Government of South Australia
Department for Transport, Energy and Infrastructure

RAIL COMMISSIONER'S STANDARD

GUIDELINES FOR THE PROTECTIVE PROVISIONS RELATED TO ELECTRICAL EARTHING AND BONDING FOR THE ADELAIDE METRO ELECTRIFIED RAIL NETWORK

AR-EL-STD-0102

Document Control

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1.0 INTRODUCTION

An AC electrified railway system induces current, by electromagnetic induction, in adjacent parallel conductors and, both under traction fault and normal running conditions, earth potential rise (EPR) occurs on the running rails and on any metalwork to which the rails are directly or indirectly bonded. The touch voltage experienced by a person contacting such metalwork occurs as a result of both voltage gradients in the soil or platform or other surfaces surrounding the metalwork and induced voltages in the metalwork, or other metalwork to which it is connected, either deliberately or fortuitously.

2.0 PURPOSE

The purpose of the Earthing & Bonding (E&B) Guidelines is to set out the principles of traction system design and installation practices to limit accessible touch and step potentials to non-hazardous values.

This system wide document incorporates and replaces previous interim documents dealing with E&B issues relating to the electric railcar depot, to trackside structures and stations and covers all E&B issues related to the Adelaide electrification project.

These guidelines are based primarily on the topics, but not the detail in the Clauses, listed for E&B design requirements set out in Rail track standard RT/E/S/21085, Issue 1 of October 1998 which is, in turn, based upon the principles specified in international standard EN 50122-1:2003 Railway Applications - Fixed Installation, Protective Provisions Relating to Electrical Safety and Earthing. Note that EN 50122-1 is functionally equivalent of IEC 62128-1.

In general only requirements which differ, or require amplification, from those set out in EN 50122-1 are covered in these Guidelines.

3.0 SCOPE

These Guidelines provide design criteria; construction practices and test specifications for the E&B related Works necessary for the electrification at 25kV AC of the Adelaide suburban rail network.

As well as covering the requirements for earthing and bonding of the traction power and overhead wiring equipment, including depot buildings, trackside structures and stations, these Guidelines embrace the requirements for earthing and bonding of other electrical power supplies and equipment associated with or adjacent to the electrified railway. It also specifies the requirements for segregation of separate earthing systems, with particular reference to segregation of traction earths from the Multiple Earthed Neutral of non-railway electrical distribution systems. Within the electrified area, a common earthing policy for 415/240V power supplies and telecommunications earths – the Common Bonded Earthing Network (CBEN) - has been adopted for these Guidelines.

These Guidelines embrace all earthing and bonding of traction power and overhead wiring equipment in 25kV ac electrified station and related areas, the bonding required to carry 25kV ac traction return and traction fault currents or to prevent dangerous voltages arising in accessible positions. It does not cover earthing and bonding which is required exclusively for signalling track circuits (where no return current or fault current bonding is required for traction purposes), signalling power supplies and signalling equipment and telecommunications equipment except as specifically noted. However, some elements of earthing and bonding are common to both the traction system and the signalling and communications systems, and reference is made to this in these Guidelines.

These Guidelines are to be followed in preparing the traction overhead Bonding Plans (including those for signalling track circuits) which indicate the traction bonding requirements for all traction power and overhead wiring equipment. Where situations arise which do not appear to be adequately covered by this Part of the Guidelines, or which require interpretation, they should be referred to the Technical Manager Electrification for determination.

It should be noted that, while the distributed earth network, which characterizes the traction earth system, provides a low impedance path for traction return currents, this is not the case for the high frequency components which characterize lightning impulses. A separate set of Guidelines is required to cover the detailed requirements for earthing at stations and depot/maintenance facilities to provide a fast transient earth to protect against lightning – these E&B Guidelines are limited to the interconnection requirements to achieve a Common Bonded Earthing Network strategy.

These guidelines sets out principles and specify design and installation practices for commonly encountered situation, however not every practice can be specified and solution to specific E&B problems, if not covered by these Guidelines, should be formulated to best suit the principles set out in these Guidelines. Where there is any doubt as to the conformance of such a design solution, the matter should be referred to the Technical Manager Electrification.

The installation of traction bonding is not normally carried out by other than specially qualified staff. The references to the requirement for bonding of structures or equipment to traction earth shall generally be interpreted as the requirement to provide a fixture or fitting to which a bond cable may subsequently be attached by others. The exception is bonding to the traction earth reference point within a station or depot building (generally the Principle Earth Terminal or an earth busbar which is, or will be, ultimately connected to traction earth).

4.0 DEFINITIONS & ABBREVIATIONS

Throughout these Guidelines, unless the context otherwise requires, the definitions have the meanings given to them in the following Clauses. Where a term is not defined, it will be in accordance with EN 50122-1.

The list of acronyms includes equipment which may not form part of the scope of works covered by this document but are included to assist in understanding or cross-referencing to such works.

4.1 GENERAL EARTHING & BONDING DEFINITIONS

4.1.1 Bonding

In these Guidelines, “bonding” signifies either:

- the effective connection between an earth electrode and any exposed electrically continuous metalwork of any equipment that may operate in an earthed situation; or
- the effective connection together of each section of the “*traction return rail(s)*” to ensure that there is no discontinuity in the traction return current system; **or**
- the effective connection together of each discrete section of the “*signalling rail*” to ensure that there is no discontinuity of the signalling track circuit system.

4.1.2 Booster Transformer

A booster transformer is a device, in essence a 1:1 current transformer, designed to extract the traction return current from the traction return rail(s) and force this current into the return conductor, thus reducing electrical interference to wayside cables arising from electromagnetic induction. This type of system is generally only applied on main lines and main line sidings and not in low speed low current areas such as depots.

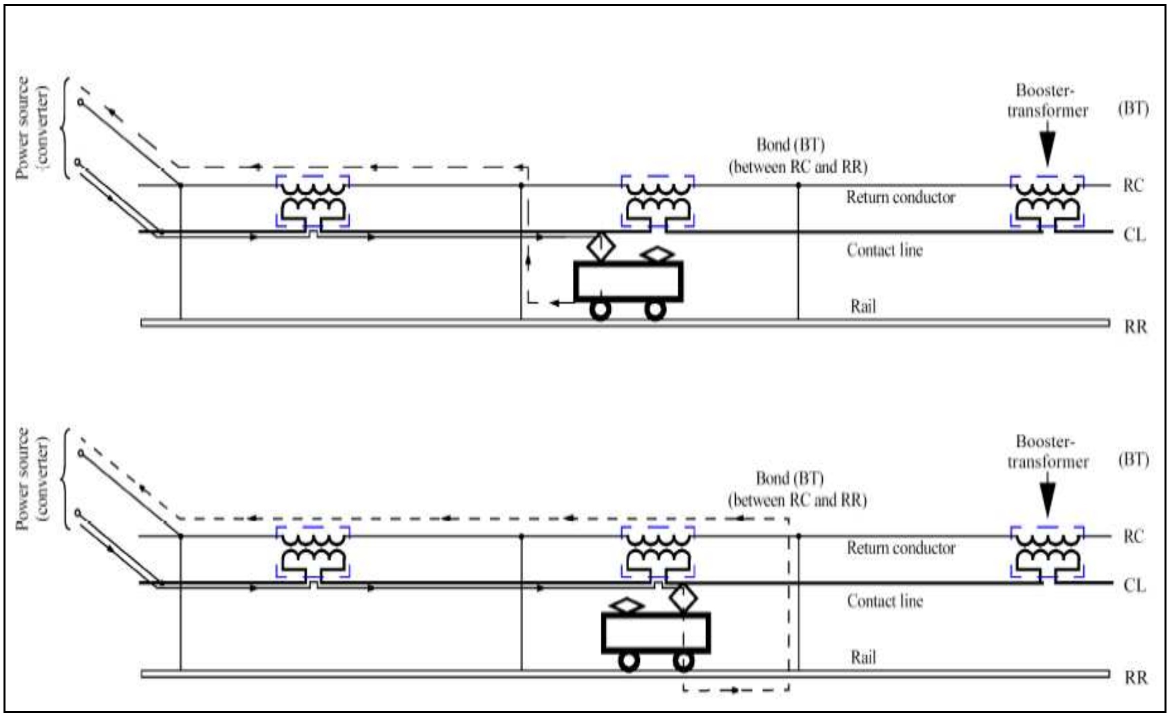


Figure 4.1.2 Booster Transformer and Return Conductor 25kV traction system

4.1.3 Buried Earth Wire

An earth electrode consisting of a horizontal buried wire or strip used to lower the rail potential by increasing the conductance (lowering the resistance) to earth of the traction system return path.

4.1.4 Catenary Wire

The catenary wire is a longitudinal wire supporting the contact wire or wires either directly or indirectly and maintained at a constant tension irrespective of the conductor temperature. Also referred to as a Messenger Wire in EN 50122-1.

4.1.5 Clearances

Clearances in air, in overhead contact line systems, are generally utilized for protection against direct contact with live conductors. Where this is not feasible, protection by Obstacles may be employed. Refer Clause 4.1.27.

All insulators which are connected to a live part shall be regarded as a live part when considering clearance dimensions in these Guidelines.

4.1.5.1 Standing surface

For standing surfaces, accessible to persons, clearance for touching in a straight line shown in Figure 4.1.5.1 below (reproduced from EN 50122-1 figure 14), shall be provided against direct contact with live parts of an overhead contact line system as well as any live parts on the outside of a vehicle (for example current collectors, roof conductors, resistors).

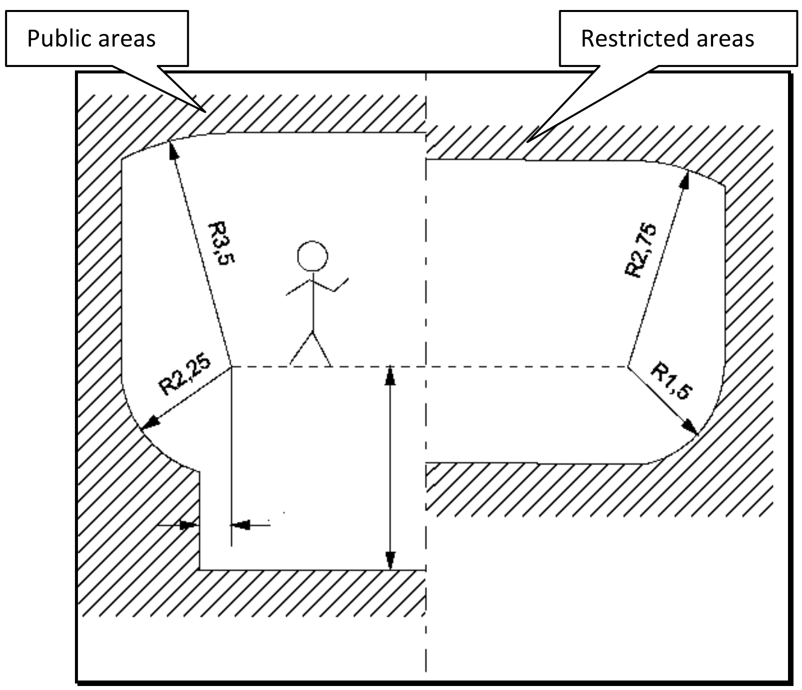
The clearances given in the following subclauses are minimum values which shall be maintained at all temperatures and with additional and exceptional line loading.

Note 1: touching in a straight line implies that live parts are accessible by a person from a standing surface without use of objects.

Note 2: this protection is not mandatory if, although contact with live parts is possible, other provisions have been taken to ensure isolation from the supply.

Note 3: Figure 4.1.5.1 assumes that the standing surface does not afford protection against contact with live parts situated below or to the side thereof. Depending on its construction, the surface may in practice meet the requirement respecting provision of Obstacles. In this case, the lower clearances applicable to Obstacles may be utilized.

The clearances were determined on the basis of the arms reach as defined in IEC 60364-4-41 to which a margin of safety was added. The margin of safety has been determined depending on the voltage of the contact line system and on whether the standing surface is in a restricted area or in a public area.



All dimensions are minimum dimensions in metres

Figure 4.04.1.5.1 – Clearances to accessible live parts on the outside of vehicles as well as to live parts of overhead contact line systems from standing surfaces accessible to persons for nominal voltages up to 25 kV a.c. to earth

4.1.5.2 Standing surfaces for working persons

Clearances shown in Figure 4.1.5.1 or the clearances according to Clause 4.1.27 for protection by Obstacles shall be used.

Note: **S**tation platform roofs, working platforms and working planks at signal bridges, working platforms at signals, maintenance-ladders, work cages of hydraulic work platforms, working platforms of tower cars which are utilized solely for execution of work at or in the vicinity of overhead contact line systems are not included.

4.1.5.3 Minimum height of overhead contact lines and associated feeders

Where a road carrying normal vehicular traffic crosses with a railway electrified by means of an overhead contact line and no road traffic restrictions are specified a minimum vertical clearance of 5.50 m shall be provided between the road surface and the lowest point of the overhead contact line and associated feeders.

If the said minimum clearance cannot be provided and unless otherwise specified by national regulation, the maximum height of road vehicles permitted to pass under the overhead contact line shall be limited so as to guarantee the following minimum vertical clearances between the highest point of the road vehicle (load included) and the live parts, of:

- 1.0m, where only road traffic signs indicating the maximum permissible vehicle height are utilized;
- 0.50m, where additional fixed barriers (for example a rigid Obstacle or a firmly fixed metallic wire made visible by means of a suspended warning sign) are erected on both sides of the crossing, physically limiting such vehicle height.

4.1.5.4 Feeders above loading roads

Feeders or line feeders may only in urgent cases be situated above loading roads or loading sidings. In such cases, there shall be a distance of at least 12m between surfaces of the loading platform (ramps) and feeders.

4.1.5.5 Clearance between overhead contact line systems and trees

A clearance of 2.50m shall be maintained in all conditions between the overhead contact line system and branches of trees or bushes.

4.1.6 Common Bonded Earthing Network (CBEN)

An earthing network strategy comprising the creation of a transient equi-potential plane where the high voltage electric traction system, the low voltage power supply distribution systems and the systems electronic equipment may operate safely and reliably.

4.1.7 Common Earth Termination Network (CETN)

The interconnecting of separate Earth Systems to provide a Common Earth Termination network

4.1.8 Communications Earth Terminal

A communications earth terminal is a conductor in the form of a terminal to which the main earthing conductor(s) and the earthing conductor(s) are connected for all earthing and bonding of communications equipment within an installation.

4.1.9 Contact Line/Overhead Contact Line System

The traction power supply reticulation system including the following:

- all overhead wiring, including the catenary (messenger wire), the contact wire, return current conductor, the earth and the feeder wire
- overhead conductor rails.

Also commonly referred to as Overhead Wiring System (OHWS) or Overhead Equipment (OHE).

Note that the term used in IEC 62128-1 and EN 50122-1 Overhead Contact Line System (OCLS) includes in addition:

- the foundations, supporting structures and any components supporting, registering, terminating or insulating the conductors
- equipment mounted on the supports for switching, detecting or protecting

4.1.10 Contact Wire

The contact wire is the electric conductor of an overhead contact line with which the current collectors make contact and is maintained at a constant tension irrespective of the conductor temperature. The pantograph(s) of electric vehicles press against the underside of this wire and collect the electric traction current required by the electric vehicle.

4.1.11 Counterpoise Loop

A counterpoise loop is a buried earthing conductor encircling a signalling relay room, signalling or communications trackside location case(s) or station platform to reduce touch and step potential. Also referred to as a Perimeter Earth and has the same functionality as a Grading Ring.

4.1.12 Double Rail Track Circuit (DRTC)

A track circuit is used to detect the presence of a train from the shunting, by the train axles, of a signal applied between the two rails. For signalling systems of the DRTC type, both rails are used to carry traction return current but for train detection purposes are divided into discrete sections by the insertion of a means of containing track circuit currents within a rail section. This is achieved, with the jointless track circuits currently used, by means of an “Electrical Separation Joint” which acts as a stop filter but does not require discrete insulation (insulated rail joint) or otherwise disturb the physical integrity of the rail. DRTC is generally only employed on main lines and main line sidings.

Note that a direct connection to a rail cannot generally be carried out for E&B purposes as this would interfere with the operation of the track circuit and such a connection can only be made using an Impedance Bond or Air Cored Inductor (ACI). There may be restrictions on the locations and numbers of ACI’s or Impedance Bonds within a track circuit section and therefore these cannot be included within any design without prior reference to the Signalling Manager.

4.1.13 Earth Bar

An earth bar is a conductor in the form of a bar, link or terminal to which the main earthing conductor(s) and the earthing conductor(s) are connected for all earthing and bonding of electrical power supplies within an installation.

4.1.14 Earth Wire (EW)

The earth wire (also known as the traction earth wire) is a continuous conductor that runs the length of the electrified system with an electrical connection to all traction masts and bonded to all exposed metalwork within the Overhead Contact Line Zone and Pantograph Zone.

Note: The EW also serves as a partial return conductor for traction return currents and is connected to the rails at regular intervals.

The interconnection to each traction mast, rail corridor structures as well as the running rails ensures that an adequate resistance to earth is maintained to limit the values of Earth Potential Rise (EPR) to acceptable levels under the worst case traction fault condition. The principal return path to earth is provided by the ladder network formed by the earth wire with the traction mast foundations and thus rail EPR is determined by the interval between rail to earth wire connections as well as the average resistance to earth of the traction masts.

Under conditions of very high soil resistivity a buried earth wire may be used to reduce the resistance of the ladder network earthing system. This earth wire does not replace the Earth Wire as it is not necessarily continuous and its continuity cannot be guaranteed by inspection

4.1.15 Earthing

Earthing means the effective connection to the general mass of the earth by means of a suitable earth electrode.

4.1.16 Earthing Conductor

An earthing conductor is a conductor(s) connecting any portion of the earthing system to the portion of the installation or equipment required to be earthed, or to any other portion of the earthing system.

4.1.17 Electric Multiple Unit (EMU)

The permanently coupled minimum number of rail cars or articulated sections capable of independent operation as a train, using electricity for motive power.

4.1.18 Emergency Supply Transformer (EST)

A single phase 25kV/240V transformer powered from the 25kV Overhead Wiring System (OCLS). Because of poor voltage regulation, EST's are generally used as backup, rather than main, supplies for signalling, telecommunications and other critical single phase loads.

4.1.19 Feeder Station

A switching station comprising transformers circuit breakers, busbars and associated protective relays and Supervisory Control and Data Acquisition (SCADA) and power fed from 132kV/25kV transformers. The traction power supply is taken between two phases of the 132kV supply and there will generally be a phase difference of 120o between sections fed by different transformers and/or feeder stations.

4.1.20 Grading Ring

A grading ring is a buried earthing conductor encircling a station or isolated structure connected to the CETN to reduce touch and step potential. This same functionality is provided by a Perimeter Earth.

4.1.21 Guard Conductor

A surface mounted conductor connected to traction earth installed to shunt traction fault current away from the underlying structure where the fault current could result in hazardous potential gradients and/or unacceptable structural damage. The cross-sectional area of the conductor shall have the thermal capacity for carrying the traction fault current until interrupted by the controlling circuit breakers. In dimensioning the guard conductor, due allowance shall be made for current flow through the traction earth connection(s).

4.1.22 Installation

In these Guidelines, “installation” or a “portion” of an installation refers to an installation or detached portion of the installation which has power supplied to it via a sub-main at 415V a.c. or 240V a.c. and not to a detached portion of an installation which is supplied via final sub-circuits at ELV or 110V ac.

4.1.23 Isolating Switch

An isolating switch is a device for opening and closing an electrical circuit, under no load, mounted on a traction overhead wiring structure, provided to connect or disconnect a section of traction overhead wiring equipment from its feeder conductor at a feeder station, track sectioning cabin or from another section of traction overhead wiring equipment.

A motorised isolating switch is a power-operated device which may be remotely controlled or indicated or both.

4.1.24 Main Earthing Conductor

A main earthing conductor is a conductor or group of conductors connecting the earth electrode to the earth collector. In the case of partly buried connections, this definition is valid only for the sections which are electrically insulated from the ground – the sections in contact with the ground forming part of the earth electrode. Note that, except for certain specific applications, separate earth electrodes are not used, this functionality being provided by the Common Bonded Earthing Network.

4.1.25 Neutral Section

The section of track and OCLS between sections fed from different transformers and/or feeders stations. The OCLS contains insulating sections either side of an earthed section to guard against inadvertently paralleling the two adjoining feeding sections by pantograph arcing if the EMU onboard circuit breaker fails to open when crossing the neutral section.

Opening of the circuit breaker is accomplished automatically by the EMU detecting trackside installed permanent magnets. Note that these magnets are installed between the structures and the closest rail to distinguish and isolate them from magnets (where) used for the signalling Automatic Warning System (AWS) which often employs the same hardware.

