AS7708:2017

Australian STANDARD®

# Signals Earthing and Surge Protection

RISSB
RAIL INDUSTRY SAFETY AND STANDARDS BOARD

Train Control Systems Standard



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This Australian Standard® AS7708 Signals Earthing and Surge Protection was prepared by a Rail Industry Safety and Standards Board (RISSB) Development Group consisting of representatives from the following organisations:

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The Standard was approved by the Development Group and the Train Control Systems Standing Committee in Select SC approval date. On Select Board approval date the RISSB Board approved the Standard for release.

Choose the type of review

Development of the Standard was undertaken in accordance with RISSB's accredited process. As part of the approval process, the Standing Committee verified that proper process was followed in developing the Standard.

RISSB wishes to acknowledge the positive contribution of subject matter experts in the development of this Standard. Their efforts ranged from membership of the Development Group through to individuals providing comment on a draft of the Standard during the open review.

I commend this Standard to the Australasian rail industry as it represents industry good practice and has been developed through a rigorous process.

**Paul Daly**
Chief Executive Officer
Rail Industry Safety and Standards Board

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# AS7708:2017

**Signals Earthing and Surge Protection**

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# 1 Introduction

## 1.1 Purpose

This Standard describes a set of mandatory and recommended requirements for the nomenclature, design and development, construction and implementation, testing and commissioning, monitoring and maintenance, modification, decommissioning and disposal of signals earthing and surge protection in Australia.

The main purpose of the requirements are to:

(a) Provide a uniform basis to address all identified hazards associated with lightning and electrical surges in railway signalling and telecommunications equipment.

(b) Clearly and accurately describe each of the essential requirements (functions, design considerations and constraints, performance, maintainability, monitoring and safety) of signals earthing and surge protection devices for railway application.

(c) Promote a consistent or uniform treatment of signals earthing and surge protection methods across the Australian railway networks.

## 1.2 Scope

This Standard provides a whole-of-life cycle approach to safety application of signals earthing and surge protection devices. It covers the general management requirements, design and development, construction and implementation, testing and commissioning, monitoring and maintenance, modification, decommissioning and disposal of signals earthing and surge protection devices in Australian rail networks.

The following are covered under this standard:

- Lightning surges;
- Traction surges
- Power surges;
- Earth potential rise from power system faults;
- Worker safety risk;
- Signalling system availability risk and possible solutions;
- Computer and data communications system interface;
- Standard requirements for products;
- Signals earthing requirements;
- Earthing, communications, traction co-ordination;
- Earth wiring within location / earth impedance;
- Electric traction drop zone and protection;
- Ongoing maintenance;
- Adjacent power lines;
- Clean and dirty wiring segregation;

- Standard requirements for surge protection devices & earthing equipment;
- Dimensions;
- Test points;
- Connections;
- Safety integrity of cross connections;
- Indexing of components;
- Fail indicators;
- Failure modes;
- Multiple earthing situations;
- Condition monitoring and remote monitoring.
- System safety

This standard does not cover electrical traction bonding for worker protection.

## 1.3 Compliance

There are two types of control contained within RISSB Standards:

(a) mandatory requirements

(b) recommended requirements

Each of these types of control address hazards that are deemed to require controls on the basis of existing Australian and international Codes of Practice and Standards.

A **mandatory** requirement is a requirement that the standard provides as the only way of treating the hazard.

Mandatory requirements are identified within the text by the term shall.

A **recommended** requirement is one where the standard recognises that there are limitations to the universal application of the requirement and that there may be circumstances where the control cannot be applied or that other controls may be appropriate or satisfactory, subject to agreement with the Rolling Stock Operator, Rail Infrastructure Manager and/or Rail Safety Regulator.

Recommended clauses are mandatory unless the RIM or RSO can demonstrate a better method of controlling the risk.

Recommended requirements are to be considered when compliance with the standards is being assessed.

Recommended requirements are identified within the text by the term should.

Hazards addressed by this standard are included in an Appendix. Refer to the RISSB website for the latest Hazard Register Guideline: www.rissb.com.au

## 1.4 Referenced documents

### 1.4.1 Normative references

The following referenced documents are indispensable for the application of this Standard:

(a) AS7702 – Type Approval Standard

(b) AS7720 – Signals Enclosure

(c) AS7722 – EMC Management

(d) AS/CA S009 – Australian Standard – Installation requirements for customer cabling (Wiring Rules)

(e) AS/ISO 9001 – Quality Management Systems

(f) AS/NZS 1768 – Lightning protection

(g) AS/NZS 3000 – Wiring rules Section 5 – Earthing arrangement and earthing conductors

(h) AS/NZS 4117 – Surge protective devices for telecommunications applications

(i) AS 4417

(j) AS/NZS 15288 – Systems Engineering – System life cycle management process

(k) IEC 62236-5: Railway applications - Electromagnetic compatibility - Part 5: Emission and immunity of power supply installations and apparatus

(l) IEC 62498-3 - Railway applications - Environmental conditions for equipment - Part 3: Equipment for signalling and telecommunications

(m) IEC 62305-4 SER Protection against lightning Part 4: Electrical and electronic systems within structures

(n) IEC 62561-3 Lightning protection system components (LPSC) - Part 3: Requirements for isolating spark gaps (ISG)

(o) Work Health and Safety Acts and Regulations

(p) Rail Safety National Law and Regulations

### 1.4.2 Informative references

The following referenced documents are used by this Standard for information only:

(a) AS/ISO 9001 – Quality Management Systems – Requirements

(b) AS/ISO 9004 – Quality Management Systems – Guidelines for Performances

(c) AS/NZS ISO 31000 – Risk Management - Principles and Guidelines

(d) AS/NZS IEC 60300 - Dependability Management - Guidance for management and application

(e) IEC 60364-1 Low-voltage electrical installations - Part 1: Fundamental principles, assessment of general characteristics, definitions

(f) IEC 60664-1 Insulation Coordination within low voltage systems – Part 1

(g) IEC 61643 -21 Low Voltage surge protective devices - Part 21: Surge protective devices connected to telecommunications and signalling networks - Performance requirements and testing methods

(h) IEC 62236-4: Railway applications - Electromagnetic compatibility - Part 4: Emission and immunity of the signalling and telecommunications apparatus

(i) IEC 62425 Railway applications - Communication, signalling and processing systems - Safety related electronic systems for signalling

(j) IEC 62497-1 Railway Applications – Insulation Coordination – Part 1

(k) IEC 62561 - 7 Lightning protection system components (LPSC) - Part 7: Requirements for earthing enhancing compounds

(l) IEC 61557-8 Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. - Equipment for testing, measuring or monitoring of protective measures - Part 8: Insulation monitoring devices for IT systems

(m) RISSB Guideline - Railway Infrastructure –Hazard

(n) RISSB National Guideline – Glossary of Railway Terminology

### 1.4.3 Definitions

General railway technical terms can be found at: https://www.rissb.com.au/glossary/

***Apparatus case:*** A housing which is intended for unprotected outdoor use. It is usually of metal construction (or wooden if a cupboard), smaller than a fixed or relocatable equipment building and usually capable of being transported as a made-up unit.

