth brushes should be examined after a 25 kV fault has occurred on a vehicle.
- G 2.1.22 Where a vehicle's bonding capacity is lower than the capacity needed to meet the requirements set out in 2.1.2.1, additional bonding should be provided between vehicles in multiple units, except for vehicles where a single bond arrangement is used.
- G 2.1.23 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 considered in touch voltage calculations.

G 2.2 Clearance to 25 kV overhead contact line (OCL)

Extract from GM/RT2111

2.2 Clearance to 25 kV overhead contact line (OCL)

- 2.2.1 Except where permitted under 2.2.2, the minimum electrical clearance between all rail vehicle parts not intended for connection to the 25 kV OCL, including any parts that have been disconnected from the 25 kV OCL, and any exposed live part of the 25 kV OCL shall be the maximum reasonably practicable, and no less than the 'normal' values, as set out in GL/RT1210 clause 3.1.7, taking into account the gauge for the routes over which it will operate.
- 2.2.2 Where adequate flashover withstand performance is demonstrated and with the application of appropriate safety measures, it is permissible to use lower electrical clearance values than those set out in GL/RT1210 clause 3.1.7 at particular infrastructure features where 'normal' clearances cannot be achieved.

- G 2.2.1 Rationale: This requirement is to control the risk from flashover between the OCL and the rail vehicle.

G 2.3 Protection of personnel – warning line

Extract from GM/RT2111

2.3 Protection of personnel – warning line

- 2.3.1. A continuous warning line 25-30 mm wide, at least 600 mm from exposed live parts of the OCL, shall be shown on all rail vehicles, except steam locomotives and wagons, operating over the 25 kV AC electrified railway. In addition, on electric rail vehicles, the warning line shall be no closer than 600 mm to the nearest train-mounted, exposed live electrical equipment. The line shall be continuous, except where this is prevented by physical features. Appendix D sets out a method for positioning the warning line.
- 2.3.2. 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 or ladders on vehicles in a position such that it is clearly visible to anyone who is about to use the steps or ladder concerned.

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- G 2.3.1 Rationale: GE/RT8000 sets out that staff working on traction units or other rail vehicles are never to go above the warning line unless a safe system of work is in place. 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 of the overhead line. The warning line defines the cant rail for the purposes of GE/RT8000.
- G 2.3.2 The required minimum clearance of 600 mm should provide safe electrical clearance for working on the side of vehicles where this is permitted, when adjacent to live parts of a 25 kV OCL.
- G 2.3.3 Where the vehicle has a physical cant rail, the warning line should be placed at this cant rail level.
- G 2.3.4 The dimensions set out in Appendix D provide adequate clearance to the overhead line above a non-electric vehicle.

G 2.4 Shore supplies

Extract from GM/RT2111

2.4 Shore supplies

- 2.4.1 Where AC shore supply systems are fitted to vehicles, they shall be compatible with the relevant fixed equipment provided on the network, as set out in 2.4.2 and 2.4.3. The shore supply shall incorporate a safety interlock circuit to ensure that it is not possible to:
- a) Disconnect or connect shore supplies to and from vehicles while energised.
- Or
- b) Access live parts of jumper plugs or receptacles.
- Or
- c) Connect a fixed shore supply to the vehicle system while it is already powered from another source.
- 2.4.2 The interface parameters of the 415 V 3-phase system shall be:
- a) Three phase with no neutral (unearthed).
 - b) 600 A per phase maximum.
 - c) 400/415 V 3-phase – 3 – pin plug / socket.
 - d) BR Catalogue number 64 / 724 or compatible for the train interface (receptacle).
 - e) BR Catalogue number 64 / 725 or compatible for the shore interface (plug).
- 2.4.3 The interface parameters of the 1000 V single phase and neutral system, normally used for electric train heating, shall be:
- a) Single phase two wire (unearthed).
 - b) 600 A maximum.
 - c) 1000 V two single pole plugs / sockets.
 - d) BR Catalogue number 64/360 or compatible for the vehicle plug interface.
 - e) BR Catalogue number 90/11401 or compatible for the vehicle receptacle interface.

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- f) BR Catalogue number 64/2419 or compatible for the shore interface plug.
- g) BR Catalogue number 64/2418 or compatible for the shore interface (receptacle).

The train interface fitted at each end of the vehicle consists of receptacles on the right (facing the vehicle), and a lead and plug on the left (facing the vehicle).

G 2.4.1 Rationale: Shore supply arrangements on rail vehicles should be compatible with the fixed shore supplies.