4.1.26 Non Track Circuited Area (NTCA)

A Non Track Circuited Area is an area or a specific length of track where track circuits are not installed. In signalled areas without track circuits, axle counters will be used as the means by which train detection on a specified length of track is achieved and thus, unless specifically excluded, any bonding requirements for NTCA apply also to axle counter areas. In any NTCA, return continuity bond connections, earth bond connections, rail to rail cross bonds and track to track cross bonds can generally be installed at any position along the track without restrictions and without requiring an ACI or Impedance Bond.

4.1.27 Obstacles

Obstacles are used as protection against direct contact with live parts, if the clearances given in Clause 4.1.5 cannot be maintained. The following Clauses are reproduced, to assist with understanding, from EN 501221-1 and this document shall be consulted before undertaking any design work with respect to Obstacles.

The design of Obstacles is dependent on the location of the standing surfaces shown in Figure 4.1.27 (reproduced from EN 501221-1 figure 15) relative to the live parts, on the clearance between the Obstacle and the live parts and on whether the standing surface is a restricted area or a public area.

The dimensions of the Obstacles shall be such that live parts cannot be touched in a straight line by persons on a standing surface. Greater heights of Obstacles may be required to prevent conductive objects from being thrown onto live 25kV equipment.

Where the Obstacle is made of conductive material, the requirements for bonding to traction earth apply.

4.1.27.1 Permitted Obstacles

- solid-wall design or solid-wall doors;
- mesh constructions, when they are of conductive material and when they are earthed.

Mesh constructions of non-conductive material or plastic coated metal shall not be utilized.

Non-conductive Obstacles shall be of solid-wall design. They are to be surrounded by a bare conductor that shall be connected to the traction system earth.

The Obstacle shall be constructed to prevent non-intentional (accidental) contact with parts of the body. Obstacles shall be fixed mechanically and reliably. They shall only be removable with tools. In locations or rooms which are accessible to the public, these Obstacles shall not even be removable with tools without destruction.

Conductive Obstacles shall be secured to ensure that the distance to live parts is maintained.

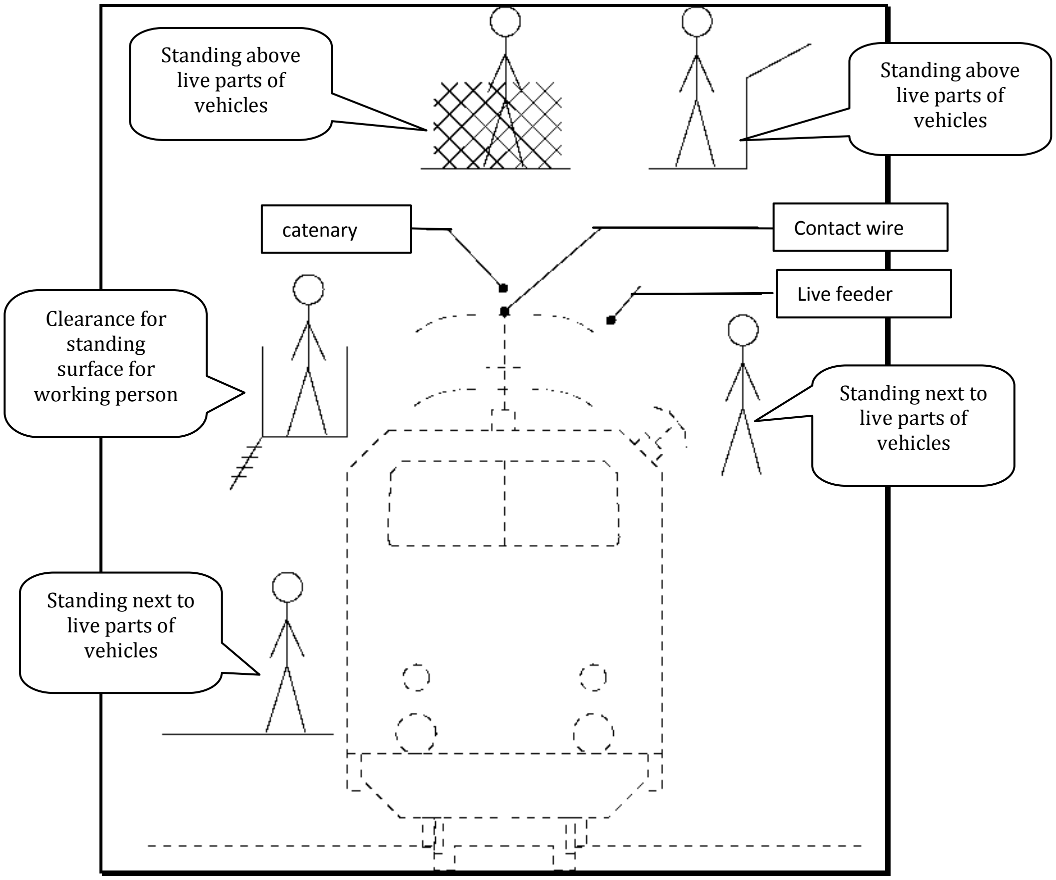


Figure 4.1.27 – Standing surfaces for persons providing access to live parts on the outside of vehicles and to overhead contact line systems up to 25 kV a.c.

4.1.27.2 Minimum Clearances

Minimum clearances shall be maintained between Obstacles and live parts. The clearance in air shall correspond to the relevant minimum clearance as defined in IEC 60913 to which the following shall be added:

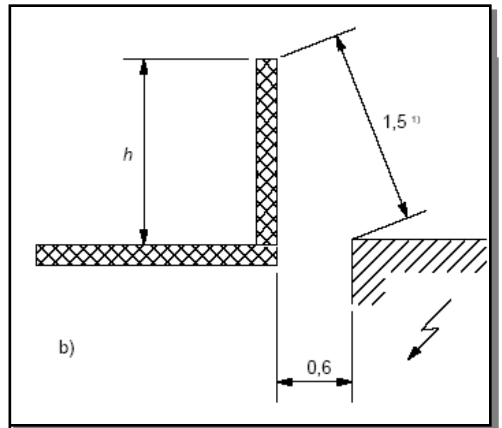
- 30mm for solid walls or solid-wall doors, if buckling or warping cannot be excluded.
- 100mm for mesh constructions, where no other minimum clearance is given in Clauses 4.1.27.3 and 4.1.27.4 as required for standing next to live parts of vehicles

4.1.27.3 Obstacles for standing surfaces in restricted areas

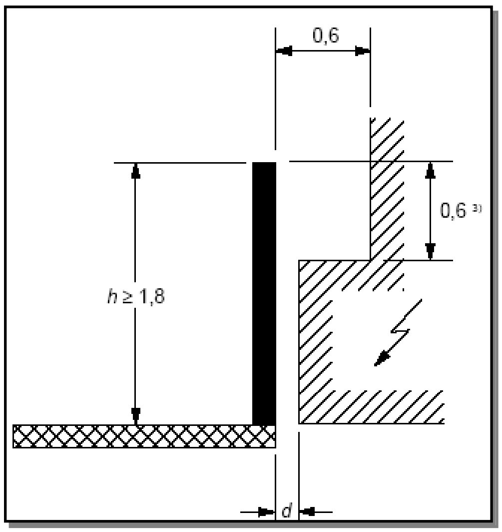
4.1.27.3.1 Standing next to live parts of vehicles

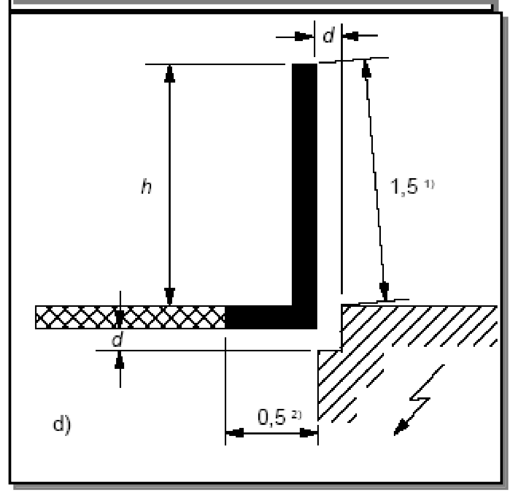
With standing surfaces adjacent to live parts on the outside of vehicles or adjacent to live parts of an overhead contact line system, Obstacles of mesh screens construction with a maximum 1 200 mm^2 mesh size and having a height "h" of at least 1.8m may be utilized, where the live parts are situated above the standing surface.

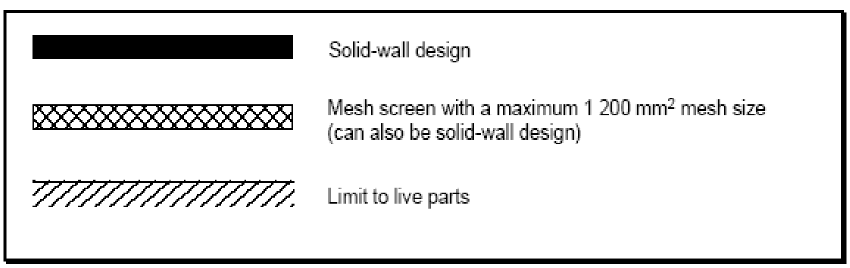
If the live parts are situated at the same height or lower than the standing surface, the height "h" of the Obstacle shall be such that a clearance of 1.5m from the top of the Obstacle is maintained as shown in Figure 4.1.27 – see example (b) opposite



The clearance between the Obstacle and live parts shall be at least 0.6 m. If this clearance is not maintained, the Obstacles shall be of solid-wall design and leave no gap between the Obstacle and the standing surface - see examples below.







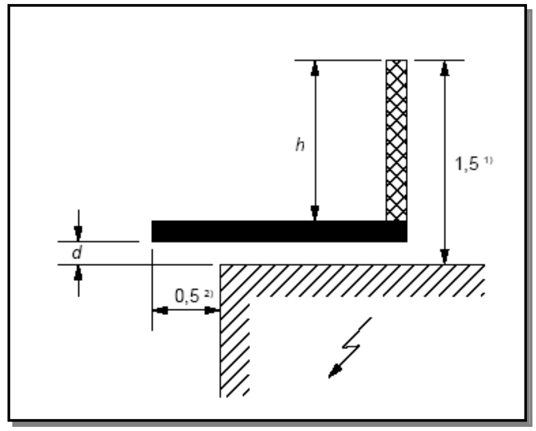
The dimension "d" between the Obstacle and live parts, shown in the above examples shall be determined as described in Clause 4.1.27.2.

4.1.27.3.2 Standing surfaces above live parts of vehicles

For standing surfaces above live parts on the outside of vehicles or above live parts of an overhead contact line system shall be of solid-walled design.

The length of the solid-walled standing surface shall correspond to the pantograph zone and extend beyond the live parts of an overhead contact line system by at least 0.5m on each side. In the case of conductors not being used for current collection (for example line feeders, reinforcing feeders, out of running overhead contact lines) there shall be a width of at least 0.5m on each side of the conductor provided that movement due to dynamic and thermal effects has been taken into account.

Obstacles of mesh screen construction with a maximum 1 200mm^2 mesh size shall be provided at the sides of such standing surfaces. The height "h" of the Obstacles shall be such that a clearance of 1.5m from the top of the Obstacles is maintained as shown in Figure 4.1.27 and example opposite. These Obstacles shall be at least as long as the length of the standing surface above live parts.



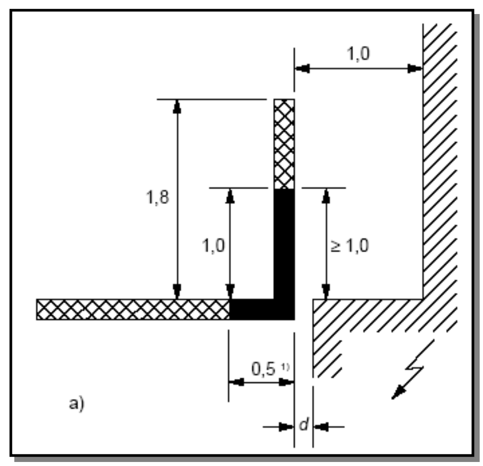
Note: The height of the side Obstacles, if necessary, will generally correspond to the height of the necessary safety railing but should have a height of at least 1.0m.
The dimension "d" between the Obstacle and live parts, shown in the example above, shall be determined as described in Clause 4.1.5.

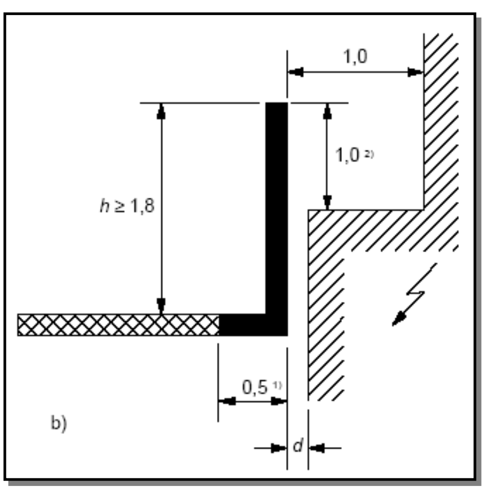
4.1.27.4 Obstacles for standing surfaces in public areas

4.1.27.4.1 Standing surfaces adjacent to live parts on vehicles

With standing surfaces adjacent to live parts on the outside of vehicles or adjacent to live parts of an overhead contact line system, if the clearances shown in Figure 1.3-2 cannot be achieved, Obstacles shall be provided and shall leave no gap with respect to the standing surface.

If the clearance between the Obstacles and live parts is at least 1.0m (see example opposite), the Obstacle shall be of solid-wall design 1.0m high, surmounted by a mesh construction with a maximum 1 200mm^2 mesh size to an overall height of at least 1.8m. Such mesh shall be arranged so as to ensure that the Obstacle remains unclimbable. If this clearance is not achieved, the Obstacles shall be of solid-wall design 1.8m high (see example below).





The dimension "d" between the Obstacle and live parts, shown in these examples, shall be determined as described in Clause 4.1.5.

The tops of such Obstacles shall be designed to prevent access for standing or walking on.

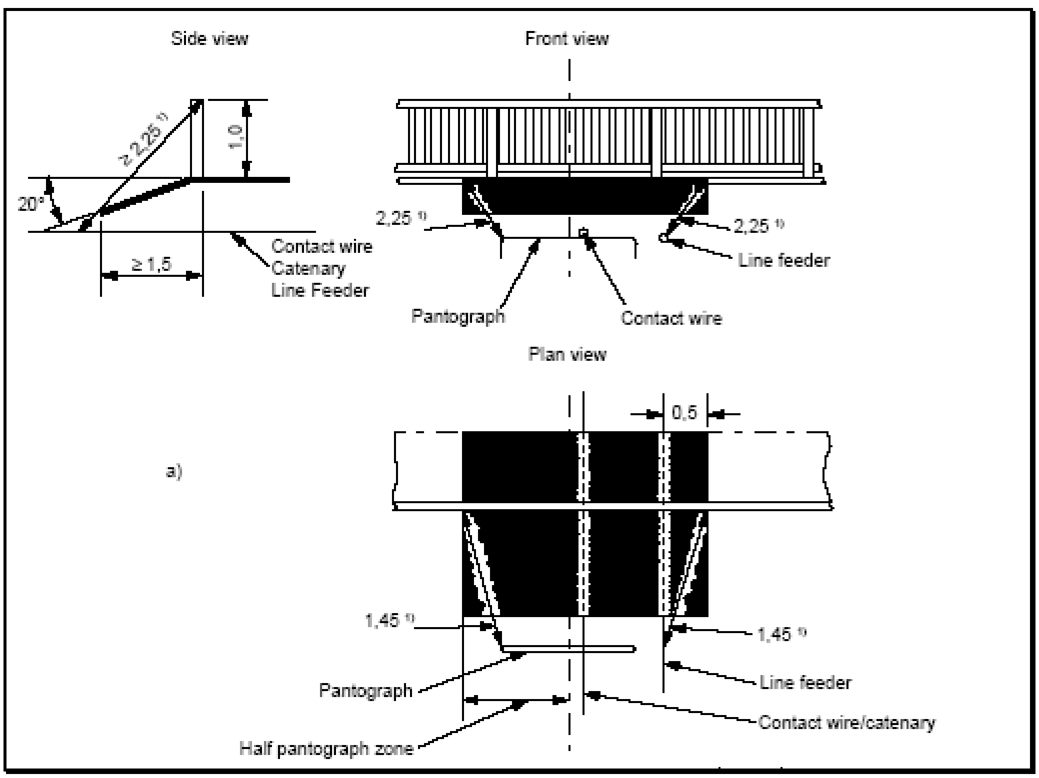
4.1.27.4.2 Standing surfaces above live parts of vehicles

For standing surfaces above live parts on the outside of vehicles or above live parts of an overhead contact line system shall be of solid-wall design.

The length of the solid-walled standing surface shall correspond to the pantograph zone and extend beyond the live parts of an overhead contact line by at least 0.5m on each side. In the case of conductors not being used for current collection (for example supplementary (live) feeders, out of running overhead contact lines) there shall be a width of at least 0.5m on each side of the conductor provided so that movement due to dynamic and thermal effects is taken into account.

Along the sides of these standing surfaces, Obstacles shall be provided in order to prevent any direct contact with live parts on the outsides of vehicles and to live parts of the overhead contact line system even where, for example, a rod or liquid jet is utilized. These Obstacles shall be provided over a length that corresponds at least to the length of the standing surface in solid-wall design.

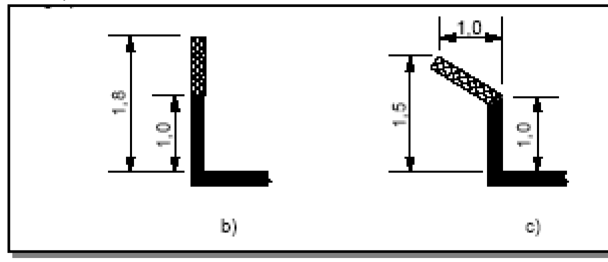
Where horizontal Obstacles extend beyond the vertical Obstacle by at least 1.5m, it becomes acceptable to refer the 2.25m lateral clearance required by Figure 4.1.27 to the top of the vertical Obstacle, instead of referring it to the edge of the standing surface (see example below from EN 50122-1 Appendix A2).



The height of the vertical Obstacle shall be consequentially increased whenever necessary, in order to achieve this clearance. The horizontal Obstacle shall be impossible to stand on.

Note: To achieve this, the horizontal Obstacle should be designed so that it is obviously not a standing surface, or it should be inclined upwards or downwards (see example above).

Whenever this horizontal Obstacle is not present, the vertical Obstacle shall conform to the requirements of Clause 4.1.27.4 for standing surfaces adjacent to live parts on vehicles (see examples opposite from EN 50122-1 Appendix A2).



The tops of such Obstacles shall be designed to prevent access for standing or walking on.

Any vertical Obstacle shall be of solid wall design at least to a height of 1.0 m (see example above), except in the case of the above said horizontal Obstacle, where a railing is sufficient, if the clearances required by Figure 4.1.27 are present.

4.1.27.4.3 Anti-climbing provisions

Anti-climbing provisions are not normally necessary. In justified cases however, anti-climbing provisions can become necessary. DTEI will specify where it is necessary to equip masts and structure anchor wires with anti-climbing provisions.

Note: provisions are required only for masts and anchor wires which can be climbed without any aids and if there is a risk of coming into unsafe proximity of live parts of the overhead contact line equipment when climbing**.**

4.1.27.4.4 Warning signs

Warning signs shall be used in areas where there is a serious risk of coming within the limits of live parts of an overhead contact line system given in Clause 4.1.5. Such warning signs shall be placed in a prominent position and readily visible adjacent to the point of access. The sign shall be as defined in ISO 3864 (see annex B of EN 50122-1) and if required, an appropriate supplementary sign may be used.

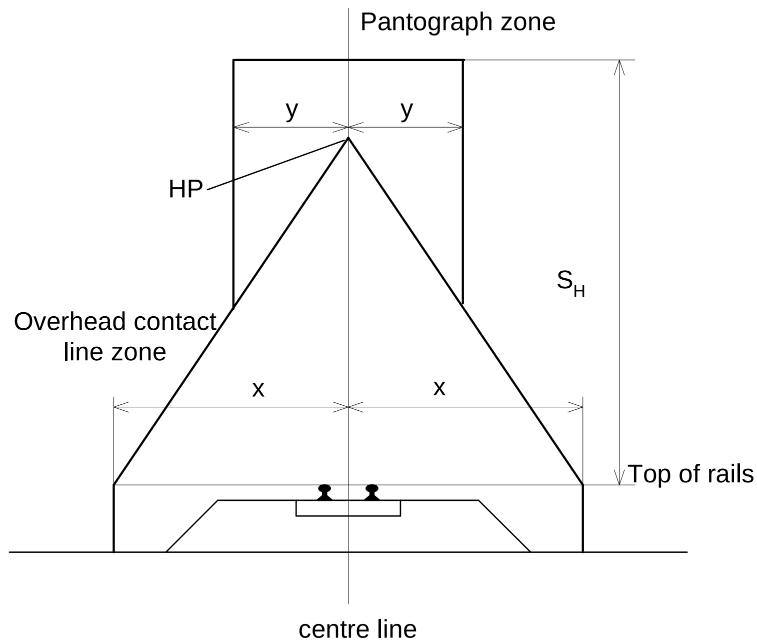
4.1.27.5 Mid Point Connection (MPC)

A mid-point connection is a bond which connects a return conductor to the traction return rail(s) installed at a point approximately mid-way between adjacent booster transformers – see also Clause 4.1.2 Booster Transformer.