***Clean wiring:*** All cables that originate from surge or transient protection units.

***Differential earth clamp:*** A device that electrically connects two earthing systems under transient overvoltage conditions, but remains electrically disconnected under normal operating conditions. [AS/CA S009]

***Dirty wiring:*** All wiring from and to the field that does not have any form of surge or transient protection.

***Earth:*** part of the Earth which is in electric contact with an earth electrode and the electric potential of which is not necessarily equal to zero. [IEV ref 195-01-03)]

***Earth Leakage Detector (ELD***): instrument intended to detect a leakage current to earth (IEV ref 313-01-24)

***Earth Potential Rise (EPR):*** A rise in voltage of an earthing system and the surrounding soil with respect to a distant earth. EPR is a condition caused by the flow of power system fault current to earth at a HV installation such as an electrical substation, HV transformer or, commonly, a HV pole with a conductive element to earth. [AS/CA S009]

***Earth Rod:*** A metal rod with earth wire connection to disperse current into the ground for safety.

***Earthing:*** Earthing of signalling equipment to protect staff from high voltage power supplies and electrification systems and to assist in protecting equipment from lightning. Signalling circuits are insulated/isolated from earth and the presence of any earth fault on wiring is a definite danger to signalling circuitry and calls for protective measures to be taken

***Earthing conductor:*** The conductor by which the final connection to an earth electrode is made. [AS1768]

***Earthing electrodes (earth rods or ground rods):*** Those portions of the earth termination that make direct low resistance electrical contact with the earth. [AS/NZS 1768:2007]

***Earthing resistance***: The resistance of the signalling earth to the general mass of earth, as measured from a test point. (AS 1768 modified)

***Equipotential bonding:*** Electrical connections intended to bring exposed conductive parts or extraneous conductive parts to the same or approximately the same potential, but not intended to carry current in normal service. [AS/NZS 3000]

***Extra Low Voltage (ELV):*** A voltage not exceeding 50V AC or 120V D.C. [AS/NZS 3000]

***High Voltage (HV):*** A voltage exceeding LV limits. [AS/NZS 3000]

***Hazardous state:*** A state that has the potential to cause harm to persons, significant material damage or other unacceptable consequences (IEC 60050-192, 192-02-26)

***Functional safety:*** part of the overall safety that depends on functional and physical units operating correctly in response to their inputs (IEC 60050-351, 351-57-06)

***Immunity Level:*** The maximum level of a given electromagnetic disturbance incident on a particular device, equipment or system which it remains capable of operating at a required degree of performance. (IEC 60050-161, IEV ref 161-03-14)

***Low Frequency Induction (LFI):*** The generation of currents in a telecommunications line due to inductive coupling with a power line carrying large unbalanced currents, e.g. during a fault condition on a HV power system.

***Low Voltage (LV):*** A voltage exceeding ELV limits but not exceeding 1000 V A.C. or 1500 V D.C. [AS/NZS 3000]

***Port:*** Particular interface of an equipment which couples this equipment with the external electromagnetic environment and through which the equipment is influenced by this environment. (IEC 60050-161, 161-01-27)

***Protection earth:*** An earth provided for lightning and surge protection purposes.

***Self-restoring:*** The ability to either recover completely or in a degraded state its insulating properties after a disruptive discharge caused by the application of an overvoltage.

***Surge:*** transient voltage wave propagating along a line or a circuit and characterized by a rapid increase followed by a slower decrease of the voltage. [IEV ref 614-03-25]

***Telecommunications Functional Earth Electrode (TFEE):*** An electrode that provides a connection to the general mass of earth for functional earthing of telecommunications equipment and cabling

***Track Coupler Unit (TCU):*** a compound containing electrical switchgear, protection and control equipment associated with a tee-off to supply a spur line.

***Track Sectioning Cabin (TSC):*** a compound incorporating electrical switchgear, protection and control equipment which is arranged to connect together a number of electrical sections of overhead traction wiring equipment.

***Transient:*** pertaining to or designating a phenomenon or a quantity which varies between two consecutive steady states during a time interval short compared with the time-scale of interest [IEV ref 161-02-01]

***Surge protective device:*** A device that is intended to mitigate surge over voltages and over currents. [AS1768]

***Potential earth clamp:*** Also known as a differential earth clamp. It is used to limit the potential difference between two separate earths

### 1.4.4 Acronyms

***AC:*** Alternating Current

***AEB:*** Arrestor Earth bar

***CBI***: Computer Based Interlocking

***DC:*** Direct Current

***ELD***: Earth Leakage Detector

***ELV***: Extra Low Voltage

***EMC***: Electromagnetic Compatibility

***EMI***: Electromagnetic Interference

***EPR:*** Earth Potential Rise

***HV:*** High Voltage

***LV:*** Low Voltage

***LFI:*** Low Frequency Induction

***LPS:*** Lightning Protection System

***MEBS***: Main Equipotential Bonding Strip

***RIM:*** Rail Infrastructure Manager

***RCM:*** Regulatory Compliance Mark

***SER***: Signalling Equipment Room

***SPD***: Surge Protection Device

***SPM:*** Surge Protection Measures (IEC 62305)

***TFEE:*** Telecommunications Functional Earth Electrode

***TCU:*** Track Coupler Unit

***TSC:*** Track Sectioning Cabin

# 2 General

## 2.1 Principles

The lightning protection system shall comply with the requirements AS/NZS 1768.

## 2.2 Safety

### 2.2.1 Functional safety

The railway signalling system is a safety system. Care shall be taken to ensure that the surge protection provided cannot create an alternative path between items of signalling equipment as this may cause a significant hazard to personnel and property.

The lightning and surge protection shall be considered as part of the “Fail-Safe” signalling system.

The surge protection equipment shall not reduce the level of safety provided by the signalling system.

### 2.2.2 Work health and safety

The design, manufacturing, construction, testing, commissioning, maintenance and monitoring shall comply with the relevant Rail Safety National Law and Regulations, the Work Health and Safety Act and Regulations.

The weight of the equipment shall be considered with regards to the current Work Health and Safety Regulations & Codes of Practice with regards to safe handling by persons and with respect to the installation and maintenance requirements.

The surge protection equipment shall present a low risk to personnel working near the surge protection equipment if a nearby lightning flash occurs.

The safety of personnel working on or near the surge protective equipment shall be considered when designing the layout of the surge protective equipment or the route for earth conductors.

## 2.3 Competency requirements

The design, installation, construction, testing, commissioning, monitoring and maintenance of all signal earthing and surge protection devices shall be carried out by a staff deemed competent and suitably qualified to undertake that work in accordance with the competency management procedures established by the Rail Infrastructure Manager (RIM).

Rail organisations should document each training requirement and associated competency certification relevant to perform each type of work on all railway signalling infrastructure.