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Part 3 Guidance on Electrical Requirements for 25 kV Electric Rail Vehicles

G 3.1 System frequency

Extract from GM/RT2111

3.1 System frequency

- 3.1.1 25 kV electric rail vehicle(s) shall be able to operate continuously over the frequency range 47 Hz to 52 Hz, as set out in EN 50163:2004+A1:2007 clause 4.2.

G 3.1.1 Rationale: Frequency is required as a characteristic of the supply. This requirement interfaces with GL/RT1210 clause 2.1.2.

G 3.1.2 The frequency should normally be controlled between the ranges of 49.5 Hz and 50.5 Hz. Although the vehicles can operate over a larger range, compatibility with infrastructure-based systems, including signalling and communications, need not be considered within the ranges 47 Hz to 49.5 Hz and 50.5 Hz to 52 Hz. The infrastructure manager (IM) is expected to manage any signalling implications associated with the system frequency being outside the range 49.5 Hz to 50.5 Hz and within the ranges 47 Hz to 49.5 Hz and 50.5 Hz to 52 Hz, as set out in GL/GN1610 clause G 2.1.9.

G 3.2 System voltage

Extract from GM/RT2111

3.2 System voltage

- 3.2.1 25 kV electric rail vehicle(s) shall be able to operate over the voltage range, as specified in EN 50163:2004+A1:2007 clause 4.1, including the special national condition for UK low voltage as specified in Annex B of EN 50163:2004+A1:2007.
- 3.2.2 It is permissible to omit compliance with the special national condition for UK low voltage, as set out in Annex B of EN 50163:2004+A1:2007, if the overhead line voltage at the pantograph is compliant with EN 50163:2004+A1:2007 clause 4.1, for all the routes over which the 25 kV electric rail vehicle operates.
- 3.2.3 Electric rail vehicle(s) shall not be damaged if the supply voltage falls to any value below U_{min2} .

G 3.2.1 Rationale: Voltage is required as a characteristic of the supply. This requirement interfaces with GL/RT1210 clause 2.1.1.

G 3.2.2 Highest permanent voltage (U_{max1}). The special condition stated in Annex B of EN 50163:2004+A1:2007 'for existing networks where there is no provision for voltage regulation systems, U_{max1} may be exceeded' no longer applies on the Great Britain (GB) mainline railway.

G 3.3 Power factor

Extract from GM/RT2111

3.3 Power factor

- 3.3.1 25 kV electric rail vehicle(s) shall meet the requirements for power factor, as set out in EN 50388:2012 clauses 6.2 and 6.3.

G 3.3.1 Rationale: This requirement interfaces with GL/RT1210 clause 2.1.6.2.

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- G 3.3.2 These values are based on existing practice, and are consistent with the LOC&PAS TSI requirements. This requirement defines the rolling stock power factor characteristics that are no less favourable than those assumed when modelling the traction power supply system. Consequently, this supports subsequent real-world compatibility when the energy and rolling stock subsystems are integrated together such that the worst case timetabled train has an average voltage at the pantograph ($U_{\text{mean useful}}$), for satisfactory traction performance.

G 3.4 Maximum allowable train current and limitation

Extract from GM/RT2111

3.4 Maximum allowable train current and limitation

- 3.4.1 The maximum allowable train current (ID_{max}) shall not exceed 300 A, except where a higher value is compatible with the OCL supply provided on the routes over which a 25 kV electric rail vehicle operates.
- 3.4.2 25 kV electric multiple units, fixed formation units and locomotives, with power higher than 2 MW, including the declared fixed and predefined formations, shall be equipped with power or current limitation function.

- G 3.4.1 Rationale: This requirement interfaces with GL/RT1210 clause 2.1.6.
- G 3.4.2 The maximum train current for a particular line is set out in the Register of Infrastructure. The maximum permitted train current for most lines on the GB mainline railway is 300 A.
- G 3.4.3 The requirement for a device to be fitted to rolling stock allowing the setting of the maximum train current demand is published in the Register of Infrastructure.
- G 3.4.4 Where some trains on a route require a train current demand in excess of 300 A, the energy subsystem on that route should be compatible with this higher value.
- G 3.4.5 The limitation function required by 3.4.2, as well as the maximum current, should also apply this reduction on a pro-rata basis with respect to the current regulation set out in 3.5.
- G 3.4.6 A facility to set the maximum train current would allow different values to be selected for different routes, thus permitting multiple units or locomotives to be used across the network. Methods by which this function might be achieved include:
- A variable current power controller where different positions selected by the driver select different current limits.
 - Driver selectable current demand profiles, either by provision of a switch or via the train management system (TMS).
 - Automatically selected current demand limits by off train systems (for example, the European Rail Traffic Management System / European Train Control System (ERTMS / ETCS)).
 - Maintenance action selectable current profiles and / or current limits.
 - Automatic variation of the current limit dependent on the train formation.