4.1.27.6 Overhead Contact Line Zone and Pantograph Zone (OHCLZPZ)

(Adapted from EN 50122-1)
The overhead contact line zone and pantograph zone (OHCLZPZ) are zones within which structures and track side equipment could accidentally become live due to contact with broken Overhead Contact Line Equipment and /or Pantograph. Figure 4.1.27.6 defines the zone inside which such contact is considered to be probable. It is also frequently referred to as the “Drop Zone”.

The point HP is the position of the highest conductor of the overhead contact line under all operational conditions considered in the centre of the track. The limits of the overhead contact line zone below the top of the rail are extended vertically downwards until the surface is reached. These limits, however, need not be extended beyond the upper surface of any barrier (deck, platform or wall).



x: Width of overhead contact line zone to the centre of track
y: Width of pantgraph to the centre of track
S_H: Height of overhead contact line zone
HP: Highest point of the overhead contact line.

Figure 4.1.27.6 Overhead contact line zone and pantograph zone

The dimensions are not specified in EN 50122-1 but are specific to the railway and are defined in Appendix C

Note 1: The breaking of 25kV feeders or solid conductor rails, which are not mechanically tensioned are not taken into consideration because the probability of a break is small.

Note 2: Special exemptions to defined dimensions x, y, $S_{H,}$ and HP, may be made, on a site specific basis by the Technical Manager Electrification.

4.1.27.7 Pantograph

A pantograph is a retractable frame, mounted on insulators on the roof of an electric vehicle (electrical multiple unit or locomotive), which presses against the underside of the contact wire and through which the electric traction current is collected from the traction overhead wiring equipment. In the absence of the OCLS, the pantograph may raise to the value given in Appendix C, which is to be mitigated in the design of above track structures.

4.1.27.8 Primary Earth Terminal (PET)

A single connection point at a passenger station or other trackside facility to which the Common Bonded Earthing Network is connected to traction earth. The PET uses links to facilitate testing of the earth continuity of each connected earthing system. The PET is enclosed within the earth collector cabinet.

Note: There can only be one PET within a trackside facility and thus, for example, within a station or depot area, signalling and communication rooms are connected to the station PET but remote signalling and communication facilities will have their own PET.

4.1.27.9 Protective Earthing System

A protective earthing system is an earthing system used to limit accidental excess voltages to safe levels. This functionality is provided in stations and depots by the CBEN

4.1.27.10 Protective Earth Neutral

The power distribution earthing continuity conductor which is connected to the neutral at the supply transformer.

4.1.27.11 Rail Bond

Connection between Earth Bar in Track Sectioning Cabin (TSC) or Track Coupling Units (TCU) and the adjacent rail(s).

4.1.27.12 Residual Current Device RCD

An electro-mechanical switching device designed to make, carry and break currents under normal service conditions and to cause the opening of the contacts when the residual current attains a given value under specified conditions.

Note: A residual current device can be a combination of various separate elements designed to detect and evaluate the residual current and to make and break current.

4.1.27.13 Residual Current Operated Circuit-Breaker with Integral Overcurrent Protection RCBO

A residual current operated switching device designed to perform the functions of protection against overloads and/or short-circuits.

4.1.27.14 Residual Current Operated Circuit-Breaker without Integral Overcurrent Protection RCCB

A residual current operated switching device not designed to perform the functions of protection against overloads and/or short-circuits (previously referred to as Earth Leakage Circuit Breaker or ELCB).

4.1.27.15 Return Current Rail Bond

A cable designated to carry a traction return current from rails adjacent to the feeder station or TSC to the return current busbar.

4.1.27.16 Return Conductor

The conductor which, together with the Booster Transformers (BT), carries typically 95% of the traction return current. This is reduced under traction fault conditions due to Booster Transformer saturation and is typically 50% for a fault close to first BT but 80% or more after the 3rd BT. The return conductor is insulated to typically 3.3kV as, although the voltage with respect to traction earth is normally low, it can rise to these levels if a return conductor breaks and the secondary of the BT is then open circuit.

4.1.27.17 Separate Earthing System

A separate earthing system is an earthing system with independent earth electrodes which do not affect one another appreciably during operation (from the point of view of danger or operation) but between such systems, a hazardous potential may exist, particularly during a traction fault and specified separation or screening is required to limit such potential to specified limits. An example of such a separate earthing system is the neutral earth of electrical distribution systems adjacent to the railway alignment.

4.1.27.18 Signalling Bond

A signalling bond is a conductor, complete with terminations, which connects together each discrete section of a signalling rail to ensure that there is no discontinuity in the rail.

4.1.27.19 Signalling Earth Terminal

A signalling earth terminal is a conductor in the form of a terminal to which the main earthing conductor(s) and the earthing conductor(s) are connected for all earthing and bonding of signalling equipment within an installation.

4.1.27.20 Single Rail Track Circuit (SRTC)

A track circuit is used to detect the presence of a train from the shunting of a signal applied between the two rails by the train axles. For signalling systems of the SRTC type, one rail is divided into discrete sections by the insertion of insulation in rail joints. This rail is known as the signalling rail. This signalling system will generally be used at station and depot interlocking areas.

4.1.27.21 Simple 25kV Traction System

A 25kV traction system is one which does not use Booster Transformers and Return Conductors (BTRC). This system has been employed in low speed, low current areas such as depots and on sections of mainline in some recent electrification projects. The interference reduction functionality of the return conductor is provided, but to a lesser degree of effectiveness, by means of a higher cross-section earth wire than with a BTRC system – this is commonly the same size as an RC. This reduced effectiveness is generally adequate with the present use of wayside communications circuits of shorter length than used historically resulting from the now widespread implementation of optical fibre technology.

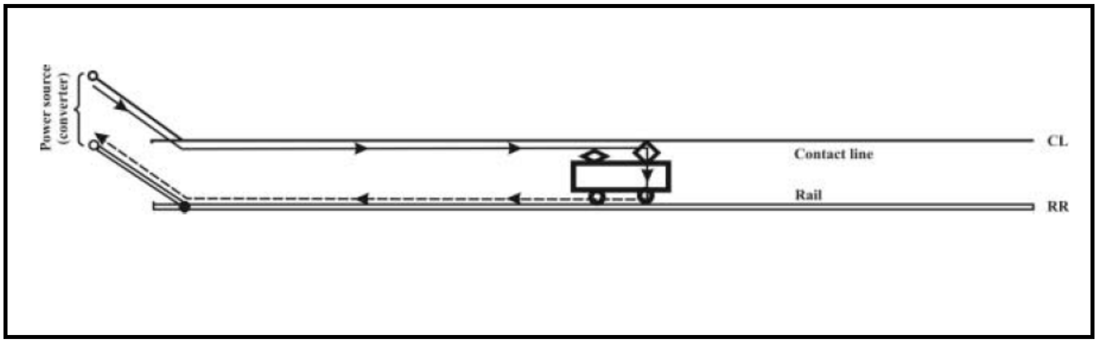


Figure 4.1.27.21 Simple 25kV traction system

4.1.27.22 Spark Gap Arrester (Voltage Fuse)

A spark gap arrester is an electrical device to provide a bond connection, and hence fault current path, in the event of a high voltage occurring as a result of contact with a traction conductor. It is installed on devices which, for operational reasons cannot normally be bonded to traction earth except in cases of emergency.

4.1.27.23 Step Potential

A step potential is an rms voltage which may appear under normal or earth-fault conditions between the points of contact of each foot with the ground and the feet being spaced about 900mm apart.

4.1.27.24 Structure Earth

The electrical interconnection of steel reinforced concrete structures, and in the case of other types of construction, the conductive interconnection of the metallic parts. This includes passenger stations, maintenance and equipment buildings, bridges, viaducts, concrete slab permanent way and tunnels. The structure earth of tunnels is known as tunnel earth and the structure earth of passenger stations or depots and other railway buildings is known as station earth or building earth respectively. Note that, with the exception of a perimeter earth, separate external earth electrode systems are not required or used for telecommunications or neutral earthing and the structure earth, in combination with (where required) signal reference grids provides the fast transient earth functionality for lightning and surge protection.

4.1.27.25 Surge Diverter

A surge diverter is a protective device usually connected between any conductor of an electrical system and earth which limits surge voltages by diverting surge currents to earth when a given voltage is exceeded. Surge Diverters connected to rails for voltage clamping purposes are also referred to as Voltage Fuses or Spark Gaps.

4.1.27.26 Switching Station

A switching station is a collective term used to describe all feeder stations, track sectioning cabins and track coupling units within an electrified area.

A feeder station compound consists of a building with electrical switchgear and equipment and the outdoor switches to which traction power supplies from the supply authority are brought and from which traction overhead wiring system is fed. Refer 4.1.19

A Track Sectioning Cabin (TSC) is a building containing electrical switchgear and equipment which is arranged to connect together a number of sections of traction overhead wiring equipment. Refer 4.1.27.29.

A Track Coupling Unit (TCU) is a single unit or a group of electrical switchgear and equipment to parallel or connect two or more adjoining sections of overhead wiring equipment.

4.1.27.27 Temporary Earthing Device

A temporary earthing device is a portable device for establishing an electrical connection between isolated traction overhead wiring equipment and traction earth.

4.1.27.28 Touch Potential

A touch potential is an rms voltage which may appear under normal or earth-fault conditions between an object touched by hand and the ground beneath the feet. It is generally taken to be 1m from the closest point of earth contact.

The touch potential is a percentage of the EPR, which, by definition is the potential to remote earth. The rail touch potential, as a percentage of EPR, depends upon the ratio of ballast resistance to the formation and subsoil resistance but generally, in Australasia, not less than 90% is allowed in the EPR modelling except in tunnels with an insulating membrane where only touch potentials between metalwork can occur in practice and there is realistically no access to remote earth. Note that the touch potential to the rollingstock is greater than that to the rail and is approximately equal to the touch potential to rail over a distance of 2m.

4.1.27.29 Track Sectioning Cabin (TSC)

A switching station to connect together feed sections of the OCLS and parallel individual tracks to reduce the overall impedance to the traction load. A mid point TSC is used to isolate feed sections normally fed from different feeders stations and is used to connect together those feed sections in the event of total failure of one of the feeder stations. A mid-point TSC is situated opposite a Neutral Section – refer Clause 4.1.25.

Circuit breakers and protection relays isolate a section of track in which a fault occurs and, with suitably placed crossovers, permit limited running around the isolated section. Isolation of smaller feed sections, for maintenance and repair activities, is achieved with manual isolators

4.1.27.30 Traction Continuity Bond

A traction bond is a conductor, complete with terminations, which connects:

- metal structures, components or appliances to traction earth;
- the individual elements of the traction earthing system together; or
- each section of a traction return rail together to ensure that there is no discontinuity in that rail.

4.1.27.31 Traction Return Rail Continuity Bond

A traction return rail continuity bond is a traction bond provided to maintain continuity of the traction return current path wherever it would otherwise be interrupted by points, crossovers, trap points or insulated or fish plated rail joints.

4.1.27.32 Traction Earth

The traction earth is an earth electrode system comprising the traction overhead earth wire, structure foundations, traction return rails and any other buried metal or earth electrodes connected thereto.

4.1.27.33 Traction Earthed Neutral System

In these Guidelines, the term Traction Earthed Neutral System means an earthing system in which the parts of an installation required to be bonded to traction earth and supplied from an isolating transformer, HV supply transformer, Emergency Supply Transformer (EST) or diesel generator are so earthed and connected within the installation to, and only to, the neutral conductor of the supply system on the secondary side of the supply transformer. No other neutral-earth connections are permitted. Unless otherwise specifically excluded this applies to all installations within the railway corridor and within the electrified area.

4.1.27.34 Traction Fault Current

The traction fault current is the current which flows from the traction overhead wiring equipment through the traction return path and earth in the event of an electrical fault. This traction fault current has a maximum magnitude of typically 6 000 Amps and returns to the power supply source (feeder station and power transformer) via indeterminate paths comprising rails, traction earth wires and the earth itself.

In calculating the size of conductors required to carry fault current, a worst-case tripping time and circuit breaker reclose shall be allowed. Refer to Cl.13.0.

4.1.27.35 Traction Overhead Wiring Structure

A traction overhead wiring structure comprises the support mast and foundation, together with the associated fittings and other attachments, by means of which the traction Overhead Contact Line System is supported in position.

4.1.27.36 Traction Return Circuit

All conductors which form the intended path for the traction return circuit and the current under fault conditions.

Note: The conductors include:

- traction return rails
- traction earth wire
- return current rail bonds
- return current cable/conductor
- traction continuity bonds
- structure and equipment to earth wire bonds
- structure and equipment rail bonds

4.1.27.37 Traction Return Current

The traction return current is the load current which flows into the traction return rails from the wheels of an electric vehicle (EMU) and which returns to the power supply source (feeder station and power transformer) via the traction return rails, traction earth wire and other return conductors.

4.1.27.38 Traction Return Rail

The traction return rail is one rail (in SRTC areas) or both rails (in DRTC areas and where axle counters are used) into which the traction return current is free to flow from the wheels of electric vehicles (electrical multiple unit or locomotive) to form part of the electrical circuit by means of which the traction return current flows from the electric vehicle to the power supply source (feeder station and power transformer). The traction return rails must be electrically continuous throughout any length of track (despite any mechanical interruption by points or crossings or means of interruption to signalling track circuit currents), insulated joints or any bonding transpositions.

4.1.27.39 Traction Supply Conductor

Any conductor having a potential of 25kV with respect to earth including, but not limited to:

- catenary
- contact wire
- separate (supplementary) feeder
- cross track feeders
- outgoing feeders

4.2 LIST OF ABBREVIATIONS AND ACRONYMS

4.2.1 List of Acronyms

AC or a.c.	Alternating Current
ARTC	Australian Rail Track Corporation
AS	Australian Standards
BS	British Standards
DRTC	Double Rail Track Circuit
E&B	Earthing and Bonding
EN	European Standard
EPR	Earth Potential Rise
ESJ	Electrical Separation Joint
EST	Emergency Supply Transformer
EMU	Electric Multiple Unit
EW	Earth Wire (also known as the traction earth wire)
HV	High Voltage
IEC	International Electrotechnical Commission
LPS	Lightning Protection System
LV	Low Voltage
MEBB	Main Equipotential Bus Bar
OCLS	Overhead Contact Line System; also known as OHWS and OHW
OHCLZPZ	Overhead Contact Line Zone and Pantograph Zone
PET	Primary Earth Terminal
MEN	Multiple Earth Neutral
RCD	Residual Current Device
RMS or rms	Root Mean Square
SCADA	Supervisory Control and Data Acquisition
SMOS	Structure Mounted Outdoor Switchgear
SRTC	Single Rail Track Circuits
VOELCB	Voltage-Operated Earth-Leakage Circuit Breaker

5.0 DESCRIPTION OF THE AC TRACTION SYSTEM

The Adelaide suburban railway electrification project is based on the use the Booster Transformer Return Conductor supply system currently used on the suburban 25kV rail systems in Brisbane and Perth. A simple 25kV system will be used in depot, stabling areas and some sections of mainline. The electric traction feed to the rollingstock is by means of an overhead contact wire with return current through either one or both rails on the main line but generally a single rail in depot and stabling areas (except where track circuiting is not required) and in locations at station and depot interlocking areas. The rails are bonded, at intervals, to an electrically continuous aerial earth wire which is suspended from and bonded to each traction mast which supports the overhead contact wire system.

5.1 DESCRIPTION OF THE AC TRACTION SYSTEM

5.1.1 The High Voltage Network

Electric power is distributed at feeder stations supplied from the high voltage grid system. The track is divided into discrete electrical feeding sections protected by high speed circuit breakers and individual tracks are paralleled at Track Sectioning Cabins (TSC's). Feeding sections are derived from separate phases of the HV supply and therefore may be displaced by 120o in phase resulting in a voltage of 44kV between adjacent feeding sections.

In the event of a traction fault the section of track in which the fault occurs is isolated by the circuit breakers at the feeder station and the TSC. A further level of track isolation, for maintenance purposes is provided by manually or electrically operated off-load isolators.

A proportion of the traction return current, and fault current, in the event of a broken overhead traction system conductor or insulator flashover, flows through the main body of earth to the earth electrode system at the feeder station and the power transformer.

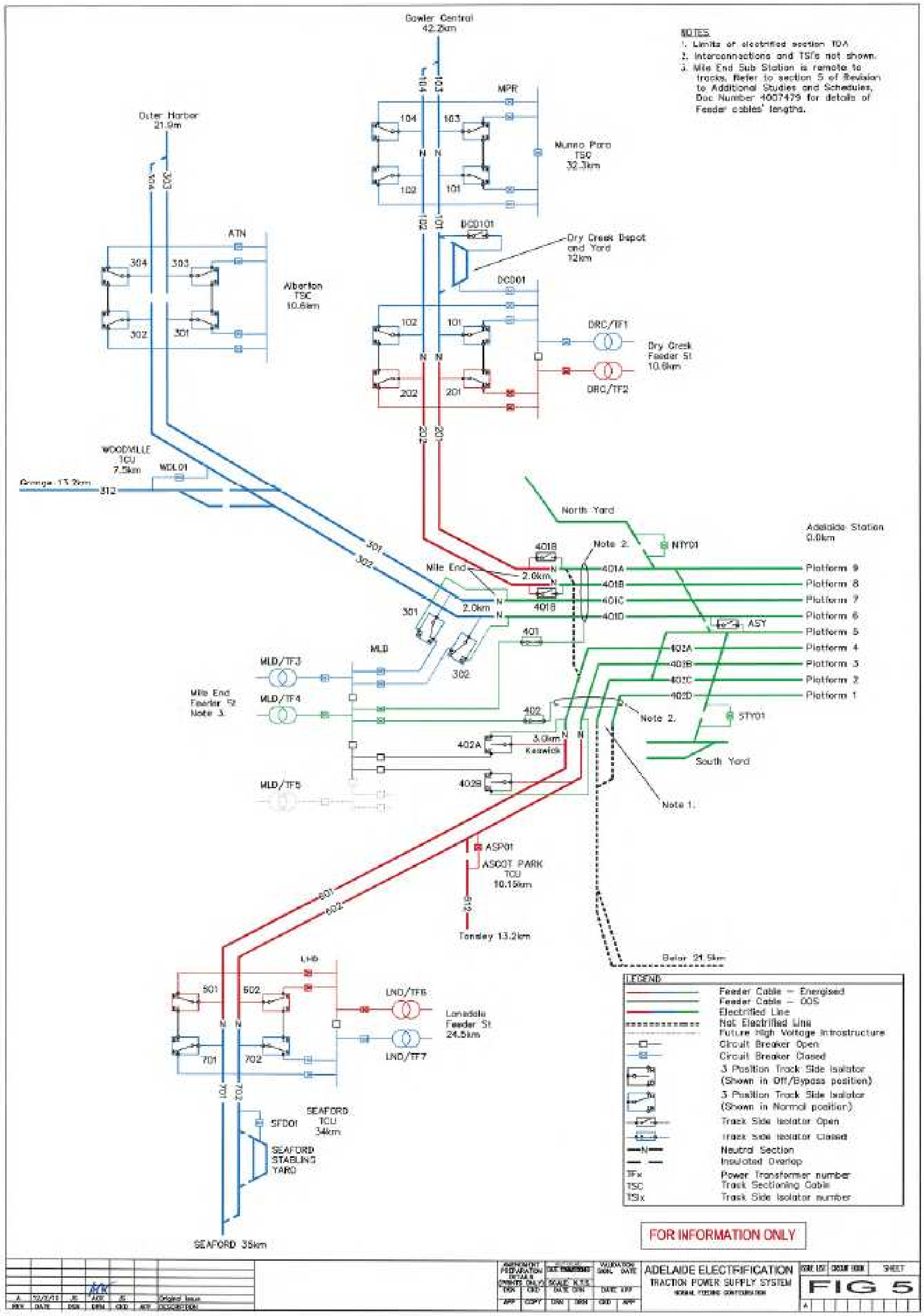


Figure 5.1.1-Adelaide 25kV traction system power supply

5.2 SERVICE CONDITIONS

- The nominal Voltage level, at the point of connection, of 25kV may, under normal operating conditions, rise to 10% above the nominal value.