## 2.4 Change management

The RIM shall ensure that change management procedures for lightning and surge protection equipment are established by all relevant stakeholders, to ensure proper identification and control of the safety risks associated with changes to the equipment protection measures.

## 2.5 Interface co-ordination

Co-ordination between disciplines shall be established to enable identification of adjacent conductive structures and any potential impacts on propagation of surges from 'ground zero' of over long distances to trackside signalling equipment.

This should be carried out early on in the design stage to enable the mitigation of the identified risks.

## 2.6 Documentation and record management

### 2.6.1 Quality assurance

The design, manufacturing, construction, testing, commissioning, maintenance and monitoring of signals earthing and surge protection devices shall be accredited to the appropriate Australian Quality Standards or recognised international equivalent if the manufacturer is based overseas.

It is considered that the following are appropriate Australian Quality Standards:

(a) - AS/ISO 9001 - Quality Management Systems – Requirements

(b) - AS/ISO 9004 - Quality Management Systems – Guidelines for Performances

### 2.6.2 Quality assurance documentation

Quality assurance documentation shall be in accordance with the requirements of Australian Quality Standard “Quality Management and Quality Assurance Standards” AS/ISO 9001 or recognised international equivalent if the manufacturer is based overseas.

## 2.7 Verification and validation

The design, development, manufacturing, construction, testing and commissioning of all signals earthing and surge protection systems shall be managed in accordance with ASNZ 15288.

A procedure for verification and validation for each lifecycle of the signals earthing and surge protection systems should be developed to demonstrate compliance with this standard. This will also ensure that the system is able to achieve the requirements and performance that was originally intended for its safe operation.

## 2.8 Risk management

The risk management of the whole lifecycle of all signals earthing and surge protection should comply with AS/NZS ISO 31000.

## 2.9 Environmental conditions

The signals earthing and surge protection shall comply with the requirements of IEC 62498-3 of use in the installation. By default surge protection device (SPD) should be suitable for installation in cubicles.

## 2.10 Design Life

The earthing and surge protection system shall have a design life such that it does not compromise the required life of the signalling system.

# 3 Design and Development

## 3.1 Design management plan

The design of all signals earthing and surge protection should be integrated as part of the signalling design management plan. The plan should clearly identify the design requirements, constraints, strategy, planning, resource requirements and financial management of the design project.

## 3.2 Safety in design

In order to meet the obligations under the Rail Safety National Law and the Work Health & Safety Act and all associated regulations, as may be amended from time to time, or successor legislations, the design of signals earthing and surge protection shall, so far as is reasonably practicable, incorporate all safety considerations associated with the full life cycle of each element of the design.

The RIM shall be responsible for ensuring that the designer clearly understands their responsibilities and obligations to ensure the design of the signals earthing and surge protection will not affect the health and safety of persons nor will it affect the integrity of the signalling system:

(a) during the construction of the signals earthing and surge protection;

(b) when the signals earthing and surge protection has been constructed and is being used for the purpose it was originally designed for; and

(c) where signals earthing and surge protection has been decommissioned and is not being used for the purpose it was originally designed for, yet has not been removed or demolished, and either all or partial components remain.

## 3.3 Surge protection design requirements

(a) The design of surge protection measures (SPM) shall be produced and assured to meet the required reliability, availability, maintainability, safety and expected life of the railway signalling installation.

(b) The design shall detail all of the installation and construction arrangements necessary to achieve the required performance.

(c) The design of the surge protection arrangements shall be based on AS 1768. The railway signalling system safety was not considered as part of the development of AS 1768. As a result two additional risk areas need to be managed; lightning damage to railway signals equipment causing a hazard and a surge protection device (SPD) causing a hazardous state that railway signalling equipment is designed to protect.

(d) Protection of structures, miscellaneous structures and property for the signalling site shall be provided based on either of the AS 1768 approaches 'no avoidable risk' or 'assessment and management of risk'.

(e) The AS 1768 'no avoidable risk' approach shall be applied for the protection of persons and equipment by application of the requirements defined in this standard.

(f) In the 'no avoidable risk' approach structures, miscellaneous structures and property are allocated a required protection level of at least AS 1768

Protection Level IV. A higher protection level is allocated based on the criticality of the railway signalling site to operation of the railway.

(g) AS1768 includes protection of fences. The earthing arrangements in Section 3.4 of this standard takes precedence over AS1768 requirements and recommendations for fences in the rail corridor or at the boundary of the rail corridor.

(h) Signalling trackside equipment locations and any associated shade structures are small buildings and shade structures in terms of AS 1768. Step, touch and transferred potential protective arrangements for people shall also be applied for equipment locations where the person is unable to enter the small building.

(i) Protective measures for equipment shall comply with AS1768 to protect against lightning flashes to the appropriate lightning protection level class, electrical traction related surges, 50 Hz EPR events and LFI that could occur at the site.

*Note: Not all signals equipment is installed within buildings. These requirements in AS1768 and this standard are applicable to all signals equipment.*

*Note: An EPR event has two main causes. Firstly an EPR event can be caused by a lightning flash. Secondly an EPR event can be caused by an electrical power or electric traction fault to earth. Each cause is addressed separately.*

*Note: IEC 61643-11 was previously known as IEC 61643-1. Some of the referenced documents still refer to the previous number.*

*Note: AS 1768 assumes that the electrical supply is an MEN arrangement which is not the typical arrangement for signals equipment.*

*Note: Many surge protection standards have references to 'signalling'. They relate to signalling for telecommunication purposes and are not directly applicable to railway signalling.*

(j) In applying AS 1768 risk assessment and management the potential for the failure of electrical and electronic systems used as signals equipment resulting in a hazardous state due to damage caused by lightning that compromises the functional safety provided by the signals equipment shall be included. This hazard can indirectly cause the loss of human life or injury to people travelling on a train and physical damage due to train collision or derailment as a result of lightning damage.

*Note: The risk management calculation tool provided with AS 1768 does not include the loss and damages resulting from compromised functional safety of the railway signalling system.*

(k) The safety requirements detailed in Section 3.3.2 Safety design detail the safety requirements to manage the risk an SPD used as part of the railway signalling system causing a hazard. SPD and SPM shall meet the safety requirements detailed in Section 3.3.2 Safety design.

(l) The equipment used shall be compliant with AS 7722 which is confirmed by AS 7702. The immunity level of each equipment port is therefore defined at common values for the product type.

(m) Co-ordinated surge protection measures (SPM) shall be provided to protect each equipment port. The co-ordinated protection measures shall control the

surge to a level below the tested immunity level of the equipment port minus the induced overvoltage or inductive voltage drop due to the installation arrangement.

(n) The SPD shall have a Regulatory Compliance Mark (RCM) as required by AS 4417.

(o) The SPD shall be designed to limit nuisance tripping of circuit protection due to normal operation of the SPD.

(p) The SPD may affect EMC immunity of the protected circuit due to a reduction in shielding effectiveness and line balance. The application designer shall consider this impact on safety and reliability for circuits that have design frequencies above 10 kHz.