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G 3.5 Current regulation

Extract from GM/RT2111

3.5 Current regulation

- 3.5.1 25 kV electric vehicle(s) that operate over lines that do not conform to the Energy subsystem Technical Specification for Interoperability (ENE TSI) shall regulate current demand so that:
- a) At supply voltages at or above 20 kV, current regulation is not required.
- And
- b) At supply voltages below 20 kV and above 12.5 kV, regulation is required. The regulation shall be implemented so that the maximum allowable train current (ID_{max}) is reduced by the ratio of the line voltage divided by 20 kV, that is, $ID_{max} = (I_{max} \times V_{line} \text{ (kV)}) / 20 \text{ kV}$.
- 3.5.2 For 25 kV electric rail vehicle(s) that operate exclusively over lines that comply with the ENE TSI, automatic regulation, as set out in EN 50388:2012 clause 7.2, shall be provided.

- G 3.5.1 Rationale: To avoid the possibility that train loading could collapse the system voltage under emergency / heavy abnormal load conditions.
- G 3.5.2 The settings for current regulation characteristics are published in the Register of Infrastructure.
- G 3.5.3 As an example, if the maximum current at a voltage at or above 20 kV is 220 A, then the maximum current at 16 kV should not be greater than 176 A, which is 220 times 16 kV divided by 20 kV. $[I_{max} \leq (ID_{max} \times V_{Line}) / 20 \text{ kV}]$, thus if $I_{max} = 220 \text{ A}$, and $V_{Line} = 16 \text{ kV}$, $I_{max} \leq 220 \text{ A} \times 16 \text{ kV} / 20 \text{ kV}$, that is, $I_{max} \leq 176 \text{ A}$.]

G 3.6 Regenerative braking requirements

Extract from GM/RT2111

3.6 Regenerative braking requirements

- 3.6.1 25 kV electric rail vehicle(s) equipped with regenerative braking shall meet the following requirements:
- a) Regenerative braking shall not be initiated if the OCL voltage at the pantograph is less than 17.5 kV.
 - b) Regeneration shall cease when the OCL voltage at the pantograph falls below 14 kV.
 - c) Regeneration shall not be initiated or continue when the OCL voltage at the pantograph is above a predetermined value within the range of 27.5 kV to 29 kV. This setting shall be selectable in a maximum of 500 V steps.
 - d) Manual inhibition of regenerative braking in the train shall be controlled from a position on the train accessible to the train driver and shall apply to the whole train.

- G 3.6.1 Rationale: This prevents trains from feeding an isolated section or generating overvoltage in the overhead line.
- G 3.6.2 The energy system normally permits the use of regenerative braking. It may be necessary to limit current and / or voltage, therefore these requirements should be adjustable to facilitate compatibility with existing infrastructure and traction units.
- G 3.6.3 Exceptionally, when the use of regenerative braking is not possible on certain sections of line, this is published in the Register of Infrastructure.

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G 3.6.4 A regenerating train should not continue to regenerate into an unsupplied line, as this could present a potential for harm to personnel. Therefore, if traction power is discharged in an emergency, then 25 kV electric rail vehicles which are capable of regenerative braking should automatically cease regeneration as soon as practicable after any of the conditions set out in b) or c) are detected.

G 3.6.5 The steps between 29 kV and 27.5 kV, set out in 3.6.1c), are selectable for compatibility with the characteristics of different routes. Selection of a voltage is not used during operation and is intended to be a maintenance action only.

Inhibition of regenerative braking in the train, as set out in 3.6.1d), is required to prevent current from being exported from the train if the infrastructure is not capable of accepting it. If 'short term' rheostatic braking is provided, this should also be isolated when regenerative braking is inhibited. If 'fully rated' rheostatic braking is provided, then this should not be isolated when regenerative braking is inhibited.

G 3.6.6 The isolation control for the inhibition, set out in 3.6.1d), does not have to be operated by the driver while driving the train, and so it can be located in a cupboard that is accessible when the train is in service but should not, for example, be mounted on the underframe.