The overhead system is designed for sparkless current collection at all speeds, but a limited degree of sparking may occur and the equipment must be capable of withstanding the resultant transient effects.

The operation of modern G.T.O. thyristor traction units produces a range of harmonics into the 25kV supply voltage and the equipment must be capable of dealing with these harmonics.

6.0 GENERAL CLAUSES

6.1 SAFETY LEGISLATION AND REGULATIONS

The earthing and bonding system design shall be safe. It shall be safe for persons concerned in its installation, operation, maintenance, repair and eventual disposal and shall be safe in service.

The system shall comply with all DTEI regulations and any other regulations of those parties having jurisdiction over the system, including compliance with the requirements of the relevant clauses of the documents issued by authorities listed in Clause 7.0.

6.2 DESIGN, MANUFACTURE AND WORKMANSHIP

The earthing and bonding system shall be designed in accordance with best practice to suit the specific 25kV power supply system configuration, the signalling system and the Common Bonded Earthing Network employed on this project.

7.0 COMPLIANCE WITH STANDARDS

7.1 INTERNATIONAL, EUROPEAN, BRITISH AND AUSTRALIAN STANDARDS

The earthing and bonding works shall be implemented in accordance with recognised national and international railway practice.

Except where otherwise stated, the works shall comply with the relevant standards, regulations, codes of practice, recommendations etc. of the following organisations:-

- DTEI Technical Standards and Procedures
- SAI Global (Standards Australia)
- The International Organisation for Standardisation (ISO)
- European Standards (EN)
- The International Electrotechnical Commission (IEC)
- The International Telephone and Telegraph Union (ITU).
- The European Committee for Electrotechnical Standardisation (CENELEC).

- International Union of Railways (UIC).
- British Standards Institution (BSI)
- Institution of Electrical Engineers (IEE).

All references to Australian, British, Australian, European and IEC Standards, Codes of Practice or other documents referred to herein shall be deemed to be the current editions and to incorporate all amendments on issue.

7.2 SPECIFIC EQUIPMENT STANDARDS

The earthing and bonding system design shall be in accordance with EN 50122-1 and other relevant standards.

8.0 PERFORMANCE REQUIREMENTS

8.1 GENERAL

The earthing and bonding system shall be fit for purpose when installed into the railway electrification system described in Clause 5.0. The system shall:

- provide a very high-reliability low impedance return path for normal traction current
- provide a low impedance path for traction fault currents which will result in rapid tripping of controlling circuit breakers, whether caused by damage during normal operations of the overhead traction power system or by acts of deliberate vandalism
- provide permanent multiple connections between the traction return system and the general body of earth
- limit readily accessible touch potentials to metalwork or semi-conductive surfaces, such as concrete, during traction fault, however caused
- limit structural damage which could occur as a result of falling traction supply conductors or accidental or reasonably foreseeable current paths from the traction system, whether caused accidentally or maliciously
- minimise the readily accessible touch potential which can occur between adjacent metalwork
- limit the export of potential, both under normal operation and traction fault, which may have an adverse impact upon railway services within the railway alignment and/or adjacent third party service providers e.g. telecommunications, power, water and gas utilities
- prevent arcing in the vicinity of flammable gas, liquid or oxygen when transfer is taking place

The maximum permitted accessible touch potentials for any metalwork connected to the traction system are as required by EN 50122-1

Table 2 – Maximum permissible touch voltages U_t in a.c. traction systems as a function of short time conditions

t	U_t
0,02	940
0,05	935
0,1	842
0,2	670
0,3	497
0,4	305
0,5	225

t is the time duration of current flow in s.

U_t is the touch voltage (r.m.s.) in V.

It should be noted that the maximum allowable touch and step potentials under traction fault conditions depend upon the tripping time of the traction supply circuit breakers. Although the typical tripping times would permit a higher value, all 25kV railways in Australasia to date have used a value of 430V with, in some cases, a higher permitted value of 670V with a broken bond.

Table 3 – Maximum permissible accessible voltages U_a in a.c. traction systems as a function of temporary conditions

t	U_a
0,6	160
0,7	130
0,8	110
0,9	90
1,0	80
≤300	65

t is the time duration of current flow in s.
U_a is the accessible voltage (r.m.s.) in V.

It should be noted that EN 50122-1 requires the lower value of 25V to be applied in depots and workshops. Although this lower value is generally easier to achieve with the low train currents in depots, this may not be the case where a depot is situated close to a feeder station and the main line rail EPR, particularly in the case of use of a simple 25kV system on the main line, will be exported to the depot.

8.2 MAINTAINABILITY

The earthing and bonding system shall be designed to minimize and facilitate maintenance.

8.3 RELIABILITY

The earthing and bonding system will normally remain in service continuously. Failure of the system can cause unsafe conditions to arise and interruption of the railway, hence the design shall ensure a high level of reliability.

9.0 VERIFICATION OF PERFORMANCE AND QUALITY

9.1 QUALITY ASSURANCE

The E&B design and implementation shall operate under a comprehensive quality management system in accordance with EN ISO 9001. This shall include a quality plan. The plan shall cover all activities from date of order to completion of the design documentation.

9.2 DRAWINGS

Bonding plans may include some information in schedule form or on separate drawings.
All drawings shall be of good, legible quality. A short description of each revision shall be provided under consecutive revision letters or numbers together with the date.

Wherever feasible, some means shall be used to identify the location of the most recent revision, for instance by revision clouds.

All drawings shall be brought up to date as necessary, to provide a permanent as-fitted record and shall be supplied in the format specified by DTEI.

10.0 INPUT DESIGN DATA

The following design data is required as an input to the E&B design process. Specific data relating to bond spacing requires an EPR study and is provided in Appendix D. In the absence of such data, typical design criteria for a maximum fault level of 6 000A existing for a maximum of 200ms is given in Clause 10.2.

10.1 ROUTE DATA

- lines to be electrified and interfaces with existing electrified and non-electrified lines,
- locations of stations, tunnels, viaducts and other structures,
- locations where provision is to be made for future electrification,
- locations of any flammable gas and liquid or oxygen installations,
- locations of other administration's earth systems closer than that permitted for separate earthing systems,
- locations of workshops.

10.2 ELECTRIFICATION SYSTEM DESIGN DATA

- signalling plans showing track circuits
- base track sectioning plans showing running rails, overhead line structures, bridges etc,
- preliminary traction power supply system design including details of earth wires and any necessary supplementary earths,

- preliminary system design for the overhead line,
- preliminary system design for the return conductors and/or earth wires.
- locations of switching stations,
- the required electrical rating of bonds,
- the magnitude and duration of fault current including re-closures,
- soil resistivity values along corridor,

The rail and structure potentials occurring depend on the resistance to earth of the traction earth. For continuous earthing installations usually the conductance, which is the reciprocal of the resistance related to the length, is applied. The unit is: Siemens per kilometre [S/km].

For the calculation of the conductance (G) per unit length the sum of the reciprocal of all earth resistances (Re) shall be taken as:

$$G = \sum \frac{1}{R_E}$$

The individual earth resistances include:

- rail conductance to earth
- mast footing resistance
- buried earth strip resistance

10.2.1 Mast Foundation Resistance

The calculation of earth resistances for mast foundations and buried earth strip conductors is shown below.

The minimum conductance to earth required to limit EPR to allowable limits depends upon the fault level, soil resistivity and the interconnection configuration of the rails to the earth wire but is typically 0.3S/km (3.3 Ohms/km) for a BTRC system where the fault level exceeds 4kA within 10-15km of the feeder station and 0.1S/km (10 Ohms/km) elsewhere. The connection intervals are typically 400-600m depending upon the distance from the feeder station.

The mast foundations form the major earth electrodes along the track. For this reason the foundation reinforcement must be electrically interconnected and connected to the reinforcement of the mast or supplemented, depending upon the soil resistivity, by other approved means such as long hold-down bolts.

Concrete masts, except in low resistivity soil (< 30 Ohm-m) and/or in areas of restricted EPR such as depots and workshops, generally require reinforcing steel work within the foundation to act as an embedded earth conductor, to provide acceptable values of mast footing resistance. The reinforcing steel work is connected to the earth rod of the mast directly or via the mast earth terminal.

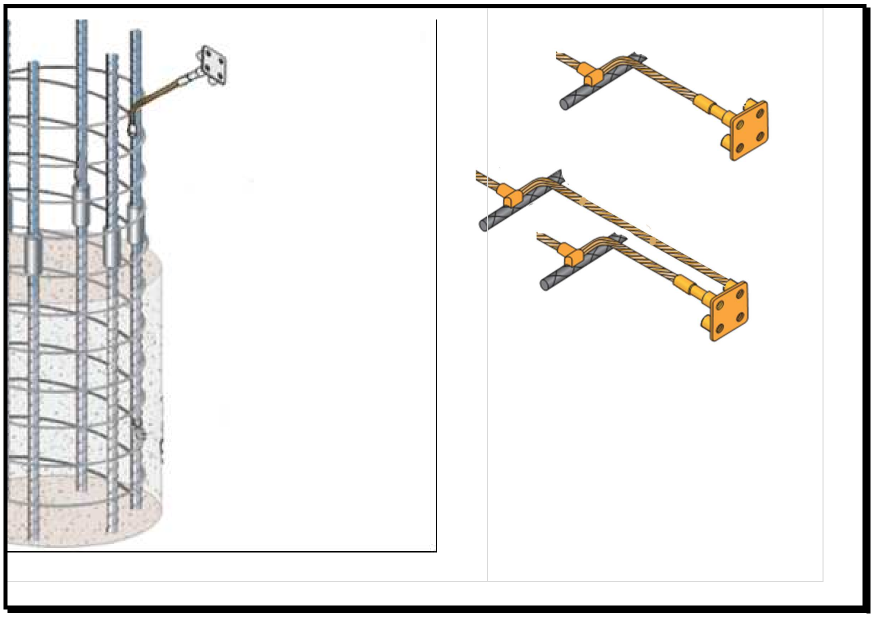


Figure 10.2.1 Typical connection to foundation reinforcement

Recommended are foundations with a low earth resistance such as metal driven piles. For concrete foundations at least three vertical reinforcement bars per foundation are (where permitted) to be welded to the foundation bolts. Where welding to rebars is not permitted, 4 mast hold-down bolts shall be extended to the base of the foundation to form the earth electrodes. For masts with other foundation types, e.g. steel tube foundations an electrical connection needs to be made and depends on mast and foundation construction. The masts and piles must have earthing points, connected to the earth wire, for the connection of, for example, but not limited to:

- overhead contact line isolator operating rods (metalwork of isolators), and
- trackside cabinets within the OHCLZPZ.
- running rails

The reinforcement for mass concrete foundations generally provides an earth resistance similar to cored foundations. Where welding is not permitted to rebars, a dedicated earthing mat may be used.

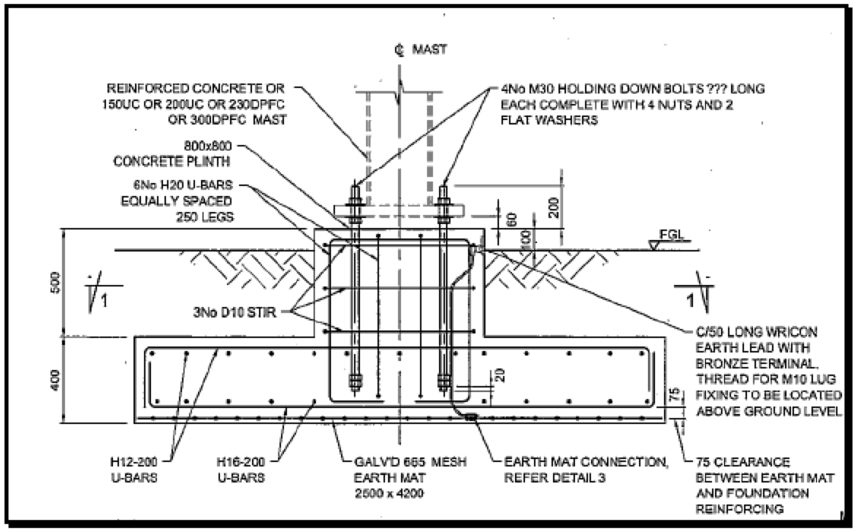


Figure 10.2.1.1Typical earth connection for mass foundation

If the soil resistivity in the area is high, additional measures may be necessary to achieve a low earth resistance along the line such as a supplementary buried earth conductor connected to each mast earth terminal in areas where the traction fault current is high.

It should be noted that the overall resistance (or conductance) to earth is dependent upon:

- the mast foundation resistance (determined by the soil resistivity, mast foundation depth and width)
- the number of masts (mast configurations, centre or marginal)
- the number of tracks
- ballast resistance
- the impedance, and hence, size and number of the earth wires
- the bonding interval between the earth wire and the running rails.

Example: For a soil resistivity of 100 Ohm-m the mast footing resistance of a 3.6m deep reinforced concrete mast foundation with 600mm diameter reinforcement cage equates to 13 Ohm. The resistance is linearly proportional to soil resistivity.

Note: Close co-operation between the traction and signalling disciplines is essential for a cost-effective design to achieve the required value of earth conductance.

Note: Low resistance of mast foundations will increase ground currents at the expense of rail currents which may result in unacceptable levels of induced voltage in cables running parallel and close to the railway alignment.

The calculation of the mast footing resistance RE is carried out with formulae for earth spike resistance. ITU-T gives a formula in their recommendation Volume II "Calculating induced voltages and currents in practical cases", which requires knowledge of the following variables:

ρ_E Soil resistivity
l Length of earth spike
r Radius of earth spike

These input data result in:

$$R_E = \frac{\rho_E}{2\pi \cdot l} \cdot \left[\ln\left(\frac{8 \cdot l}{2 \cdot r} \right) - 1 \right]$$

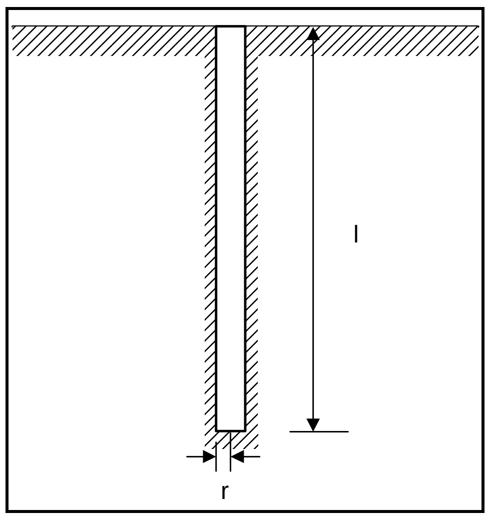


Figure 10.2-1 Earth Spike Dimensions

Note: The applicable radius dimension for a concrete foundation is the diameter of the reinforcing mesh (located close to the perimeter of the foundation diameter). Four hold-down bolts on the same pitch circle diameter have approximately 50% greater resistance than a mesh cage.

10.2.2 Supplementary Earth Resistance Calculations

The calculation procedure for the earth strip conductor electrode is shown below and requires knowledge of the following variables:

ρ_E Soil resistivity
l Length of earth strip
r Radius of earth strip
t length

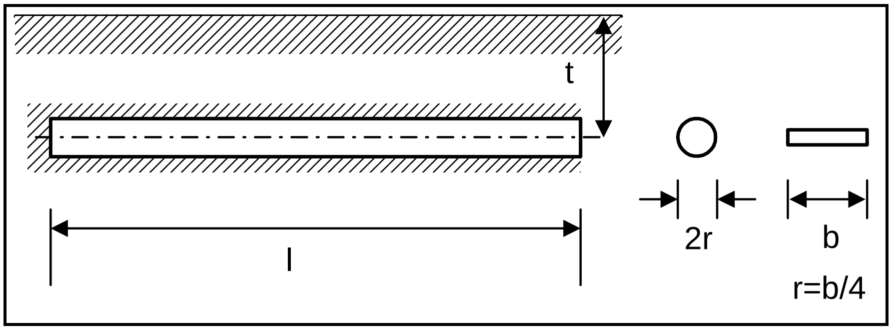


Figure 10.2-2 - Example of Dimensions of Earth Strip Conductor

The input data result in:

$$R_E = A + B$$

$$A = \frac{\rho_E \cdot \left[\operatorname{arsinh}\left(\frac{l}{2r}\right)\right]}{2\pi \cdot l} \qquad B = \frac{\rho_E \cdot \left[\operatorname{arsinh}\left(\frac{l}{2(2t + r)}\right)\right]}{2\pi \cdot l}$$

11.0 DESIGN CRITERIA

11.1 TRACTION RETURN RUNNING RAIL BONDING

Traction bonding shall be provided to ensure that the traction return running rails are electrically continuous throughout and a redundant path is available. At least one running rail of every track equipped with overhead line equipment shall be utilised as a traction return rail.

The traction return circuit shall consist of not less than two adequately rated metallic return paths to ensure the integrity of the system should one path become interrupted.

In single rail traction return areas, only one running rail of each track is utilised as a traction return rail. This rail shall normally be the closest rail to the traction structures in order to reduce the length of bonds between the rail and such structures etc. Earthing and bonding connections shall be made to only this rail.

In double rail traction return areas not equipped with track circuits, both running rails of each track are utilised as traction return rails. Earthing and bonding connections not carrying return current may be made to either rail except for rail to earth wire bonds which shall be made to both rails.

In double rail traction return areas equipped with track circuits, earthing and bonding connections shall be made to these rails only by way of *Air Cored Inductors* (ACI's) or *impedance bonds*. Where the track circuits are of jointless type, special earthing and bonding requirements apply and are specified in the track circuit suppliers design documentation.

Protective measures shall be implemented to prevent inadmissibly high touch voltages or step voltages occurring or being accessible in the event of insulator flashovers, short-circuit faults to the running rails or to the earth wire or any other faults with no direct contact to any part of the traction return system. Protective measures are to be taken in the OHCLZPZ against dangerous touch voltages from the OCLS system by bonding at risk metalwork to traction earth.

Additional protective measures, for example, signal screening cages, are required where maintenance personnel are required to work closer to live OCLS equipment than the minimum clearance distances for restricted areas specified by EN 50122-1 Clauses 5.1.2 and 5.1.3 and/or as modified by clearance requirements – refer Clauses 4.1.5 and 4.1.27.

Protection against potential differences between easily accessible metalwork can be achieved by equipotential bonding of the metalwork or by insulation or barriers. Where bonding is the preferred or only practical solution it is sometimes necessary to limit the export of potential to adjacent structures to eliminate the requirement for remedial work, particularly where this intrudes into third party areas. Insulation and/or barriers may then be used to limit such export by deliberate bonding and create "traction earthed island" within the railway corridor.

In the event of a broken contact wire or dewired pantograph, the traction supply to the OCLS system must be automatically disconnected, in all cases of contact with partially conductive structures, metallic components and electrical equipment. Care shall be taken at overlaps of the OCLS . The OHCLZPZ may need to be extended, subject to risk review on the case by case basis, where the contact wire and catenary are tensioned at anchor supports. This is particularly important for wayside parallel fences and noise walls.

11.1.1 Rail Joint Bonds

A duplicated bond shall be provided across each uninsulated fishplated joint in the traction return rails in sidings and in similar areas where maintenance is less stringent than on main running lines. Rail joint bonds are not required for traction return current purposes in running lines where the standard of maintenance of fish plated rail joints is adequate to ensure good conductivity across the rail joint.

11.1.2 Continuity Bonds

A traction return rail continuity bond is installed to maintain traction return where it may be interrupted by points, crossovers, catch points or fishplated joints. Examples include:

- a traction return rail point and crossing bond, which is across the moving parts of points, expansion joints, redundant insulated rail joints, movable bridges and rail weighbridges;
- a traction return rail transposition bond, which is installed where it is necessary to transpose the traction return and signalling rails; and
- a traction return rail joint bond, which bridges across a fishplated rail joint in the traction return rail; and
- SRTC – DRTC transitions

Particular care must be taken when bonding structures to the traction return system. Metalwork of the structure must be electrically continuous and capable of carrying full traction fault current. Where these structures are not continuous, a 608/0.50mm flexible copper conductor is to be fitted to ensure continuity.

11.1.2.1 Traction Fault Current Path Continuity

Electrical continuity is frequently assumed for structural steelwork however this cannot be assumed for steelwork which is pre-painted before erection as modern painting systems can have very high values of insulation breakdown.

Each mating bolted surface within the OHCLZPZ shall include at least two bolts with stainless steel star washers under the bolt head and under the nut, or other approved means, to provide a guaranteed metal-to-metal contact between bolted members. Suitable installation measures shall be used to eliminate water ingress resulting in long term degradation of the paintwork and/or electrical contact area.