(q) IEC 62305-4 provides more detail regarding SPM including the basic protection measures of earthing and bonding, magnetic shielding and line routing, coordinated SPD system and isolating interfaces. The design of the SPM should apply the detailed concepts and arrangements provided in IEC 62305-4.

(r) AS/CA S009 provides informative guidance in an appendix on "Interference from HV power systems" which covers EPR hazard zones, LFI and Electrostatic coupling. This guidance information is focused on the safety of people. The design of the SPM shall protect people working on and using the signalling system from harm due to EPR hazard zones, LFI and Electrostatic coupling where practical. Work practices are applied for the other cases. The SPM shall be designed to protect the equipment (including SPDs) from damage due to these causes.

(s) Terminals, wiring, cables and miscellaneous items shall be selected to withstand the expected impulse voltage due to a lightning flash when use for the proposed application. Rated impulse voltages are defined for a range of pollution environments by IEC 60664-1 and IEC 62497-1.

(t) The rated impulse voltage should at least meet IEC 60664-1 category II in PD2 or IEC 62497-1 OV2 in PD3.

### 3.3.1 SPD selection

(a) The SPD shall be selected based on analysis and consideration of these requirements:

i. The application of the SPD shall be analysed to determine the compliance with the safety requirements in the particular application of the SPD in accordance with Section 3.3.2.

ii. The site shall be assessed to determine the required lightning protection level and EPR immunity voltage and current.

*Note: Some signals circuits use low resistance per km conductors which results in higher EPR fault currents, increasing the likelihood an EPR damaging a SPD.*

iii. Equipment port immunity level, allowed protection margin, surge rating.

iv. Protected circuit voltage range, current range, frequency range, insertion loss or voltage drop parameters shall be determined.

v. Co-ordination of SPD operation with particular circuit protection device.

vi. SPD capacitance to earth for ac IT arrangements shall be capacitance to earth less than 10 ηF for each leg of the supply with values less than 50% different from one to the other. If more than 10 SPDs are to be used on the one ac power supply then the electrical safety of the power supply shall be assessed for touch current hazards.

vii. Temporary over voltage (TOV) performance for power SPDs

viii. Follow on current breaking performance.

ix. The SPD shall be designed to indicate failures so far as reasonably practicable.

(b) For all SPDs 50 Hz EPR immunity rating should at least meet IEC 61643-21 AC durability test using the 20 A with 1 s duration and 5 applications.

(c) SPD should be compliant with an appropriate part of IEC 61643. If no appropriate part of IEC 61643 exists then the requirements and application shall be assessed as part of type approval.

(d) The SPD should conform to the standardised terminal numbering of SPDs detailed in IEC 61643.

### 3.3.2 Safety design

The standards AS 1768, IEC 62305 (all parts) and IEC 61643 (all parts) have not identified and controlled the risks associated with the application of surge protection to railway signalling systems. Selection and application of surge protection to railway signalling systems needs to identify and control the risks.

(a) The SPD shall be selected and used so that under fault free conditions and the identified failure modes it will not prevent the fulfilment of the safety function or cause a hazardous state.

*Note: The railway applications standard IEC 62425 identifies hardware component failure modes and provides detailed technical requirements for assurance of operation under fault free conditions and the effects of faults for areas of the system that have been allocated a safety function.*

(b) The inherent fail-safe principle should be used for the SPD so that when the SPD is used it does not compromise meeting the functional safety requirements of the protected function. The use of composite fail-safe or reactive fail-safe principles shall be fully assured in conjunction with a specific safety case.

*Note: The use of inherent fail-safe principle means that there shall be no un-revealed safety failures for the SPD, no need to indicate safety related failures for the SPD and no preventative maintenance activities necessary to inspect and test for the safety related conditions of the SPD.*

(c) The surge protection measures shall consider human errors associated with installation and maintenance. One such risk is the installation of a similar but incorrect SPD that has the potential to introduce a hazard.

(d) Failure modes to consider:

i. SPD circuit to other circuits independent of the SPD (open circuit and resistive)

ii. SPD protected circuit to earth (open circuit and resistive)

iii. SPD circuit to other circuits within the SPD (open circuit and resistive)

iv. SPD line terminal to the corresponding SPD protected terminal (open circuit and resistive)

v. Leakage currents (normal and fault conditions )

## 3.4 Earthing arrangement

(a) Signals earthing arrangement applies to fixed signals infrastructure installed in the rail corridor. The rail corridor can have different earthing arrangements for signals, signals ELD test, telecommunications, electrical LV, electrical HV and electric traction and services installed in the rail corridor or crossing the rail corridor.

(b) The different earthing arrangements shall be either co-ordinated or effectively independent and designed to limit impacts under fault conditions.

(c) Two independent earthing systems shall be effectively insulated or physically separated by more than touch distance.

(d) Effectively independent earth systems shall manage potential for unintended connections between two earthing systems due to installation and earth bonding of equipment.

(e) The signals earthing arrangement provides a functional earth for surge protection, noise filtering and signalling safety power supplies.

(f) Functional earthing for surge protection purposes shall comply with AS 1768 given the amendments detailed in the following sections.

(g) The earthing arrangement provided for floating signalling power supplies should comply with earthing for IT (Insulated Terra) power distribution systems as defined in IEC 60364-1.

(h) EPR shall be managed in compliance with AS/CA S009.

(i) Item earths shall be bonded to its applicable earth systems.

(j) Earthing and bonding arrangements for structures and buildings shall be co-ordinated with the responsible electrical discipline.

### 3.4.1 AC Traction railway earthing arrangement

To ensure safety of personnel working within the vicinity of an AC electrified system, the following requirements shall apply:

(a) All metal structures shall be bonded to either the traction return or to the traction earth system depending on its proximity to the running rail, traction feeder station, TSC or TCU as determined by the RIM.

(b) Signal structures positioned outside of the overhead electrification drop zone at a level crossing (e.g., flashing lights on the traffic islands) in an AC electrified line shall be bonded if it is deemed possible that overhead wire may come in contact with the signalling structures due to de-wiring (e.g. truck bringing down overhead line wire).

(c) Metallic signal structures, enclosures or buildings shall be bonded to the traction earthing system unless assessed not required by Traction power.

(d) Equipment enclosures containing equipment connected to the traction system (e.g. track circuit equipment) shall be bonded to the traction earthing system regardless of proximity to overhead wire equipment.

(e) On single rail track circuited or no track circuited track, safety bonding shall be provided between all signalling structures (e.g. location cases, pedestrian gates, flashing light posts, signals, point machines, etc.) and the traction return rail.

(f) On double rail track circuits, safety bonding shall be provided between all signalling structures to the traction neutral terminal of an impedance bond or an overhead traction mast.

(g) Aerial signalling circuit conductors shall not be used in Electrified Territory.

(h) The local authority neutral and earth shall have galvanic isolation between local authority's neutral and AC traction return.

i. All earthing with respect to an isolation transformer shall be forward bonded to the AC traction return conductor.

ii. There shall be adequate separation as determined by the Rim between the local authority's system and the AC traction earthing system.