G 3.7 Control of the train in-feed circuit breaker, pantograph and associated interlocks

Extract from GM/RT2111

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

- 3.7.1 Each pantograph shall only be permitted to be raised when its associated train in-feed circuit breaker is in the open state.
- 3.7.2 The train in-feed circuit breaker associated with that pantograph shall not close until the associated pantograph is in contact with the live OCL.
- 3.7.3 When pantograph lowering has been initiated, the associated train in-feed circuit breaker shall open immediately.

G 3.7.1 Rationale: The current is to be switched by the train in-feed circuit breaker and not by the pantograph.

G 3.7.2 These requirements define that when the pantograph touches or leaves the overhead line it is disconnected from any significant load and does not therefore draw a significant arc.

G 3.7.3 The transformer in-rush may need to be limited, in order to be compatible with signalling systems. A method of reducing this is to stagger the closure of each train in-feed circuit breaker (AC) associated with a transformer.

G 3.8 Automatic connection and disconnection of 25 kV loads

Extract from GM/RT2111

3.8 Automatic connection and disconnection of 25 kV loads

- 3.8.1 A 25 kV voltage measurement device shall be electrically connected directly to each pantograph. This device is not considered a 25 kV load.
- 3.8.2 Each pantograph shall be able to be disconnected from all 25 kV loads that it supplies using a circuit breaker. This circuit breaker is called the train in-feed circuit breaker.
- 3.8.3 Each pantograph shall have a train in-feed circuit breaker associated with it.
- 3.8.4 The train in-feed circuit breaker associated with a pantograph shall open on the application of an automatic power control (APC) pulse from the APC system associated with that pantograph, only if that train in-feed circuit breaker is closed at the time the APC pulse is applied.

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3.8.5	A train in-feed circuit breaker associated with a pantograph opened by an APC system as set out in clause 3.8.4, shall open within 150 ms of the associated APC receiver passing over a magnet.
3.8.6	The train in-feed circuit breaker associated with a pantograph shall open, within three seconds, on loss of the 25 kV OCL supply detected by the voltage measurement device electrically connected to that pantograph.
3.8.7	Each train in-feed circuit breaker associated with a pantograph shall close on the application of an APC pulse from the APC system associated with that pantograph, when both the conditions in a) and b) below are met: a) The 25 kV OCL supply is energised. b) The train in-feed breaker associated with that pantograph is open.
3.8.8	Any train in-feed circuit breaker shall be inhibited from being automatically closed for a period of 15 minutes after detection of the 25 kV overhead line supply, excepting as set out in 3.8.7.

- G 3.8.1 Rationale: This permits the IM to test the line with all loads disconnected after an overhead line supply trip.
- G 3.8.2 The features set out in 3.8.6 and 3.8.7a) allow testing of the 25 kV overhead system for faults after an overhead line trip. This test requires all train loads to be disconnected in order to function.
- G 3.8.3 The feature in 3.8.6 is provided so that vehicles being fed from the overhead line section to be tested are disconnected from the overhead system.
- G 3.8.4 The feature in 3.8.7a) is provided so that vehicles running into a de-energised overhead line section remain disconnected from the overhead system.
- G 3.8.5 This overhead system fault testing can only be provided when all 25 kV vehicles operating over a route meet the requirements of both 3.8.6 and 3.8.7a). Vehicles which predate GM/RT2111 do not have these features.
- G 3.8.6 Loss of the overhead supply may be interpreted as a voltage level below 10 kV for more than two seconds.
- G 3.8.7 Rationale: Disconnection from the supply prior to the train reaching the neutral section reduces the likelihood of neutral section flashovers.
- G 3.8.8 Clauses 3.8.6 and 3.8.7 define the way the APC system responds to a pulse from the APC receiver, as set out in clause 4.11.
- G 3.8.9 The APC system provides a toggle feature and is designed so that the first pulse encountered on the approach to a neutral section opens the train in-feed circuit breaker and disconnects the train's electrical equipment from the pantograph. The next pulse closes the train in-feed circuit breaker and reconnects the train's electrical equipment to the OCL.
- G 3.8.10 The 150 ms timing specified in 3.8.5 is the total time from passing over a magnet to the breaker being open. It comprises the receiver detection time, together with the train in-feed circuit breaker operation time.
- G 3.8.11 The toggle feature results in a train in-feed circuit breaker being closed if it is open when the rail vehicle approaches a neutral section.
- G 3.8.12 For compatibility, all trains within the electrical section should be disconnected from the 25 kV supply when the overhead line trips. This then allows the IM to test a line for faults with no load connected. The permission to auto-reclose after 15 minutes is so that trains stabled do not remain de-energised.