Suitable installation measures shall be used to eliminate water ingress resulting in long term degradation of the paintwork and/or electrical contact area.

11.1.3 Cross Bonding

11.1.3.1 In Electrified Areas with Traction Earth Wire

11.1.3.1.1 SRTC sections

A track to track cross bond, being a standard traction bond, is installed between adjacent electrified lines at the same location as the traction overhead wiring structure to rail bonds at intervals typically not exceeding 300m although this may be reduced in the high fault current area close to a feeder station and/or in areas of very high soil resistivity. The interval required on a given line is specified in Appendix D. There shall be a minimum of a 200mm separation between the track to track cross bond and the traction overhead wiring structure to rail bond connections on the common rail.

11.1.3.1.2 DRTC sections

A track to track to earth wire cross bond, via an ACI or impedance bond, being a standard traction bond, shall be installed between adjacent electrified lines at the same location as the traction overhead wiring structure to rail bonds (refer to Clause 8.1). The interval required on a given line is specified in Appendix D but is typically at intervals not exceeding 600 metres or not more than 400 metres for areas between a feeder station up to the second booster transformer. Impedance bonds or ACIs shall be situated, wherever possible, within 2m of the traction mast to which they are bonded and, in the case of marginal masts, shall not be displaced, along the track from each other by more than one mast separation.

Additional rail-to-rail bonds are necessary in the area between a feeder station and the first booster transformer. These rail-to-rail bonds shall be either a high impedance, impedance bond specified by the signalling designer or a voltage fuse (spark gap) which only connects the rails in case of an excessive voltage.

Note that the signalling system indicates the operation of the voltage fuse. It has to be replaced afterwards.

11.1.3.1.3 Non track circuited areas

A track to track to earth wire cross bond, being a standard traction bond, are installed between adjacent electrified lines at the same location as the traction overhead wiring structure to rail bonds at intervals typically not exceeding 300m although this may be reduced in the high fault current area close to a feeder station and/or in areas of very high soil resistivity. The interval required on a given line is specified in Appendix D.

Additional rail-to-rail bonds are frequently necessary in the area up to 10km from a feeder station to limit rail voltage rise including EPR imported from the grid substation.

In non track circuited areas a greater flexibility in location of bonds to overcome any restrictions imposed by physical track constraints may be exercised. The rail bond connection should be located such as not to cause maintenance access difficulties to axle counter sensors.

11.1.3.2 In Electrified Areas without Traction Earth Wire

A track-to-track cross bond shall be installed between adjacent electrified lines at intervals generally not exceeding 300m although this may be reduced in the high fault current area close to a feeder station and/or in areas of very high soil resistivity. Installation shall be in accordance with the requirements of Clause 11.1.3.1. Refer Appendix D for details for specific lines.

11.1.3.3 Wired Sidings

The traction return rail(s) of a wired siding shall be bonded to the traction return rail(s) of the main electrified line using track to track cross bonds, as described in Clause 11.1.3. These bonds shall be provided as near as possible to the turnout points and another at the buffer stops of the siding, or behind the last traction overhead wiring structure for part-wired sidings. Intermediate track to track cross bonds shall be provided at intervals typically not exceeding 400m or as specified in Appendix D.

If the wired siding is not track circuited, a traction return rail to rail cross bond (as described in Clause 11.1.3.7) shall be provided on the wired siding immediately after the last insulated rail joint in the signalling rail and thereafter adjacent to each track to track cross bond. There shall be a minimum of a 200mm separation between the track to track cross bond and the traction return rail (in SRTC areas) to rail cross bond connections to the common rail.

In multi-track wired sidings, bonding of each track shall be in accordance with the appropriate paragraph above. Rather than connecting each traction return rail(s) of a wired siding to the traction return rail(s) of the main electrified line, these connections shall be to the nearest adjacent traction return rail which has been bonded to the main electrified line. Points, crossings and catchpoints of multi-track wired sidings shall be bonded in accordance with Clause 11.1.3.8.

The requirements of Clause 11.16 for isolation and separation of traction earth from the electricity service provider's MEN System or any other separate earthing system shall be observed.

11.1.3.4 Unwired Sidings (on Railway Property)

If the rails of the unwired siding are in contact, or may reasonably be expected to come into contact, with the electricity service provider's MEN System or any other separate earthing system, or if a dangerous situation may otherwise be created, then two sets of insulated rail joints for electrical separation purposes shall be provided in the connection to the electrified line. Note that a set of insulated rail joints comprises one joint in each of the two rails. The first set of insulated rail joints is to be located as near as possible to the turnout points. The distance between this set and the second set shall be not less than 20m.

Where an unwired siding runs adjacent to the electrified lines for a distance of 200m or more, the unwired siding shall be bonded to the traction return rail(s) of the electrified lines, in accordance with the requirements of Clause 11.1.7. Only when the unwired siding diverges completely from the electrified line shall the unwired siding be isolated in accordance with the above Clause.

If there is no reasonable possibility of contact between the rails of an unwired siding and the electricity service provider's MEN System or any other separate earthing system (refer to Clause 11.16), nor of a hazardous situation otherwise being created, no action is required to bond or insulate the rail(s) of unwired sidings to traction return.

11.1.3.5 Unwired Sidings (Private)

All private unwired siding shall be provided with two sets of insulated rail joints in the connection to the electrified line. Note that a set of insulated rail joints comprises one joint in each of the two rails. The first set of insulated rail joints is to be located as near as possible to the turnout points. The distance between this set and the second set shall be not less than 20m.

11.1.3.6 Particular Locations

Track-to-track cross bonds shall be installed between adjacent electrified lines in the following particular locations:

- at switching stations: 2 bonds (refer to Clause 11.5)

In SRTC areas each bond shall follow a separate route and be connected to the traction return rail at locations not less than 5m apart. In DRTC areas each bond shall run in a separate duct and be connected separately to the ACI or impedance bond bus such that both bonds can never be inadvertently removed. In non track circuited and axle counter areas each bond shall be connected to a separate rail and to a separate rail stud from that used for the associated rail-to-rail bond.

- at, or near as possible, to mid-point connections: 1 bond

At a point approximately midway between booster transformers, a connection shall be made between the return conductor and, in SRTC areas, the traction return rail or, in DRTC areas. the ACI or impedance bond of the associated track. The MPC shall be made with duplicate standard traction bonds In SRT area each bond shall follow a separate route and be connected to the traction return rail at locations not less than 5 metres apart. In DRTC areas each bond shall run in a separate duct and be connected separately to the ACI or impedance bond bus such that both bonds can never be inadvertently removed.

Where mid-point connections for adjacent electrified lines in multi-track areas are separated by more than 100 metres1, separate track to track cross bonds shall be provided at each mid-point connection. Where the separation is 100 metres or less, only one track to track cross bond at one mid-point connection is required.

Note1: In DRTC areas with marginal masts in which the MPC's are separated by 100m or more, each bond consists of an earth wire to track to earth wire bond. In areas with centre masts, each bond comprises an earth wire to track bond. A full track to track bond at less than 400m separation would degrade the broken rail detection/protection functionality of the track circuits.

- at the end of electrification: 1 bond (refer to Clause 11.1.7.1) Where electrification ends but adjacent non-electrified lines continue, a track to track cross bond shall be provided behind the last traction overhead wiring structure on each non-electrified line.
- at SRTC to DRTC transitions: 2 bonds from the centre tap of the ACI or impedance bond to traction return. One bond shall be connected to the traction return rail in the SRTC section, and one to the closest traction mast.
- in areas within the section from a feeder station to the second booster transformer from that feeder station, a second impedance bond or voltage fuse shall be provided at not less than 300 m from the SRTC-DRTC transition. The second impedance bond will normally be a high impedance type to ensure correct functioning of the track circuit.

11.1.3.7 Traction Return Rail to Rail Cross Bonding

In electrified areas where the electrified line is not track circuited, the two rails of each track shall be bonded together by standard traction bonds:

- at every rail to earth wire bond
- at every track-to-track cross bond
- immediately after the last insulated rail joint in the signalling rail and at not more than 400m intervals thereafter or as specified in Appendix D.

11.1.3.8 Traction Return Rail Points and Crossing Bonding

Standard traction bonds shall be provided in the traction return rail to maintain continuity of the traction return current path wherever it would otherwise be interrupted by points, crossings or catch points.

Insulation shall be inserted in all spreader bars, gauge tie plates and tie and locking bars at the points.

11.1.3.9 Traction Return Rail Transposition Bonding

Standard traction bonds shall be provided in the traction return rail to maintain continuity of the traction return current path wherever it would otherwise be interrupted by transposition of the signalling rail of single rail track circuits (SRTC).

11.1.3.10 Traction Return Rail Joint Bonding

Traction return rail joint bonding is not required specifically for traction return current on main electrified lines where the standard of maintenance of fish plated rail joints is adequate to ensure good conductivity across the rail joint at all times. Refer to IEC62128-1 clause 9.2. Signalling rail joint bonds are required in main electrified lines for signalling track circuit purposes in both the signalling and traction return rails.

The rails of all electrified roads in all non-track circuited areas shall be bonded. Special approved economical bonding methods may be used through turnouts. Standard signalling rail joint bonds may be used for this purpose.

11.1.3.11 Spark Gaps in Single Rail Track Circuits

In electrified areas with single rail track circuits, spark gap arresters shall be installed between the traction rail and signalling rail approximately at the midpoint on each track circuit on all electrified roads and those adjacent track circuits within the overhead contact line zone. These spark gap arresters shall be installed to afford protection to the signalling equipment in the event of fallen traction overhead wiring equipment contacting the signalling rail and to provide a guaranteed fault path back to the traction return. These requirements shall be varied for single rail track circuits at level crossings so that they comply with clause 11.18.4.2.

11.1.4 Signalling Bonds

Specific types of signalling bonds are identified by references to their applications, examples of which follow:

- Signalling Rail Transposition Bond: this is a signalling continuity bond provided, in SRTC areas, wherever the signalling rail and the traction return rail are transposed for signalling purposes.
- Signalling Rail Joint Bond: this is a signalling continuity bond bridging across the fishplated rail joint in the signalling rail. The most commonly used bond is a signalling rail joint bond.

11.1.5 Impedance Bonds

On tracks where both rails are traction return rails and are equipped with double rail track circuits, all bonding to the traction return rails shall be made via impedance bonds.

11.1.6 Track Connections with Non-Electrified Lines

At junctions with non-electrified main or branch lines (sections where rollingstock is mobile) which diverge from the electrified lines, the rails of the non-electrified line have to be isolated from the electrified line. This is necessary if the non-electrified line extends into an area where rails may come into contact or close proximity to the electricity service provider's MEN system or any other separate earthing system, or where a hazardous situation may be created by potential difference between the rails and other metalwork earthed to a separate earthing system.

If the non-electrified line is not track circuited, this isolation is achieved by inserting two sets of insulated rail joints in series in the turnout to the non-electrified line. Note that a set of insulated rail joints comprises one joint in each of the two rails. The first set of insulated rail joints shall be located as near as possible to the turnout points and immediately after the last insulated rail joint in the signalling rail. The distance between the first set and the second set of insulated rail joints shall be not less than 1.6km, except subject to the approval of the Technical Manager Electrification, where this distance may be reduced to not less than the maximum length of a train which may use the line.

If the non-electrified line is track circuited, then fully immunised track circuits will be necessary (as required by standard signalling practice) adjacent to electrified areas. The first set of insulated rail joints is to be located as near as possible to the turnout points. The distance between the first set and the second set of insulated rail joints shall not be less than 1.6km, except subject to the approval of the Technical Manager Electrification, where this distance may be reduced to not less than the maximum length of a train which may use the line. There may be other insulated rail joints inserted in the signalling rail between these two sets of joints for signalling track circuit requirements. Insulated rail joints, as required by the Senior Project Manager Signals and Communications in the signalling rail for track circuits, will normally serve as one of the insulated rail joints of either or both sets.

Note that the requirements of Clauses 11.1.3.4 and 11.1.3.5 are applicable within any section of non-electrified track in close proximity to the electrified line.

11.1.7 Adjacent Non-Electrified Lines

Where non-electrified lines run adjacent and parallel to electrified lines for a distance of 200m or more, the non-electrified line shall be bonded to the traction earth of the electrified lines. This requirement applies only where the non-electrified line does not diverge completely from the electrified line. Following divergence, non-electrified lines shall be isolated to prevent export of traction return currents from rail sections bonded to traction earth in accordance with the above Clauses.

To ensure isolation of the non-electrified line from the traction earthing system outside these areas, two sets of insulated rail joints shall be inserted in series in each location where the non-electrified line commences to run adjacent to the electrified line and where the non-electrified line departs from the electrified line. Note that a set of insulated rail joints comprises one joint in each of the two rails.

The first set of insulated rail joints shall be located as near as possible to where the non-electrified line commences to run adjacent to the electrified line and as near as possible to where the non-electrified line departs from the electrified line.

The distance between the first set and the second set of insulated rail joints shall be not less than 1.6km in a direction away from the adjacent area of non-electrified line, except subject to the approval of the Technical Manager Electrification, where this distance may be reduced to not less than the maximum length of a train which may use the line. There may be other insulated rail joints inserted in the signalling rail between these two sets of joints for signalling track circuit requirements. Insulated rail joints, as required by the Senior Project Manager Signals and Communications in the signalling rail for track circuits, will normally serve as one of the insulated rail joints of either or both sets.

A rail (in SRTC non-electrified areas) of the non-electrified line shall be bonded to the traction earth of the main electrified lines using track to track cross bonds, as described in Clause 11.1.3. These bonds shall be provided as near as possible to where the non-electrified line commences to run adjacent to the electrified line and another at the departure of the non-electrified line. Intermediate track to track cross bonds shall be provided typically at intervals not exceeding 400m or as specified in Appendix D.

If the non-electrified line is not track circuited, a traction return rail (in SRTC areas) to rail cross bond (as described in Clause 11.1.3.7) shall be provided on the non-electrified line immediately adjacent to each track to track cross bond. There shall be a minimum of a 200mm separation between the track to track cross bond and the traction return rail to rail cross bond connections to the common rail.

The requirements of Clause 11.16 for isolation and separation of traction earth from the electricity service provider's MEN System or any other separate earthing system shall be observed for the area of non-electrified line which is bonded to the traction return rail.

11.1.7.1 End of Electrification

11.1.7.1.1 On a Continuing Main Line

Where an electrified line ends but a non-electrified line continues, the non-electrified line may have to be isolated from the electrified line. This is necessary if the non-electrified line extends into an area where rails may come into contact or close proximity to the electricity service provider's MEN System or any other separate earthing system, or where a hazardous situation may be created by potential difference between the rails and other metalwork earthed to a separate earthing system.

If the non-electrified line is not track circuited, this isolation is achieved by inserting two sets of insulated rail joints in series in the non-electrified line. Note that a set of insulated rail joints comprises one joint in each of the two rails. The first set of insulated rail joints is to be located not less than 200m from the end of electrification. The distance between the first set and the second set of insulated rail joints shall not be less than 1.6km, except subject to the approval of the Technical Manager Electrification, where this distance may be reduced to not less than the maximum length of a train which may use the line.

If a non-electrified line is track circuited, then fully immunised track circuits will be necessary, as required by standard signalling practice, adjacent to an electrified area. The first set of insulated rail joints is to be located not less than 200m from the end of electrification. The distance between the first set and the second set of insulated rail joints shall not be less than 1.6km, except subject to the approval of the Technical Manager Electrification, where this distance may be reduced to not less than the maximum length of a train which may use the line. There may be other insulated rail joints inserted in the signalling rail between these two sets of joints for signalling track circuit requirements. Insulated rail joints, as required by the Senior Project Manager Signals and Communications in the signalling rail for track circuits, will normally serve as one of the insulated rail joints of either or both sets.

11.1.7.1.2 At a Terminus

If the terminus of a line is not track circuited, a traction return rail to rail cross bond shall be provided immediately after the last insulated rail joint in the signalling rail, and another at the buffer stops or behind the last traction overhead wiring structure, as appropriate. Intermediate traction return rail to rail cross bonds shall be provided typically at intervals not exceeding 400m or as specified in Appendix D.

11.1.8 Traction Return Rail Identification

In SRTC areas, where there is no traction bond at a traction overhead wiring structure or where there are more than two tracks, the traction return rail is to be identified by painting, in the colour light blue, the field side of the traction return rail head and web as near as possible to each traction overhead wiring structure and at such other positions at points and crossings as is necessary to clearly identify the traction return rail.

Typically, the traction return rail will be the rail closest to the traction overhead wiring structures.

11.1.9 Flammable Gas and Liquid or Oxygen Installations

Special precautions are necessary in the design of earthing and bonding for lines serving installations for the storage or handling of low flash point products and oxygen. These Guidelines do not cover the special precautions required at such installations, and where such installations exist on or near an electrified line or on a siding connected to an electrified line, the measures to be adopted shall be determined by the Technical Manager Electrification. All available precautions, as described in

EN50122-1 section 6, to avoid the creation of a hazard shall be taken and shall ensure that any relevant statutory regulations or safety standards are observed.

The special precautions are not required where the flash point of the products being stored or handled exceeds 61℃. Thus, no particular precautions (othe r than those included in other Clauses of these Guidelines) are required at diesel locomotive or railcar fuelling points.

Immediately on the transfer point side of the insulated rail joints nearest to the transfer point, the electrically isolated rails shall be cross bonded and connected to the earth electrode. The resistance to earth of the cross bonding and rails shall be less than 7 Ohms under dry ground conditions.

The electrically isolated rails on the transfer point side of the insulated rail joints shall be provided with rail joint bonds throughout together with track-to-track and rail-to rail bonds at intervals not exceeding 70m and shall be bonded to the transfer installation and connected to the earth electrode. The resistance to earth of the bonds, rails, and transfer point shall be less than 7 Ohms under dry ground conditions.

Where convenient, all connections may be made to the same earth electrode. The earth electrode used for this purpose shall be completely separate from traction earth.

Note I. Where any normally live overhead line equipment is closer than 9m to a transfer point, facilities are provided so that the overhead line equipment can be switched off and connected to traction earth before transfer is permitted.

Note 2. The transfer of flammable gas or liquid or oxygen is not carried out on tracks equipped with overhead line equipment or which lie within the overhead contact line zone of neighbouring electrified tracks or whilst the insulated rail joints are bridged by rail vehicles.

11.2 OVERHEAD LINE STRUCTURES

Each overhead line structure shall be bonded to traction earth.

In nominated areas, where it is necessary to restrict the export of traction potential to adjacent buildings, telephone exchanges etc., double insulation shall be used for traction support structures. The traction insulators shall be mounted on an intermediate insulator with a nominal 3kV rating which shall be, in turn, attached to the building structure. The traction earth wire shall be bonded to the junction of the intermediate and main (25kV) insulators, thus in the event of a 25kV insulator flashover, all fault current flows in the traction earth wire and none in the protected building structure.

11.2.1 Areas without Earth Wires

In areas with single rail traction return, each overhead line structure shall be separately bonded to the nearest appropriate traction return rail except where physical difficulties make the separate bonding impracticable. In this situation an aerial route shall be provided, e.g. where buildings interpose.

Where electrical continuity between masts is provided by a span wire or boom, only one mast shall be bonded.

11.2.2 Areas with Earth Wires

It is possible, in SRTC areas, to bond each traction overhead wiring structure to traction earth by an individual traction overhead wiring structure to rail bond from the structure to the nearest traction return rail. Similarly, it is possible in non track circuited areas to bond both rails to each traction mast. However, a continuous traction earth wire in SRTC and non track circuited (and axle counter) areas may be provided to minimise the number of direct connections to the traction return rail. The traction earth wire is bonded to the traction return rail at appropriate intervals, to limit rail EPR, as defined in Clause 11.1.3.1 and Appendix D.

Where there is only a single track, it is necessary for safety and security to ensure that there are two effective paths for the traction return current to protect against the possibility of a broken rail. The action to be taken depends on the particular situations that follow:

- if the section of single track is not track circuited, the two rails shall be bonded together such that each forms an independent traction return current path and no further special action is necessary; or
- if the section of single track is track circuited, and there is only one traction return rail, a traction earth wire must be installed to provide the alternative traction return current path. Traction overhead wiring structures to rail bonds alone are not adequate.

An earth wire shall always be installed in sheds and maintenance facilities (see Clause 11.17.2.1).

In areas where a traction earth wire is installed, each and every traction overhead wiring structure shall be directly connected to at least one traction earth wire. This connection to the traction earth wire constitutes the earthing of the structure. In the case of multi-track traction overhead wiring structures and portals where electrical continuity between the support masts of these structures is provided by span wires or booms, one support mast only need be bonded to the traction earth wire. It is acceptable for more than one traction earth wire to be connected to a multi-track traction overhead wiring structure or portal.