### 3.4.2 DC traction railway earthing arrangement

(a) The signals earthing arrangements for a DC traction railway shall be co-ordinated with telecommunications and electrical LV. Co-ordination is by provision of physically independent earthing arrangements connected by means of a potential earth clamp between the signals and electrical LV earth. If no electrical LV earth is provided at the particular site then the telecommunications earth can be directly bonded to the signals earth without the use of a potential earth clamp.

(b) The signals earthing arrangements for a DC traction railway shall be effectively independent from electrical HV earthing and any electric traction earthing. Effective independence is defined as follows:

i. no equipotential bonding between signals and electrical HV or electric traction;

ii. electrical HV and electric traction faults to earth do not cause the signals earth to rise in potential relative to the general earth potential by more than 430 V 50 Hz or 600 VDC

iii. Potential earth clamp shall comply with IEC 62561-3 *Lightning protection system components (LPSC) – Part 3: Requirements for isolating spark gaps* requirements for isolation spark gaps. The required parameters are as follows:

1. The rated power frequency withstand voltage shall be at least 300 V.
2. The potential earth clamp should be a normal duty or heavy duty isolating spark gap.
3. Rated power frequency discharge current shall be at least 200 A for 1 second.
4. DC spark-over voltage shall be less than 1000 V

5. Failure mode due to over current or long duration current shall be defined

(c) The design of signals earthing in DC traction territory may be constrained by state based legislation for the prevention of corrosion on metals due to electro -chemical reaction caused by stray DC currents known as electrolysis.

(d) The signals earthing design and installation practice shall comply with the methods required to control electrolysis. The signals earthing design and installation practice shall be co-ordinated with and support the overall railway control of electrolysis. Methods used to control electrolysis are as follows:

i. Not provide stray paths for traction return current to earth

ii. Continuous conductive structures along the rail corridor have insulation provided at regular intervals

iii. Electrical isolation from earth of circuits that run between locations with independent earths

iv. Not using MEN LV earthing arrangements in rail corridor

v. Electrolysis Protection systems – (not signals responsibility)

### 3.4.3 Non-electrified railway earthing arrangement

#### 3.4.3.1 Communications earth

(a) Earthing shall be installed at all communications equipment locations. All distribution frames, communications pillars and communications equipment shall be earthed.

(b) The Communications Earth system shall be bonded to any other earths via hard bond or a potential earth clamp as determined by the RIM.

(c) Where a CBI system and its data communications system are connected to a signals earth at the signals equipment room and a communication earth at the control room, the following shall apply:

i. After both the signals earth and the communications earth have been tested and certified as having met the requirements of this standard and other relevant standards, the earthing systems shall be connected together.

#### 3.4.3.2 Low voltage power earth

If a low voltage power earth is provided at the signalling location, then the low voltage power earth and signalling earth shall be bonded via a potential earth clamp (or Differential earth clamp) with a break down voltage of 290 volts, surge rating of 100kA or more, and a 50Hz current rating of at least 50 amps

### 3.4.4 Earth system

(a) The earth terminations, earth electrodes and earth wiring shall comply with AS 1768.

(b) Metallic items potentially exposed to corrosion shall be selected to meet the expected installation life with the planned maintenance arrangement.

*Note: Railways with DC electric traction are a source of direct current that represents an electrolytic hazard as detailed in AS 1768.*

(c) The earthing resistance for a site should be less than 10 ohms. Acceptance of higher earth resistances shall consider the hazards being managed prior to considering the cost benefit obtaining an earthing resistance of less than 10 ohms.

(d) For installation requiring the use of earth enhancing compounds as a measure to reduce the earth resistance, the earth enhancing compounds to be used should meet the requirements of IEC62561-7 and used in accordance with manufacturer's instructions.

(e) Components used to form the lightning protection system (LPS) for railway signalling shall comply with either:

i. AS 3000 requirements for protective earth, or

ii. IEC 62561 requirements for LPS components.

(f) Hot dipped galvanised surface treatment shall not be used for vertical and horizontal earth electrodes.

(g) The earthing conductor from the MEBS to earth electrodes shall be sized appropriately, but shall not be smaller than 16 $mm^2$.

(h) Earth electrode inspection housings shall be provided.

(i) Welding, including exothermic welding is acceptable for use as a permanent connection in the LPS.

(j) A TFEE in accordance with AS/CA S0009 is not acceptable for use as the lightning protection earth.

### 3.4.5 Reliability Availability and Maintainability (RAM)

(a) The design of a surge protection device shall be able to provide adequate protection to withstand induced surges and transients from field cabling to the equipment it is designed to protect without adversely affecting the circuit being protected under normal operating conditions.

(b) The design should provide for a means to test the equipment without interrupting the operation of the circuit it is protecting.

(c) Signals earthing and surge protection should provide improvement in the availability (i.e., reduced failure rates) and contribute to prolonging the life of the equipment being protected.

(d) Where practicable, the system should be self-restoring. This means that once the surge is passed, the system should not prevent the operation of the system that is protected either by a fuse or not continuing follow on current, etc. This will minimise the need for immediate maintenance intervention.

(e) Where practicable, a surge protection device shall be able to be replaced without requiring a system power off/shutdown.

### 3.4.6 Adjacent structures

#### 3.4.6.1 Tower

The design of a signals earthing and surge protection system shall consider the impact of towers, tunnels, bridges, viaducts, fences, etc. as conductive structures that could have

potential impact on the propagation of surges from 'ground zero' over long distances to trackside signalling equipment.

#### 3.4.6.2 Adjacent power lines

Overhead structures and transmission lines are also conductors that can introduce surges to the signalling system. Designers should be aware of the effects of these on signalling systems in order to mitigate such effects.

#### 3.4.6.3 Communications line

Design of surge protection shall comply with the requirements of AS/NZS 4117 and AS 7722: EMC Management.

### 3.5 Test points

(a) An independent test earth shall be provided for locations requiring Earth Leakage detection where required by the RIM.

(b) The independent test earth for an Earth Leakage Detector shall not be bonded to the ELD detection earth.

### 3.6 Earth Leakage Detector

(a) Earth leakage detectors should be installed on all floating AC and DC signalling supplies, including extended voltage mains. The detectors shall indicate the occurrence an earth fault on either side of the supply bus.

(b) The detection arrangement shall be such that any earthing caused by the detector will not under any circumstances cause interference to the signalling circuits.

(c) Earth Leakage Detector sensitivity shall be set to detect a fault condition at a level less than that which would cause a safety hazard.

(d) The ELD should be an insulation monitoring device in accordance with IEC 61557-8 selected for the type of IT power supply system being monitored AC, DC or AC/DC.

(e) A visual indication only for the local warning is accepted with the audible indication not required as part of the device.

(f) Indication of an earth fault is an accepted method of indicating that the ELD is unable to perform its function.

(g) The ELD response time shall be more than 2 seconds and less than 10 seconds.

(h) System leakage capacitance shall be 1uF or higher.

(i) Maximum measuring current shall be less than 3 mA.

(j) The ELD should not indicate an earth fault at power on.

(k) Resistance response value shall be set in accordance the ELD sensitivity given in Table 1.

*Table 1. Earth Leakage Detector Sensitivity Settings*

| Leakage Detector Sensitivity Settings | | | | | |
|---|---|---|---|---|---|
| Busbar volts (nominal) | 12 DC | 24VDC | 50 DC | 120 AC | 415 AC |
| ELD sensitivity | 15 kΩ | 15 kΩ | 40 kΩ | 40 kΩ | 100 kΩ |
| Equivalent earth Leakage current | 1 mA | 1.5 mA | 1.3 mA | 3 mA | 4.2 mA |

## 3.7 Dimensions

(a) The design of all signals earthing and lightning protection shall take into account the size and weight of the device as fitting for the proposed application.

(b) The design shall consider the safety requirements for installation and maintenance of the device to both personnel and equipment.

## 3.8 Documentation of earth wires

(a) All earth wires connected to protective safety earth bars or AEBs should be documented in the design.

(b) All earth wires should be individually identified in the design.

## 3.9 Type approval requirements

(a) The use of signals earthing and surge protection equipment shall undergo the normal type approval process adopted by the RIM;

(b) Only type approved signals earthing and surge protection devices shall be used unless the RIM authorises otherwise according to established and approved procedures;

(c) Type approval of signals earthing and surge protection equipment shall comply with AS7702.

## 3.10 Verification and Validation

(a) The constructor of all signals earthing and surge protection system shall verify that the system is constructed according to the design requirements, fit for the purpose it was designed and is free from faults and defects.

(b) The manufacturer of all signals earthing and surge protection devices shall provide the performance criteria for the product and any specific requirements for its installation.

(c) Signals earthing and surge protection systems shall be installed in accordance to this standard and the design requirements.

## 3.11 Records and Documentation

(a) Designers of earthing and surge protection systems shall produce and submit a technical report on the performance of the proposed surge protection. The technical report shall detail how the performance criteria will be met (to the

RIM's satisfaction) for particular site or sites with the nominated equipment and installation practices.

(b) The technical report is also to consider any special needs for a particular installation due to site aspects or equipment aspects and any special training required for competent staff to carry out installation, testing and maintenance of equipment.

# 4 Construction and Implementation

## 4.1 Detailed requirements

The Construction of signals earthing and surge protection shall be carried out in accordance to this standard, AS7722 EMC Management, AS/NZS 3000 Wiring Rules, AS/CA S009 Installation requirements for customer cabling, AS/NZS1768 Lightning Protection and AS/NZS4117 Surge protective devices for telecommunications.

## 4.2 Factors to be considered

(a) Safety integrity of inter-connections

(b) Interface co-ordination

(c) Signalling availability risk and possible solutions

(d) Accessibility and maintainability

(e) Wiring separation and cable routing

### 4.2.1 Safety integrity of inter-connections

Where an existing signals earthing system is to be interfaced with a new installation, the constructor shall ensure that:

(a) the safety integrity of inter-connections between components of earthing system is achieved for all new and modified construction works;

(b) consideration of the effects of installation of new system on the existing one in as far as the following is concerned:

i. Integrity of the existing system

ii. The safe operation of the system

### 4.2.2 Interface co-ordination

(a) In addition to design interface co-ordination, an interface co-ordination plan with relevant stakeholders should be developed to ensure the minimal interference by construction works to existing system. Hazards from nearby installations including:

i. conductive materials within the installation,

ii. conductive structures;

iii. electrical transmission lines; and

iv. communications cable lines

should be identified and risks mitigated to ensure the safe conduct of installation of the new system and equipment.

(b) If additional risks are identified, they shall be referred back to the designer for resolution.

### 4.2.3 Signalling system availability risk and possible solution

(a) The constructor should maintain the integrity of any existing earthing systems that may be affected by the proposed works.

(b) Drilling, excavation works, etc. are some activities that can cause loss of integrity of an installed earthing system. Procedures should be in place to ensure that existing earthing systems are properly identified and protected during construction works.

### 4.2.4 Accessibility and maintainability

(a) The construction of all signals earthing and surge protection systems shall take into account the accessibility of the equipment after installation to allow easy access for testing, commissioning and maintenance works.

### 4.2.5 Wiring separation and cable routing

(a) Construction shall implement surge protection measures as directed by the design.

(b) Surge protected wiring or clean wiring shall be physically separated from non-surge protected wiring. Earth wires are considered as non-surge protected wiring or dirty wiring. See Figure 1 for the concept of separation.

(c) Separation shall be in accordance with AS/CA S0009. If the separation cannot be achieved then a barrier consisting of an earthed piece of metal work is an acceptable solution to provide the separation.

(d) Cable routing to comply with AS7664 Railway Signalling Cable Routes, Cable Pits and Foundations

(e) If surge protected wiring shall cross non-surge protected wiring then it shall cross at right angles. Earth wires from surge protectors shall be treated as unprotected wiring.

(f) As most parallelism between cables or wires occurs in the cable routes, this needs to be taken into account when segregating wiring.

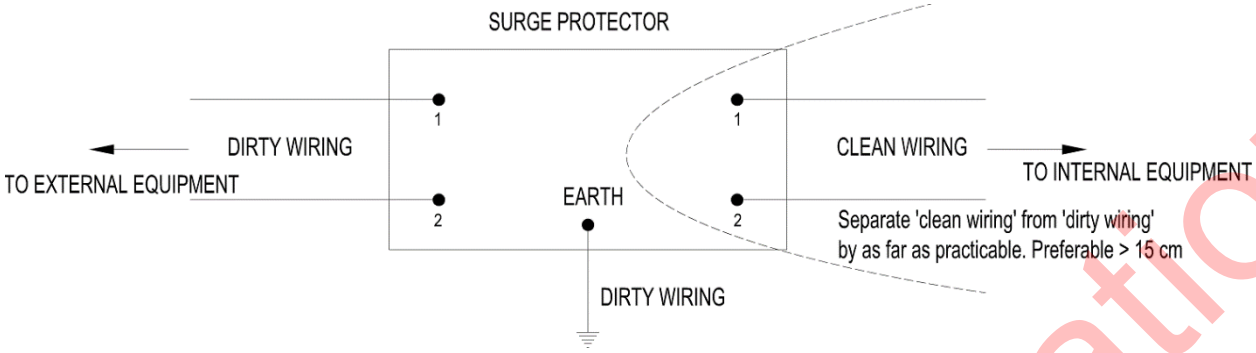


*Figure 1. Concept of Separation*

## 4.3 Cables

(a) To mitigate the effects of ground surge currents cables maybe buried, use twisted pair, longitudinal spiral, insulation rating, shielding and armouring.

(b) In non-electrified areas another established means of mitigating the effect of ground surge currents is the provision of an earthed stainless steel drain wire 300 mm below ground level, and 300 mm above the cables. However careful consideration is required to ensure that this does not create problems due to High Voltage power supply EPR faults being transferred to other locations via the stainless steel wire.