Note that where concrete masts are used as the traction overhead wiring structure, the earth rod of the support mast and the reinforcement in the mast foundation shall be electrically connected to the traction earth wire.

The termination method of the traction earth wire, including, but not limited to, the earth wire element in headspan track structures shall be such as to ensure electrical continuity and bonding shall be carried out across components with limited contact area such as, but not limited to, turnbuckles, shackles, clevises etc.

Depending on the signalling system, different distances between bond connection points to the traction rail return need to be applied.

In SRTC sections, for each traction earth wire, a traction overhead wiring structure to rail bond is provided at intervals typically of the order of 300m but this may be less in the high fault level area close to a feeder station. The frequency of installation of such bonds is determined by the maximum system fault current, earth electrode resistance, soil resistivity, protection equipment design and the permitted touch and step potential and is determined by an EPR study. An additional buried earth wire may also be required within this area where the soil resistivity is higher than 100 Ohm-m (refer to Clause 10.2). The project specific criteria and the requirement for additional buried earth wire are given in Appendix D

11.2.2.1 Installation

A traction earth wire serves as both a traction fault current path and a connection between the traction system earth electrodes. To ensure that both purposes are fulfilled, installation of the traction earth wire shall comply with the following rules:

- each traction earth wire shall form part of an electrically continuous conductor throughout the electrified area;
- bonds connecting the traction earth wire to the traction rail return path shall be provided at intervals, as defined in Clause 11.1.3.1 and Appendix D;
- wherever it is necessary to terminate a traction earth wire, it shall be bonded at the termination to the traction return rail of the track with which it is associated.
- the use of separate sections of traction earth wire is prohibited unless special approval is granted by the Technical Manager Electrification. The traction earth wire is provided to ensure that a continuous fault current path is maintained under all track maintenance and disarrangement conditions. When authorised, any separate section of traction earth wire shall be bonded to the traction return rail at its point of commencement and termination, or as directed.

11.2.2.2 Size of Traction Earth Wire

The traction earth wire requires a cross-sectional area (csa) sufficient to carry both full traction fault current and traction return current. The traction earth wire impedance is an important design parameter in meeting the maximum rail EPR requirement and the maximum induced voltage in lineside cables and the cross-section may have to be increased over and above normal and fault current ratings. The csa of the earth wire is specified in Appendix D.

11.2.3 Areas with Return Conductors without Booster Transformers

This configuration is used for the railcar depot where the earth wire carries a significant proportion of the return current and provides screening against induction into adjacent cables.

The bonds shall be continuous from the earth wire to the traction return rails – the bond interval is given in Appendix D. The overhead line reinforcement structure shall not be used as part of the electrical circuit.

11.3 OVERHEAD LINE STRUCTURES CARRYING AN EMERGENCY SUPPLY (25 KV SINGLE PHASE) TRANSFORMERS (EST)

The earth side of the high voltage winding of an EST shall be provided with duplicate paths to traction earth to enhance the security of the earth connection. In SRTC sections these connections shall be by means of two standard traction bonds, categorised as “red” bonds (refer Clause 11.22), from the traction overhead wiring structure to the nearest traction return rail. Each bond shall follow a separate route and be connected to the traction return rail at locations not less than 5m apart. In axle counter areas, one connection shall be made to the earth wire and another to both rails.

In electrified sections with a DRTC system, a traction earth wire is always obligatory. Neither connection can be carried out to the running rails and each red bond shall be made to opposing masts to the traction earth wire where marginal masts are installed. Grading rings shall be installed around EST’s to minimise the touch and step potential on the support mast.

Where centre masts are installed, each red bond shall follow a separate route to the same mast. In addition grading ring shall be enhanced with additional earth rods as required to form an independent earthing system capable of carrying the full load current of the EST. This earth shall be connected to the EST and shall form a counterpoise or perimeter earth around the EST in accordance with the requirements of Clause 11.4

The return current connection of EST's at feeder stations and TSC's will depend upon the location of the EST and will be subject to approval of the Technical Manager Electrification but shall comply with the requirements for two separate return paths and step and touch potential protection for isolating switches for the EST.

11.4 OVERHEAD LINE STRUCTURES CARRYING EARTHING CIRCUIT BREAKERS OR DEVICES

Each traction overhead wiring structure supporting an isolating switch shall be provided with duplicate paths to traction earth to enhance the security of the earth connection.

In SRTC or non track circuited sections in which the structures are not connected to an earth wire, these connections shall be by means of two standard traction bonds from the traction overhead wiring structure to the nearest traction return rail. Each bond shall follow a separate route and be connected to the traction return rail at locations not less than 5m apart.

Where, in SRTC or non track circuited sections, the traction overhead wiring structure supporting an isolating switch is connected to a traction earth wire, a single traction overhead wiring structure to rail bond will suffice. Note that in single track areas, the connection to the traction return rail shall be arranged to ensure that there is a traction return current path which is secure even in the event of a broken traction return rail or return conductor.

Traction overhead wiring structures which support isolating switches shall also be provided with a permanently fixed earth mat or grading rings to minimise the touch and step potential on the support mast. Grading rings may also be required in areas of high soil resistivity close to feeder stations where traction fault currents are high and will be required for ground mounted EST's.

The grading ring shall consist of a length of standard 107mm^2 bare copper contact wire or an equivalent copper buried in a continuous ring around the traction overhead wiring structure at a depth of approximately 150mm and a radius of not less than 1m.

The grading ring shall be directly connected to the traction overhead wiring structure by a tinned copper lug brazed to the copper grading ring.

The earth mat shall be directly connected to the traction overhead wiring structure and the mechanism handle by a tinned copper lug brazed to the earth mat or other acceptable method.

11.5 SWITCHING STATIONS

All metalwork not intended normally to carry currents shall be connected to the return current busbar by a hard drawn high conductivity copper strip (switchgear earthing strip) not less than 25 x 6 mm or equivalent. The return current busbar shall be connected to a local earthing system for the switching station.

The local earthing system for the switching station shall be provided, generally in accordance with IEC-60364 and to the requirements of Clause 11.5.1.1 of these Guidelines.

The switching station shall be treated in accordance with the requirements of Clauses 11.5.1 & 11.17 of this Part of these Guidelines. Care must be taken to ensure that any auxiliary supplies which enter the switching station are correctly treated in accordance with Clause 11.16

Incoming services, such as railway or public telecommunications services which present a remote earth, entering feeder stations, shall be galvanically isolated by means of an optical fibre link, or other approved method.

Note: The requirement for such isolation is not generally applicable to TSC's as the fault level, and hence EPR is comparatively low. It shall be applied if the TSC is close to a feeder station and the fault level is comparable to that at a feeder station.

At feeder stations, the return current busbar shall be bonded to the rail(s) (and to the earth wire) of each separate track by means of two Return Current Bonds rated for traction fault currents and the load current of the transformer under maximum load condition. Each bond shall follow a separate route. The return current busbar shall never be disconnected from traction earth when any of the switching station main or auxiliary ac equipment is live.

The switching station shall carry in a prominent position alongside the return current busbar a permanently affixed warning sign reading:

"WARNING - DO NOT DISCONNECT EARTH CONNECTIONS
UNLESS ALL POWER IS ISOLATED"

11.5.1 Feeder Stations

Figure shows the schematic circuit diagram of earthing and bonding for a typical feeder station. Note that this figure is generic, intended to illustrate earthing of auxiliary equipment and is thus applicable to 25kV feeder stations without a separate Return Conductor.

Note: Connectivity of both ends of HV cable sheathing, entering the feeder station area, shall be agreed between power supply provider and DTEI. The fault current carrying capacity of the HV cable sheath shall be suitable for the duration of such current.

11.5.1.1 Earthing Grid

For the traction power feeder stations an earthing grid must be integrated within the foundations of the related buildings. Therefore, all foundations within the feeder station area must be interconnected. The earthing grids must be electrically connected to the return circuit, i.e. traction earth. The interconnection of return current circuit and earthing installation in feeder stations is shown in Figure and 8.5-2.

Cable shields must be electrically connected to traction system earth at one end only, at the end closest to the source of supply. Calculations shall be performed to investigate the level of induced voltages on the cable shields. If the reduction effect of the cable screening conductors is required to reduce inductive interference, the screening conductors may be required to carry a significant proportion of the return current, both under normal operation and traction fault.

The earthing grid and (if required) grading rings around fences and/or auxiliary trackside earth conductors shall be designed to limit step and touch potential under all earth fault conditions, including, not only 25kV faults, but, not limited to:

- the import of EPR into the 25kV feeder station compound which can occur as a result of an earth fault at the grid substation from which the main traction supply transformers are fed with no connection to the rail/earth wire at the feeder station (i.e. minimum earth resistance)

- step and touch potentials, under normal traction return bonding, to and between rails, traction structures, rollingstock and any other traction bonded metalwork in the vicinity of the feeder station during an earth fault at the grid substation.

The Technical Manager Electrification will advise what assumptions may be made in relation to connection of the railway feeder station to traction return and the permissible voltage levels under various earthing system interconnection configurations.

11.5.1.2 Incoming High Voltage Feeder Cables (where applicable)

Incoming high voltage feeder cables to the traction power supply transformer substation from the high voltage network shall be in accordance with the requirements of IEC-60364. The earthing and bonding requirements for the traction supply transformers are not covered by these Guidelines and are the responsibility of the supply authority.

The requirements for earthing and bonding of the sheaths or armouring of incoming high voltage feeder cables shall be determined in conjunction with the HV grid supply authority.

11.5.1.3 Earthing and Bonding and Traction Return Circuits within Feeder Stations

Traction power supply transformer substations shall be in accordance with the requirements of IEC-60364.

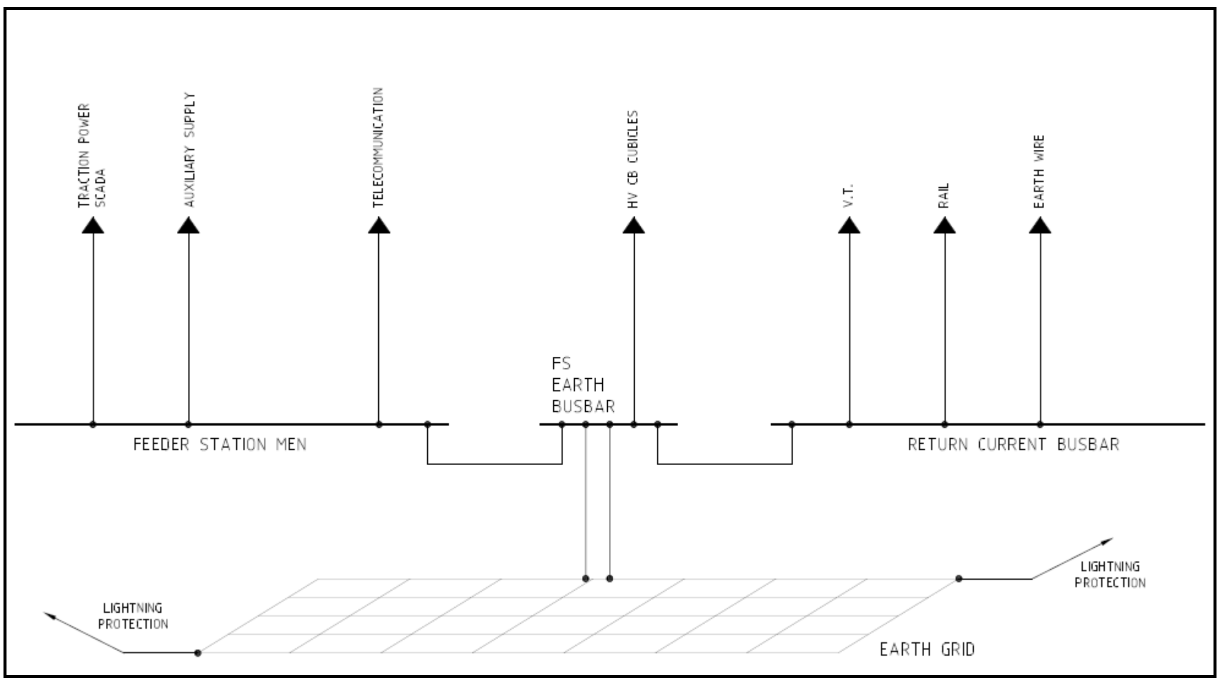


Figure 11.1.5.3 : Schematic Circuit Diagram for Earthing and Bonding of Feeder Station

All bonding conductors from rail(s) and Earth Wire shall be insulated to 600V in accordance with IEC 60502-1 Part 1

Lightning protection systems for traction power supplies shall be determined in conjunction with the HV supply authority. The installation shall be in accordance with IEC 62305:2006.

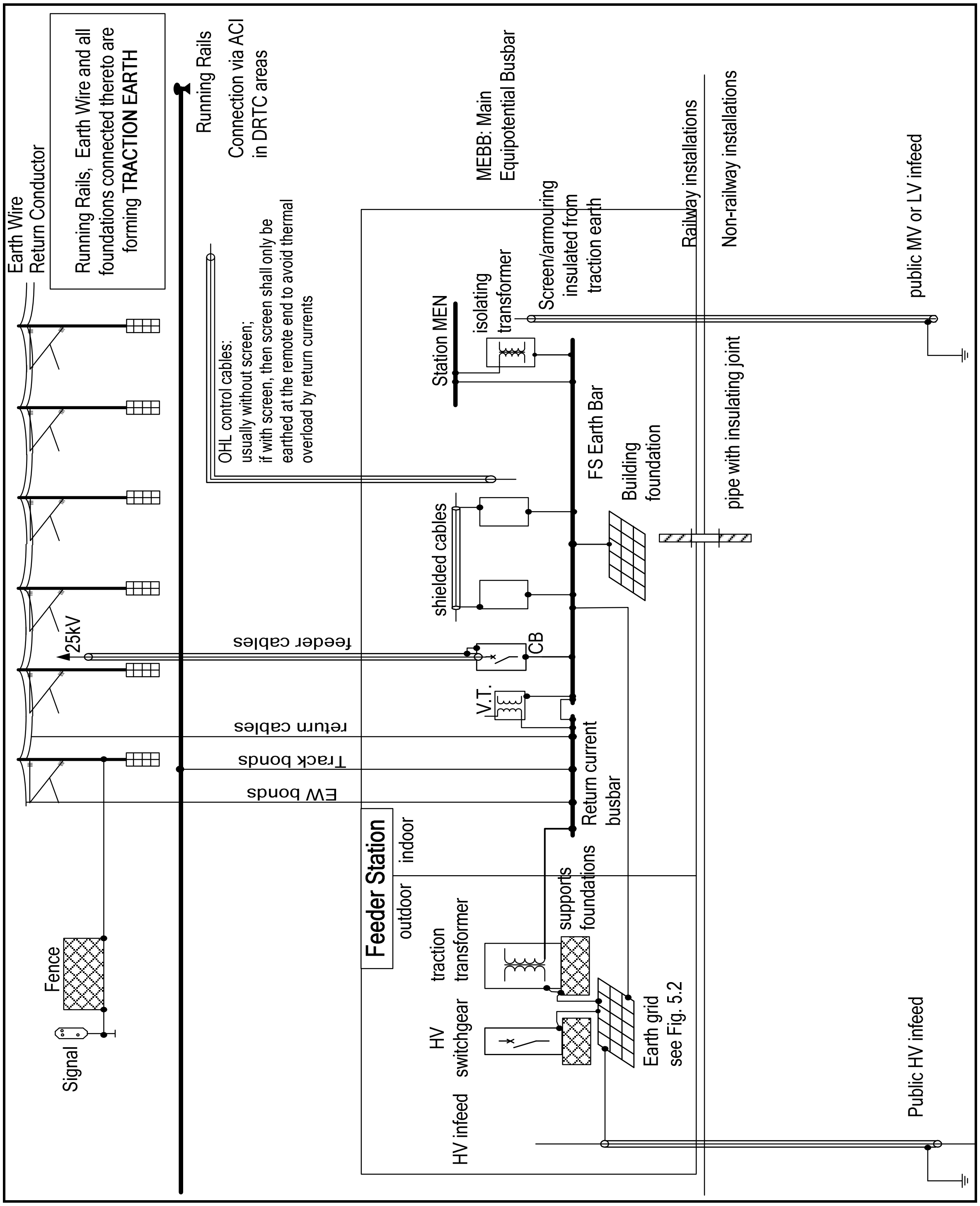


Figure11.5.1.3.1 Return Current Circuit and Earthing in the Feeder Station

11.5.1.4 Voltage Transformers

One end of the high voltage winding of voltage transformers shall be connected to the return current busbar by a suitably rated insulated cable. The switchgear earthing strip shall not be used for this purpose.

11.5.2 Connections to Traction Return Rail

Duplicate connections shall be made by means of two Return Current Bonds in the switching station to:

- the traction return rail in SRTC areas
- each rail, together with a rail-to-rail cross bond in non track circuited areas

of each separately fed track. Each bond shall follow a separate route and be connected to the traction return rail(s) at locations not less than 5m apart

Note: a railway track fed by two circuit breakers, one each side of the overlap or neutral section is considered to be a one track, not two tracks, for the purpose of bonding.

11.5.3 Surge Diverters

The small part steelwork on which a surge diverter is mounted shall be bonded to traction earth by means of a standard traction bond. The solid metallic connection from the base of the surge diverter to this small-part steelwork will provide an adequately high conductivity path for the discharge current. A surge diverter requires two independent earth paths. Sharp bends and kinks in the bond cables must be avoided.

11.5.4 Isolating Switches and Support Metalwork

The metalwork supporting each isolating switch or group of isolating switches shall be bonded together and to the nearest traction earth at the top of the traction overhead wiring structure (or other structure on which the switch is mounted).

The metalwork supporting each isolating switch mechanism and all moveable, accessible metallic parts (whether motorised or manually operated) shall also be bonded together and to traction earth (usually to the earth ferrule at the base of the traction overhead wiring equipment) in accordance with Clause 11.4

11.6 SWITCHING STATIONS (SMOS TYPE)

11.6.1 SMOS Installations Adjacent to Track

Where the SMOS structures are adjacent to track, they shall be connected to traction return in the same way as for overhead line structures, except that in addition each structure providing the neutral earthing connection for the 25 kV primary winding of a voltage transformer shall be bonded in the same manner as an EST, refer Clause 11.3.

The return current busbar, normally provided only at feeder stations, shall be bonded to traction return generally in accordance with Clause 11.5 to ensure a traction or fault return path in the event of any single break in the rails or earth wire. The bonds shall be provided in duplicate to each separately fed track. Where necessary for traction loading, additional bonds shall be provided. Each bond connected to a return current busbar shall be attached such that its removal or replacement does not disturb any other connection.

Note: Each track is usually fed at each side of a neutral section or overlap. For the purpose of these Guidelines this is considered as a separately fed track.

11.6.2 SMOS Installations Remote from Track

Where some or all SMOS structures are remote from track they shall be connected together to form a loop and bonded to a return current busbar by connections from two separate SMOS structures. At a feeder station the return current busbar shall be bonded to traction return as specified in clause 11.6.1.

At track sectioning locations the return current busbar shall be bonded to the closest traction structures on each track in multi-track areas and with a second bond to rail, by means of an impedance bond or ACI, as necessary, in single track areas. Each bond connected to a return current busbar shall be attached such that its removal or replacement does not disturb any other connection.

Where the routing of bonds between the return current busbar and the traction return rails is such that a derailment is likely to sever all bonds, measures shall be taken to prevent a dangerous voltage arising from the disconnection of the 25 kV primary neutrals of voltage and other transformers such that where the combined earth resistance of the loop connected SMOS structures alone is insufficiently low to ensure that the steelwork of the installation does not rise above the accessible voltage values stated in Appendix B, supplementary earthing shall be provided. The supplementary earthing shall be strategically located such that it remains intact in the event of a derailment.

11.6.3 25 kV Single Core Cables

The metallic sheath, screen and armouring of 25 kV single core cables shall normally be bonded to traction earth at only one end – that closest to the source of supply. Measures shall be taken to ensure that the metallic sheath, screen and armouring at the remote end cannot be touched simultaneously with other metalwork. The selection of the end at which the connection to traction earth is made shall take account of the desirability of avoiding accessible and touch voltages at high level, of consistency with other cable installations and the need to gain access to the connection for testing purposes.

If as a result of earthing at only one end, an inadmissibly high voltage occurs at the remote end, both ends shall be bonded to traction earth. In this case, measures shall be taken to ensure that an inadmissible temperature rise does not occur in the bonded conductors as a result of current flow.

11.7 AUXILIARY CABLES

Where an auxiliary supply cable terminates on an overhead line structure the metallic sheath, screen and armouring shall be bonded to the overhead line structure.