(c) Cables in external cable routes may be exposed to a lightning flash that exceeds their rated impulse voltage. In this case these cables should be protected by either a metallic shielding or supplementary insulation.

*Note: Typically metallic toughing or conduit is used to provide shielding.*

*Note: Typically PVC or GRP toughing or PVC conduct is used to provide supplementary insulation.*

### 4.3.1 Labelling

(a) All earth wires to the protective earth should be labelled as per design and in accordance with existing industry labelling practice.

(b) A procedure should be established so that Main Earth connections are protected from accidentally being removed.

## 4.4 Worker safety risks

A system should be in place to ensure that worker's safety risks are eliminated or reduced in so far as is reasonably practicable in carrying out the installation, testing, commissioning, monitoring, maintenance, decommissioning and disposal of all signals earthing and surge protection systems and devices. A safety risk management system for worker safety protection should be documented.

Approved and appropriate PPEs shall be used in carrying out such activities.

The common worker safety risks may include:

(a) Electrocution due to Step and touch potential

(b) Trip hazards from protruding earth connections

(c) Lack of training

(d) Other location specific risks identified in risk assessment

# 5 Testing and Commissioning

## 5.1 General

(a) The testing and commissioning of all signals earthing and surge protection systems and devices shall be carried out in accordance with the testing and commissioning plan prepared for a specific project or location and approved by the RIM.

(b) The testing and commissioning plan shall comply with the requirements of RIM's approved safety management plan in conjunction with AS7717 - Testing and Commissioning management.

## 5.2 Inspection and test plans

(a) Testing and commissioning shall confirm that the design and construction was implemented in accordance to the purpose that the signals earthing and surge protection was designed for and has met all the requirements to the RIM's satisfaction.

(b) Tests to be carried out include but are not limited to:

i. earth resistivity test

ii. condition of soil (wet, dry, backfilled, etc.)

iii. visual inspection (cable size, length and cable routing)

iv. continuity test

### 5.2.1 Earth system resistance testing

(a) Australian Standard AS1768 shall be the basis for the methods to be used for carrying out earth resistance tests.

(b) Earth resistance testers generate a signal that could cause interference to railway equipment. Earth resistance testers shall be selected and usage managed in accordance with AS7722 EMC Management.

### 5.2.2 Testing of safety integrity of inter-connections:

(a) The testing and commission shall not only verify the integrity of the signals earthing and surge protection system and equipment installed or modified but shall also ensure that all interfaces between the new or modified signals earthing and surge protection equipment are effective and operational.

### 5.2.3 System availability risk and management

(a) The testing and commissioning plan should identify the risk to operational system availability of the works to be carried out and how this is to be managed.

(b) The testing and commissioning activities shall mitigate the risk of accidental disruption to the availability of operating systems by the works being carried out.

### 5.3 Testing documentation

(a) All testing and commissioning works shall be carried out in accordance to RIMs approved procedure to ensure the use of approved and current plans.

(b) The tester in charge shall be responsible in ensuring that the works have been satisfactorily constructed to the design requirements and confirms the same through the issuance of test certificates.

(c) Upon completion of works, as-constructed drawings shall be provided by the Designer to the RIM in a timely manner as agreed between parties.

### 5.4 Verification and Validation

(a) The testing and commissioning process shall verify that the signals earthing and surge protection system were safely installed as per design and validate that it has been built to the specification of the design.

## 6 Monitoring and Maintenance

### 6.1 Maintainability

#### 6.1.1 Periodic examination

(a) The integrity of the earthing system should be properly monitored to ensure that the system continues to be for the purpose it was designed.

(b) Earthing electrodes, conductors and connections should be periodically examined and earth resistance measured as determined by the RIM.

(c) The signal engineer should initiate a signal design review where there have been changes that affect the earthing system.

(d) Periodic examination intervals shall be adjusted based on the potential corrosion due to electrolytic hazards.

#### 6.1.2 Performance monitoring

(a) The RIM shall monitor the performance of surge protection, investigate inadequate performance and take corrective action as required.

### 6.2 Failure modes and indicators

(a) The expected failure modes of the surge protection equipment should not prevent the protected equipment continuing normal operation if the protected equipment is still operational.

(b) When a surge protection device breaks down due to a surge event, the failure of the device should be readily identified.

## 7 Modification

### 7.1 Configuration management

(a) The integrity of the signals earthing and surge protection equipment needs to be considered in carrying out modification to the existing location. Factors to

be considered that may lead to loss of integrity of the earthing and surge protection device include but are not limited to:

i. Construction works including that of adjacent locations which may affect the existing arrangement of earthing conductors;

ii. Site access

iii. Relocation of equipment (even minor relocations may have significant effect);

iv. Digging;

v. Changes to drainage which affect earth resistance;

vi. New electrical installations.

(b) Where the integrity of the earthing and surge protection may have been compromised due to modification, the design should consider the upgrade of the system as deemed appropriate.

### 7.2 Risk management

(a) The modification to all existing signals earthing and surge protection shall identify all the risks to the overall system operations and integrity of the system.

(b) It should be ensured that any risk posed to the system operations and integrity of the existing system are fully addressed and mitigated.

(c) The management of risk resulting from the modification of the signals earthing and lightning protection shall be carried out in accordance to AS/NZS ISO 31000 – Risk Management principles and guidelines and the RIM's approved safety management system.

## 8 Decommissioning and Disposal

### 8.1 General

All signals earthing and surge protection systems and equipment that have been decommissioned shall be disposed of in a safe manner in so far as is reasonably practicable.

### 8.2 Decommissioning

The following shall be taken into account prior to the decommissioning, dismantling and disposing of signals earthing and surge protection:

(a) where some systems are decommissioned in close proximity to other systems that may be retained, the retained systems' operational integrity due to surges should be maintained;

(b) that the work can be carried out without risks to health and safety so far as is reasonably practicable;

(c) that all possible hazards inherent in the process of decommissioning and dismantling the device (e.g. integrity of other remaining system etc.) are identified and appropriate mitigation processes put in place;

(d) signals earthing and surge protection systems and equipment should be dismantled in accordance with designers and manufacturers instructions, where they exist;

(e) disposal work shall be carried out in accordance to a manner acceptable to the requirements of Work Health and Safety Act; and comply with good practice; and a manner acceptable to the relevant Commonwealth, State and Territory regulatory safety requirements.

## 8.3 Disposal

The disposal of all signals earthing and surge protection equipment shall ensure works are carried out in a safe manner. It shall be ensured that the disposal of the equipment will not cause potential damage to people and the environment.

During the disposal work, due consideration shall be taken of the need to ensure and maintain assurance of public safety and environmental safeguards.

Where applicable, the RIM shall record and, if appropriate, notify the relevant Commonwealth, State and Territory authority of all decommissioned sites that have used notifiable activities or have been contaminated by hazardous material.

# Appendix A Hazard List

Below are the Hazards addressed by this standard. For the latest Hazard Register Guideline refer to RISSB website: www.rissb.com.au

| Hazard Number | Hazard | Related Factors | Section Addressing |
|---|---|---|---|
| 9.2.1.2 | Cables failure (Design) | Leakage between circuits | 3.3 |
| 9.2.1.4 | Cables failure (Design) | Low frequency / mains induction | 3.3 |
| 9.4.1.2 | Cable communications failure (Design) | Crosstalk between communication channels | 3.3.1 |
| 9.4.1.5 | Cable communications failure (Design) | Low frequency / mains induction | 3.3 |
| 9.5.1.9 | Wireless communications failure (Design | Power, transients and earthing | 3.3, 3.4 |
| 9.6.1.1 | Field equipment and or enclosures failures (Design) | Equipment not operating as intended and/or equipment failure | 3.3 |
| 9.7.1.1 | Level crossing failure (Design) | Incorrect design resulting in the crossings not operating as intended which, in turn, could result in road or rail collisions | 3.3 |
| 9.9.1.15 | Power supply failure (Design) | Inadequate surge protection | 3.3 |
| 9.10.1.8 | Signals (Definition: Any indication given to a driver, lights on stick, driver display, notice boards) failure (Design) | Inadequate isolation between aspects | 3.3.2 |
| 9.10.1.10 | Signals (Definition: Any indication given to a driver, lights on stick, driver display, notice boards) failure (Design) | Inadequate transient protection & earthing | 3.3, 3.4 |
| 9.10.1.18 | Signals (Definition: Any indication given to a driver, lights on stick, driver display, notice boards) failure (Design) | Inadequate consideration of failure modes | 3.3.2 |

| Hazard Number | Hazard | Related Factors | Section Addressing |
|---|---|---|---|
| 9.12.1.1 | Train detection failure (Design) | Incorrectly showing section to be clear when actually occupied | 3.3.2 |
| 9.12.1.3 | Train detection failure (Design) | Incorrectly showing occupied when clear, disrupting the operation of the network, moving to a degraded mode | 3.3 |
| 9.13.1.19 | Interlocking failure (Design) | Inappropriate Power Supply Units, no break supply, earthing or transient protections. | 3.3, 3.4, 3.6 |
| 9.3.1.21 | Interlocking failure (Design) | No consideration for maintainers | 3.3 (a), 4.2, 4.4, 6.2 |
| 9.14.1.1 | Communication cables & route lines failure (Construction) | Cables damaged and earth to core | 3.6, 4.3 |
| 9.14.1.6 | Communication cables & route lines failure (Construction) | Cables having low insulation resistance core to core and earth | 3.6, 4.3 |
| 9.14.1.8 | Communication cables & route lines failure (Construction) | Cables jointed and faults to earth | 3.6, 4.3 |
| 9.14.1.9 | Communication cables & route lines failure (Construction) | Low frequency / mains induction | 4.1, 4.3 |
| 9.15.1.1 | Cable routes failure (Construction) | Cable routes close to hazardous voltages | 4.1, 4.2, 4.3, 4.4 |
| 9.16.1.5 | Cable communications failure (Construction) | Low frequency and mains induction | 4.1, 4.2, 4.3, 4.4 |
| 9.18.1.19 | Control system failure (Construction) | Lightning surge damage to equipment | 4.1, 4.2 |
| 9.19.1.1 | Field equipment and or enclosure failures (Construction) | Lightning surge damage to equipment | 4.1, 4.2 |
| 9.22.1.13 | Power supply failure (Construction) | Surge protection being ineffective | 4.1, 4.2, 4.3 |

| Hazard Number | Hazard | Related Factors | Section Addressing |
|---|---|---|---|
| 9.22.1.14 | Power supply failure (Construction) | Signalling power supply being connected to earth | 4.1, 4.2.5, 3.6 |
| 9.25.1.4 | Train detection failure (Construction) | Shorting or electrical interference of train detection equipment in the location case | 4.1, 4.2.5 |
| 9.26.1.20 | Interlocking failure (Construction) | Power, availability, ranges, earthing, suppression | 4.1, 4.2, 3.6 |
| 9.27.1.1 | Communication cables & route lines failure (Test and Commission) | Testing Processes | 5.1, 5.2, 5.4 |
| 9.28.1.7 | Control system failure (Test and Commission) | Incorrect or uncalibrated or wrong version of tools and test equipment | 5.2.1 |
| 9.28.1.17 | Control system failure (Test and Commission) | Scope definition between contractors and the Railway being inadequately defined (who tests what) | 5.1 |
| 9.29.1.6 | Level crossing failure (Test and Commission) | Incorrectly functioning level crossing systems compared to design | 5.1, 5.2, 5.4 |
| 9.31.1.5 | Power supply failure (Test and Commission) | Stray voltages on busbar | 3.3.2 (g) |
| 9.31.1.11 | Power supply failure (Test and Commission) | Surge protection ineffective | 5.1, 5.2, 5.4 |
| 9.31.1.12 | Power supply failure (Test and Commission) | Signalling power supply being connected to earth | 5.1, 5.2, 3.6 |
| 9.31.1.13 | Power supply failure (Test and Commission) | Incorrect interfacing to existing systems | 5.2.3 |
| 9.32.1.6 | Signals failure (Test and Commission) | Incorrect or uncalibrated tools and test equipment | 5.2.1 |
| 9.32.1.15 | Signals failure (Test and Commission) | Scope definition between contractors and the Railway remaining inadequately defined (who tests what) | 5.1 |

| Hazard Number | Hazard | Related Factors | Section Addressing |
|---|---|---|---|
| 9.35.1.6 | Interlocking failure (Test and Commission) | Incorrect or uncalibrated or wrong version of tools and test equipment | 5.2.1 |
| 9.35.1.16 | Interlocking failure (Test and Commission) | Scope definition between contractors and Railway being inadequately defined (who tests what) | 5.1 |
| 9.46.1.1 | Communication cables & route lines failure (Maintenance) | Signalling circuit wrong side failure from stray voltage | 3.3.2 (g) |
| 9.47.1.6 | Control system (including telemetry failure) failure (Maintenance) | Introduction of new COTS (Commercial off the shelf) products and versions | 3.3.2 (g) |
| 9.53.1.8 | Train Authority System failure (Maintenance) | Poor access to equipment to carry out maintenance activities | 4.2.4 |
| 9.55.1.6 | Interlocking failure (Maintenance) | The introduction of new COTS products and versions | 3.3.2 (g) |
| 9.56.1.3 | Communication cables & route lines failure (De-commission) | Signal equipment being damaged | 8.2 |
| 9.58.1.1 | Field equipment and or enclosure failure (De-commission) | Signal infrastructure failure | 8.2 |
| 9.59.1.1 | Level crossing failure (De-commission) | Signal infrastructure failure | 8.2 |
| 9.60.1.1 | Points and or release failure (De-commission) | Decommissioning the wrong equipment leading to signal equipment failure | 8.2 |

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