Where an auxiliary supply cable terminates on other than an overhead line structure the metallic sheath, screen and armouring shall be bonded to other exposed metalwork within simultaneous touching distance.

11.8 BRIDGES AND STRUCTURES (OTHER THAN OVERHEAD LINE AND SIGNAL STRUCTURES)

All the following descriptions and drawings show and describe typical methods for earthing and bonding of Civil Works and Structures. These methods are provided for guidance purposes only and due to the number of different types of structures the actual requirements will vary in detail, e.g. configuration, number, position and cross section of earthing conductors, number and location of terminals etc.

All earthing measures are subject to design approval by the Technical Manager Electrification before designs are issued for construction. The construction requirements for current carrying capacity, welding of conductors and termination requirements etc. shall be in accordance with section 13.3

In general, unless required as a Structure Earth and/or Common Bonded Earthing Network, Guard Conductors may be employed in lieu of bonding of reinforcement.

For wholly or partially conductive structures which will become live by a broken overhead contact line or a broken or dewired pantograph, as defined by the OHCLZPZ, protective measures against inadmissible touch voltages shall be taken.

The objectives for earthing and bonding are:

- the safety of persons: the safety of persons is characterised by the value of the touch voltage
- the protection of installations: damage to installations may arise from overheating of conductors, by arcing and by electrical corrosion.

Those involved with the design and construction of all civil works and structures must consider that:

- any exposed metalwork or wholly or partially conductive material within the OHCLZPZ requires design measures to ensure that there is no hazard to personnel or unacceptable damage to structures from contact with energised equipment.
- special exemptions may be made, on a site specific basis, by the Technical Manager Electrification, where it can be determined that through a structured and documented analysis of the probability of occurrence and any resulting hazards, although within the confines of the zone, such contact cannot reasonably occur or any hazardous outcomes to people and structures has an acceptably low probability of occurring.
- the conductive interconnected reinforcement of steel-reinforced concrete structures and the metallic components of other structures are designated as structure earth. These include, for example, traction masts, passenger stations, power supply rooms, equipment rooms, depots and workshop areas, bridges, viaducts, concrete slab permanent way and tunnels. The structure earth of tunnels is also known as tunnel earth.
- structures connected to the traction earth or within the OHCLZPZ form part of the earthing and bonding system of an electrified railway system.
- reinforcing steelwork which, by design, is bonded to the traction earth must be designed and installed to ensure that normal operational and fault currents are carried without unacceptable temperature rise and loss of continuity at joints. This will also ensure that hazardous potential gradients do not occur on the surface of the structure.
- reinforced concrete structures which, by design, bonding of reinforcing steelwork is not possible may require additional design measures to prevent high potential gradients on the concrete surface which represent a readily accessible personnel hazard and can result in leakage currents of sufficient magnitude to result in damage with consequent structural degradation.

Although local potential gradients can be reduced, loss of contact to earth may cause a rise in accessible potential in adjacent structures which may then require supplementary earthing. Therefore, earthing conductors embedded in concrete that are bonded to traction earth become part of the earthing system of the railway and need careful consideration in design and installation. Requirements must be defined at an early stage before execution of construction.

Connections to traction earth are to be adapted to the type of signalling system used, i.e. SRTC or non track circuited sections.

11.8.1 Protection of Reinforced Concrete Structures using Guard Conductors

In some cases, by design, reinforcement is not used as structure earth:

- on existing structures where the reinforcing is not accessible and/or cannot be guaranteed to be electrically continuous and capable of carrying normal sustained or fault current without risk of overheating, and/ or
- where environmental conditions require cathodic protection to alleviate corrosion of the reinforcement
- where the required welding of reinforcement to ensure electrical continuity would result in an unacceptable reduction in the mechanical strength of the reinforcement

In these cases additional Guard Conductors external to the concrete structure may be required to ensure that:

- prompt tripping of circuit breakers occurs through provision of a low impedance fault return path
- local voltage rise within the immediate area of the fault is limited to permitted values of step and/or touch potential
- fault current through the concrete structure is reduced to minimise the possibility of an unacceptable risk of structural damage
- leakage currents to third parties are reduced to levels acceptable to such parties

Where existing reinforced concrete structures are within OHCLZPZ, protective measures may not require implementation subject to a structured and documented process of analysis taking into account, but not limited to, the following:

- public access is not possible
- potential rise cannot be transferred to public areas or third party services
- probability of first contact with an energised line to the reinforced concrete structure is acceptably low
- any persons having access are protected from high voltage gradients by existing barriers or earthed metalwork
- any resulting damage to the reinforced concrete structure will not cause structural damage or unacceptable equipment degradation or failure or damage to third party service providers
- EPR does not rise to unacceptable values due to low values of conductance to earth – see also Clause 11.11.2.

Priority is to be given to personnel protection against high voltage gradients within structures which can appear as a hazardous step or touch potential either within the immediate area of the fault or be transferred to an adjacent area, particularly where such an area may have public access. Measures taken to achieve this will also assist in the protection of the underlying structure from structural damage.

Protection consists basically of bare Guard Conductors parallel to the track which serve both to provide a preferential low impedance path to fault currents and to minimise potential gradients within the vicinity of the guard conductor within the underlying reinforced concrete structure.

The Guard Conductors shall have sufficient cross section to carry fault currents as required by Clause 13.2 and shall be installed to restrict, as far as practicable, current flow into the underlying reinforced concrete structure. Existing structures such as handrails or cable trays may be suitable, or by appropriate continuity bonding, be made suitable for this purpose. For example, surplus contact wire or other suitable conductors can be used.

If parts of overbridges lie within the OHCLZPZ, protective measures are required for personnel safety, these include:

- bare galvanised steel strips or copper contact wire on both bridge walls, if lying within the overhead line contact zone
- galvanised steel strip or angle section above the overhead line equipment on the bridge portals, if within the pantograph zone
- fence or horizontal protection screen against overhead line equipment

Each of these guard conductors shall be bonded to traction earth at two points, no further apart than 2m, to ensure reliability of connection and prevent traction return current from flowing through the conductors. In the case of a need for guard conductors to exceed 100m in length the guard conductor shall be earthed every 100-120m. This will inevitably result in some circulating current however this is preferable to a hazardous potential between the guard conductor and any other accessible metalwork bonded to traction earth including an adjacent guard conductor which would occur if the guard conductor were sectionalized. This is of particular consequence where an easily accessible metallic object such as a handrail cable tray or pipe is used to act as a guard conductor.

Note: In some cases, where a continuous metallic walkway or pipeline, of length greater than 100m and sectioning is impractical, is installed along the railway track, some return current under normal traction operation can be experienced. The design shall assess the risk of a current passing through the installation versus the induced potential associated with such installation.

Refer to Clause 11.8.2.1 for a typical example of bonding requirements for overbridges.
Guard conductors are required on structures forming parts of stations or other places with public access, refer Clauses 11.11.3 and 11.11.1 and may be required on the walls of tunnels, refer Clause 11.9 and noise walls within the OHCLZPZ.

11.8.2 Overline Bridges and Structures

11.8.2.1 Reinforced and Pre-Stressed Concrete Bridges

The use of Guard Conductors to protect an existing reinforced concrete overbridges within the OHCLZPZ is illustrated in the following example:

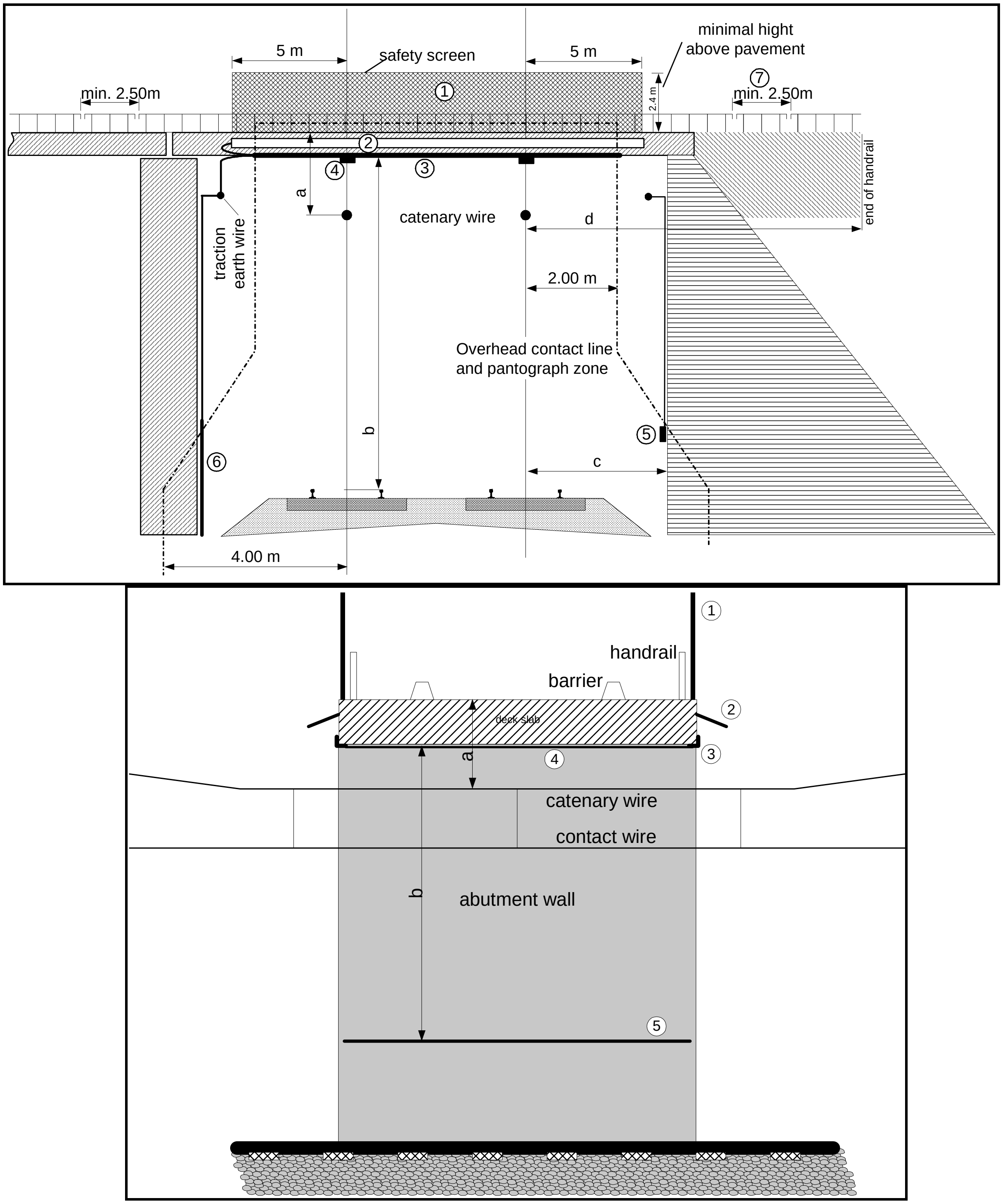


Figure 11.8.2.11 - Example of Earthing and Bonding of Overbridges

The dimensions of Figure 8.9.1-1 shall be determined from the following dimensions:

a) clearance between standing surface on the bridge and any live part (usually catenary wire at top of mast)

b) clearance between top of rails and lower edge of bridge

c) distance between centre of tracks and side walls or columns

d) distance between centre of tracks and end of handrails

Depending of the dimension a, b, c and d protective measures are necessary as indicated in Figure 11.8.2.1-2.

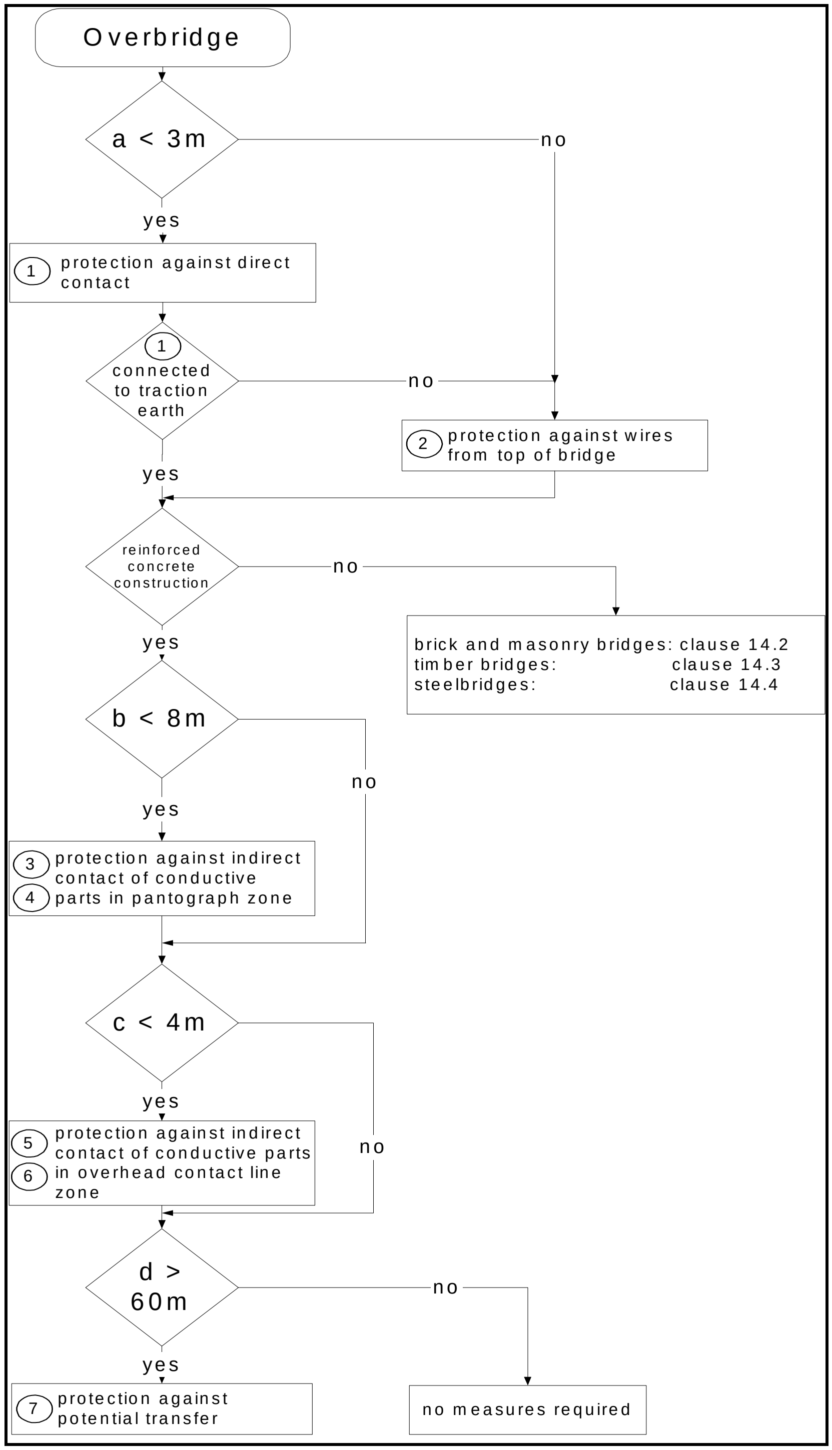


Figure 11.8.2.1-2 - Decision Diagram

The following constructional elements have to be foreseen:

1. safety screen on the bridge

   On overbridges and access ways and/or roads beside the railway line with public access, a safety screen shall be installed if any person can encroach within 3m from the closest live part of the OHE system. The screen shall be solid, of an approved material or be fitted with a wire mesh with mesh size not exceeding 30x30mm and a minimum height of 2.4m. In the case of additional handrails and/or barriers which may transfer the rail potential, the safety screen is not required to be connected to traction earth if item (2) is installed. Where the screen material is non-metallic e.g. armoured glass a conductive strip of the specified cross-section to carry traction current, shall run over the top of the screen and be bonded to traction earth.

2. horizontal safety screen connected to traction earth (optional)

   If the protection mesh (1) on top of the bridge is not necessary or it cannot be connected to traction earth, a horizontal extension forming a safety screen, protruding from the bridge shall protect against wires thrown from the top of the bridge. This flange must be connected to traction earth.

3. short circuit rail (cut-off rail, L-shape) connected to traction earth

   At each end of the bridge at the lower edge a short circuit rail (cut-off rail), made from galvanised L-profiles shall be installed and connected to traction earth to be the first touchable part in case of a derailed pantograph.

4. longitudinal earthing rails above catenary connected to traction earth

   Longitudinal earthing rails above the catenary shall be installed and connected to traction earth to be the first earthed point of contact in the case of a derailed pantograph.

5. Longitudinal earthing rails at side walls connected to traction earth

   Longitudinal earthing rails on the side walls have to be installed and connected to traction earth so as to be the first touchable part in the case of a broken contact wire.

6. vertical earthing rail at columns connected to traction earth

   Vertical earthing rails at columns shall be installed and connected to traction earth to be the first earthed point of contact in the case of a broken contact wire

7. interruption of handrails

   Interruption of handrails shall be carried out in order not to transfer the rail potential. The handrail shall be cut twice within a distance of 2.5m.

For all earthing rails the total cross-section shall be at least 100 mm^2 steel. In the case of new built concrete bridges the measures (3), (4), (5) and (6) shall be embedded in concrete. Existing reinforcement may be sufficient for this purpose.

Road overpasses of fabricated steel shall be connected to traction system earth twice if they are within the pantograph zone.

11.8.2.2 Brick and Masonry Bridges

If traction overhead wiring equipment is attached to a brick or masonry bridge, all small-part steelwork supporting the 25kV ac traction overhead wiring equipment and any substantial metal parts, such as handrails and safety screens, on the bridge shall be bonded together and to traction earth. Small-part steelwork supporting, where applicable, supplementary 25kV feeder insulators shall be bonded together and to a traction return rail or traction earth wire.

It is not necessary to bond across bolted, riveted or welded joints, subject to the qualifications of Clause 11.1.2.1 for pre-painted assemblies, provided that all metalwork is electrically continuous and capable of carrying full traction fault current.

If traction overhead wiring equipment is not attached to the bridge, any substantial metal parts within the OHCLZPZ, such as handrails and safety screens, on the bridge shall be bonded together and to a traction return rail or traction earth wire, unless the provisions of Clause 11.8.2.6 allow otherwise.

For the requirements for earthing of handrails and safety screens refer to Clause 11.8.2.1.

11.8.2.3 Timber Bridges

If traction overhead wiring equipment is attached to a timber bridge, all small-part steelwork supporting the 25kV ac traction overhead wiring equipment (including, where applicable, supplementary 25kV feeders) and any substantial metal parts, such as handrails and safety screens, on the bridge shall be bonded together and to the traction return rail or traction earth wire.

It is not necessary to bond against bolted, riveted or welded joints, subject to the qualifications of Clause 11.1.2.1 for pre-painted assemblies, provided that all metalwork is electrically continuous and capable of carrying full traction fault current.

If traction overhead wiring equipment is not attached to the bridge, any substantial metal parts, such as handrails and safety screens, on the bridge shall be bonded together and to the traction return rail or traction earth wire unless the provisions of Clause 11.8.2.6 allow otherwise. Metal bracing, strapping, handrails and safety screens which may accidentally (by breakage of conductors, conductor sag, flashover, vandalism, etc) come into contact with live traction overhead wiring equipment shall be bonded together and to the traction return rail or traction earth wire to eliminate risk of fire from leakage or traction fault current passing through timber.

Metal conduits for electrical wiring shall not be used on timber overbridges. All such conduits shall be rigid PVC. Light fittings with metal standards or parts which may accidentally (by breakage of conductors, conductor sag flashover, vandalism, etc) come into contact with the traction overhead wiring equipment shall not be permitted on timber overbridges where exposed metalwork of the bridge is not earthed.

11.8.2.4 Steel Bridges

If traction overhead wiring equipment is attached to a steel bridge, all small-part steelwork supporting the traction overhead wiring equipment and all metal parts of the steel bridge shall be bonded together and to the traction return rail or traction earth wire.

It is not necessary to bond against bolted, riveted or welded joints, subject to the qualifications of Clause 11.1.2.1 for pre-painted assemblies, provided that all metalwork is electrically continuous and capable of carrying full traction fault current.

If traction overhead wiring equipment is not attached to the bridge, all metal parts of the steel bridge shall be bonded together and to the traction return rail or traction earth wire unless the provisions of Clause 11.8.2.6 allow otherwise.

For the requirements for earthing of handrails and safety screens refer to Clause 11.8.2.1.

11.8.2.5 Air Space Development

Air space developments, and any case where bridges with metal parts are supported by buildings on one or both sides of the track, may present special problems, particularly if the buildings are not railway property.

In general the export of traction EPR is to be avoided and Double Insulation and gapping of traction bonded steelwork may be used to create a traction earthed island for the railway infrastructure

Note: although traction EPR from insulator flashover can be contained within the railway alignment, Guard Conductors can only limit EPR in the event of a falling traction conductor onto a third party wall and, depending upon the assessment of the structural consequences of such an occurrence, a full screen, mounted on stand-off insulators may be required to protect the wall over the total area over which such a conductor might reasonably be expected to strike the wall

Each case is to be investigated and determined in consultation with the party or Authority responsible for the building or installation therein. All cases should be referred to the Technical Manager Electrification.

11.8.2.6 Bridges or Trackside Structures with Metal Parts

If 25kV ac traction overhead wiring equipment or, where applicable, 25kV supplementary feeders are attached to an overbridge with metal parts, the appropriate provisions of the above Clauses shall be observed.

If no traction overhead wiring equipment is attached and/or there is no reasonable probability of sustained contact between live traction overhead wiring equipment and accessible parts attached to, or forming part of, the overbridge or trackside structure, traction bonding of such metal parts may be omitted provided that all the following conditions are fulfilled:

- there are no connections from metal parts to earth via pipes, conduits or cables which are connected to the electricity service provider's MEN system or any other separate earthing system;
- the clearances and insulation resistance from the metal parts to the traction return rail or traction earth wire are adequate under all ambient conditions to ensure that flashover or puncture of structural material will not occur in the event of contact between metal parts and live traction overhead wiring equipment, including, where applicable any 25kV supplementary feeders (by breakage of conductors, conductor sag, flashover, vandalism, etc); and
- there is no danger to persons on the overbridge or trackside structure due to touch and step potentials in the event of contact between metal parts and live traction OCLS system (by breakage of conductors, conductor sag, flashover, vandalism, etc).

All cases where bonding is omitted shall be subject to the specific approval of the Technical Manager Electrification.

11.8.2.7 Public Safety Screens on Bridges

Public safety screens installed on overbridges shall normally be bonded to the traction return rail or traction earth wire.

11.8.2.8 Area and Street Lighting Installations on Bridges

If any metal supports or components of the lighting installation on a bridge may come into contact with live traction overhead wiring equipment (by breakage of conductors, flashover or vandalism), the metal parts of the installation shall be bonded together and to traction earth wire by means of a standard traction bond (refer to Clause 13.4.1).

Light fittings fed from the isolated railway supply and installed within the OHCLZPZ shall be earthed in accordance with Clause 11.20.6.

Electrical supplies from the electricity service provider shall be fed from an isolating transformer and configured, as appropriately, in accordance with Clause 11.20.2 to prevent any contact with the electricity service provider's MEN and any simultaneous contact between metalwork connected to the electricity service provider's MEN and traction earth.

If the metal supports or components of the lighting installation are located so that contact with live traction overhead wiring equipment is impossible under any reasonable circumstance, but the requisite clearance of 2.5m from the metalwork which is connected to the traction earthing system cannot be achieved, the appropriate provisions of Clause 11.16 shall be observed.

If contact with the live traction overhead wiring equipment is impossible under any reasonable circumstance, and a clearance of 2.5m from the metalwork which is connected to the traction earthing system is maintained, no special bonding or insulation is necessary.

11.8.3 Underline Bridges

The reinforcement of viaducts forms the structure earth of viaduct sections, refer to Figure 11.8.3.

For bridges smaller than 100 m length the connections to the columns may be omitted. That is, vertical earthing and bonding measures may be omitted and only longitudinal earthing and bonding measures are required.

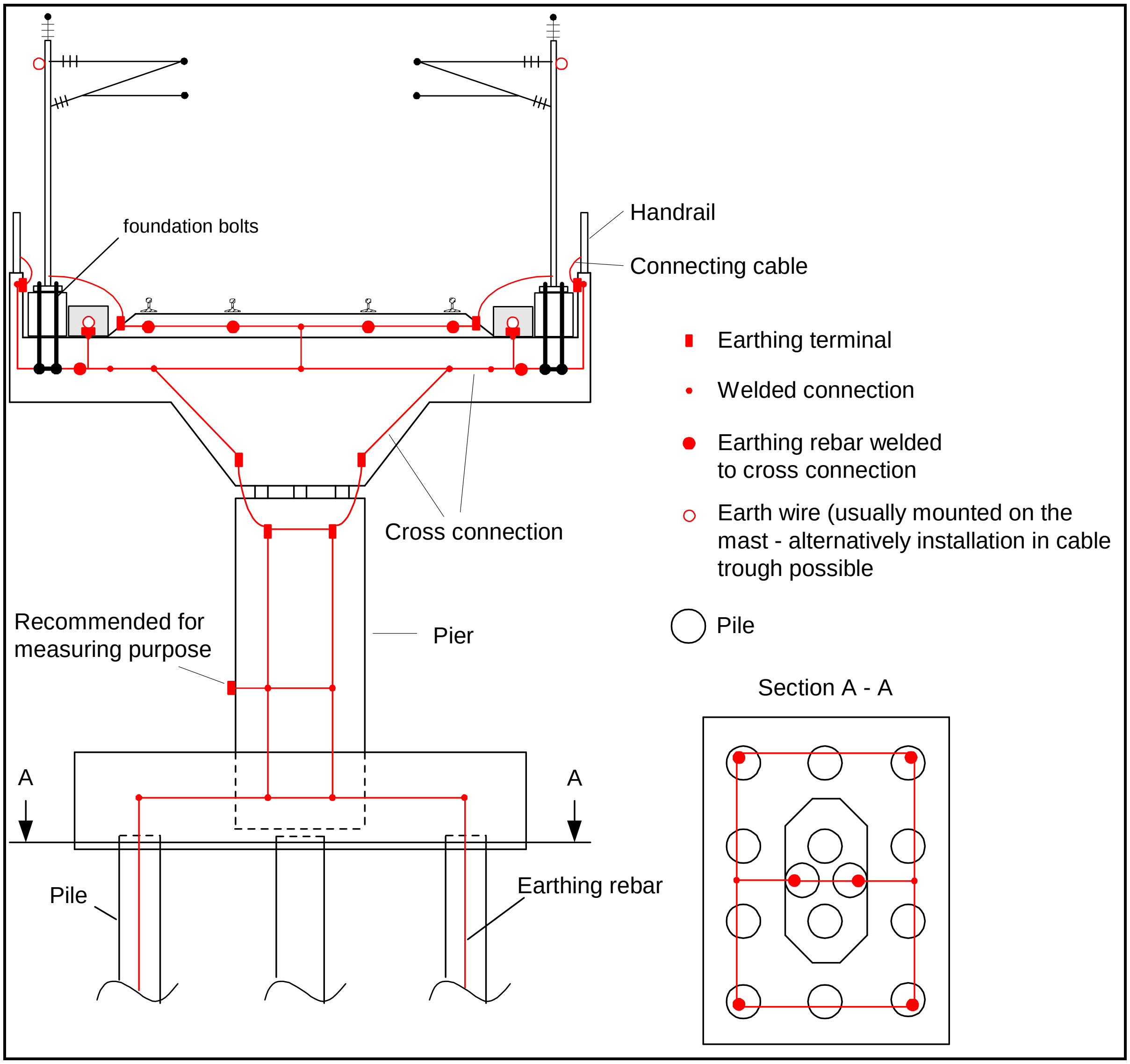


Figure 11.8.3 – Example of Earthing Connections for Steel Reinforced Concrete Viaduct

Therefore the reinforcements of single segments have to be electrically interconnected and the dedicated earthing rebars shall be welded together via cross connections.
Figure shows the schematic earthing connections of viaducts. The foundations of the piers form the earth electrodes for viaducts. The reinforcement of the foundation shall be electrically connected to the reinforcement of the piers and the viaduct segments.

1. dedicated rebars in the piles shall be used for earthing purposes, i.e. in the top of the piles a certain number of rebars must be accessible. In case of steel piles the pile itself works as an earth electrode
2. in the pile cap the rebars of the piles or the steel piles shall be welded together with a steel strip or similar
3. provide terminal rebars in the pile cap for welding to the rebars in the pier

4. provide earthing terminals in the pier 1m above ground level (if not in water) and close to the top for jumper cable via the bearing or connection from the deck.
5. dedicated longitudinal rebars shall be provided in the beams with earthing terminals at regular distances on each side of the beam and at the beginning and end for connecting the jumper cable via the bearing or to the substructure.
6. if possible the foundation bolts for the masts shall be welded to the longitudinal rebars of the beam
7. provide dedicated longitudinally continuous rebars in the reinforced concrete track bed of at least 100 mm² cross-section below each rail.

Note: This requirement may be waived where ballasted track is employed which provides a high resistance surface which minimizes step potential and there is no reasonable chance of structural damage to the underlying deck beams from a falling 25kV conductor – see also Clause 11.10.1.

8. cross-connect the longitudinal rebars at regular distances of 100m (maximum) by welded strip steel or alike
9. provide earthing terminals at each side at the cross-connector locations

The required number of rebars used for earthing and earthing wires need to be designed with respect to detailed planning and with respect to lightning protection. The required cross section of the longitudinal earthing rebars or reinforced bars shall be designed with respect to the maximum earth fault currents. Based on a maximum short-circuit current of 6kA a cross-section of 100 mm² steel is sufficient for this purpose.

Earthing terminals for earthing measurements and bonds are recommended at approximately one metre above ground level of the piers of viaducts and within the cable ducts at the top of the viaduct.

It is not necessary to bond across bolted, riveted or welded joints, or to bond concrete reinforcement or the anchorages of such reinforcement unless the latter are accessible or connected to accessible metalwork, in which case the procedure shall be determined by the Technical Manager Electrification.

Lighting installations attached to an underbridge shall be treated the same as for such installations on overbridges (refer to Clause 11.8.2.8). For pipes on underbridges, refer to Clause 11.12.

11.9 TUNNELS

11.9.1 General

The following paragraphs apply to tunnel constructions without provisions against the penetration of groundwater. In case of such provisions, e.g. waterproof membranes etc. the described measures will not be completely sufficient and the Technical Manager Electrification shall be involved in a very early stage of planning.

The required cross section of the longitudinal earthing rebars or reinforced bars per track are to be designed with respect to the maximum earth fault currents. Based on a maximum short-circuit current of 6 kA, a cross-section of 100 mm² steel is sufficient for this purpose. This applies also to the welded cross-connectors. Note that, although ballasted track in tunnels does not require any special protection for the track as such, the provisions of this Clause apply to the protection of concrete walls of such tunnels.

11.9.2 Cut & Cover and Bored Tunnels

This section deals with cut & cover and bored tunnels which have longitudinal reinforcement in their tunnel shell.

The reinforcement of the tunnel forms the earthing system of tunnel sections.

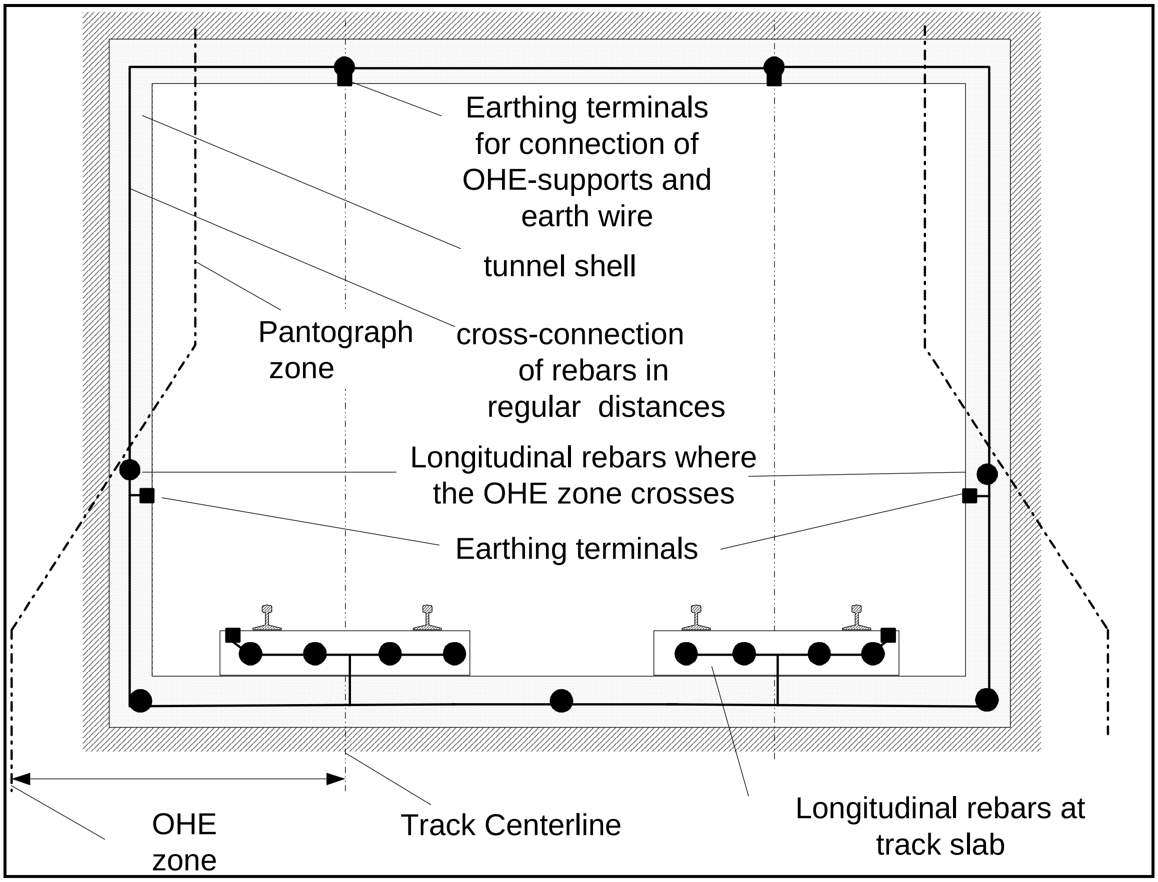


Figure 11.9.2 - Example of Arrangement of Earth Wires in Tunnels

The typical earthing measures in bored tunnel and cut & cover tunnels are similar. They depend on the type of construction of the tunnel and will be defined during detailed design phase.

Typically, the following course of activities shall be considered during construction of tunnel shell:

1. provide dedicated longitudinally continuous rebars of at least 100mm² cross-section below each rail, at side walls inside the OHCLZPZ and at the ceiling of each track in the pantograph zone
2. joints of conductive rebars need to be welded together with a total seam length not less than 100mm (see Clause 13.3).
3. cross-connect the longitudinal rebars in regular distances of 100m (maximum) by welded strip steel or the like.
4. provide earthing terminals at each side at the cross-connector locations
5. at constructional expansion joints, the longitudinal conducting bars need to be cross-connected by welding to a circular wire surrounding the tunnel tube. On both sides of the tunnel and at the top of

each track earthing terminals shall be welded to the cross-connection. These earthing terminals are the connecting points where the segments will be connected to the earth wire

6. embedded attachments (e.g. C-rails, anchor bolts) shall be welded to the tunnel reinforcement.

7. all other reinforcement steel (excluding tensioning strands of pre-stressed reinforcement) has to be connected by wire wrapping to each other and to the conducting bars.

8. the rebars used for earthing purposes shall be covered by at least 50mm of concrete, but not more than 100mm.

9. in case of elements in the OHCLZPZ such as walkways, handrails and cable troughs additional earthing rebars and/or cross-connectors are necessary.

Note: The conducting bars can either be part of the structural reinforcement (excluding tensioning strands of pre-stressed reinforcement) where the total cross sectional area of the reinforcement is not less than the requirements for conducting bars, or additional bars provided in accordance with the requirements.

10. In case of non-accessible reinforcement in the tunnel shell, external longitudinal Guard Conductors shall be installed as described in Clause 11.8 under *Protection of Reinforced Concrete Structures using Guard Conductors*.

11.9.3 Bored Tunnels

This section deals with bored tunnels which consist of single segments and have no specific longitudinal reinforcement in their tunnel shell.

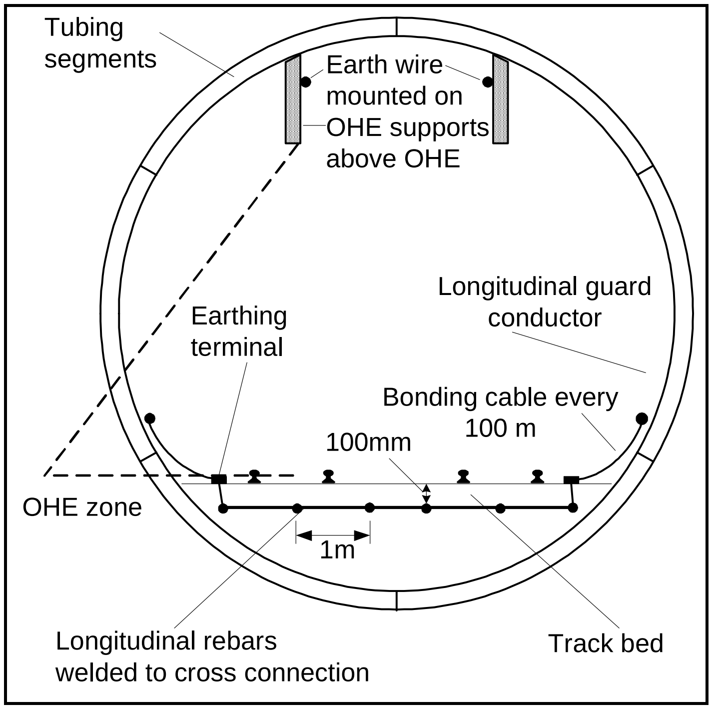


Figure 11.9-3 - Example of Earthing and Bonding Measures for Bored Tunnels

For bored tunnels with segmental lining extensive measures are necessary to install through-connected reinforcement in the tunnel shell. In order to achieve protection of the reinforced tunnel lining elements, at the tunnel wall a longitudinal guard conductor shall be installed and connected to traction earth. In absence of mast foundations, the reinforcement of the track substructure (track bed) has to be used as earth electrodes and therefore through-connected as shown in Figure 11.9.3.

Note: bored tunnels using a waterproof membrane have in effect zero conductance to earth and thus accessible EPR is limited to the differential voltage between the different items of accessible metalwork, including the rails, within the tunnel. Under these circumstances, bonding of reinforcement does not function as a tunnel earth as such but provides an equi-potential plane to limit step and touch potentials within the tunnel.

Typically the following course of activities shall be considered:

1. provide dedicated longitudinally continuous rebars of at least 100mm² cross-section in the track slab. The distance between the individual earthing rebars shall be 1m (maximum).
2. joints of conductive rebars shall be welded together by a total seam length not less than 100mm (see Clause 13.3).
3. cross-connect the longitudinal rebars in regular distances of 100m (maximum) by welded strip steel or similar.

4. provide earthing terminals at each side at the cross-connector locations
5. at expansion joints, the longitudinal conducting bars shall be cross-connected by welding to a circular wire surrounding the tunnel tube. On both sides of the tunnel and at the top of each track earthing terminals shall be welded to the cross-connection. These earthing terminals are the connecting points where the segments will be connected to the earth wire
6. at the side where the OHCLZPZ crosses the tunnel wall a longitudinal guard conductor shall be installed and connected to the track bed terminals at regular distances of 100m (maximum). This conductor shall be made of galvanized steel or copper strip with a cross-section of at least 100mm² for steel or 50mm² copper.
7. at the ceiling of the tunnel the earth wire shall be connected to the OHE-supports directly above the contact wire and catenary wire.
8. every 200m a cross-bonding of earth wires, longitudinal guard conductor and embedded earthing rebars shall be carried out.
9. the rebars used for earthing purposes shall be covered by at least 50mm of concrete, but not more than 100mm.
10. in case of elements in the OHCLZPZ such as walkways, handrails and cable troughs additional earthing rebars and/or cross-connectors are necessary.

11.10 REINFORCEMENT IN PAVED (SLAB) CONCRETE TRACK

Unballasted track consists of the track slab and the track bed (depending upon the track construction). It forms the track substructure for at grade section as well as for civil structures. For reinforced structures, the rebars shall be protected against the effects of a broken contact wire by longitudinal continuous welding and cross-connecting. The topmost layer of the reinforcement may serve this purpose if the cross-section of the longitudinal bars is sufficient. Otherwise additional earth bars shall be used and bonded to the reinforcement by wire-wrapping. Earthing terminals are to be provided at locations where gaps in the continuously welded longitudinal bars are necessary and in regular distances of 50m or to suit mast spacing. Locations of additional earthing terminals depend on detailed construction and the necessity of connections.

The total cross section of longitudinal earthing rebars (reinforcement bars) shall be at least 100mm² steel per track.
Figure 11.10 shows an example of the implementation of this requirement using reinforcement as an earthing grid.

As an alternative to bonding of reinforcement, a Guard Conductor outside each rail of each track may be used.

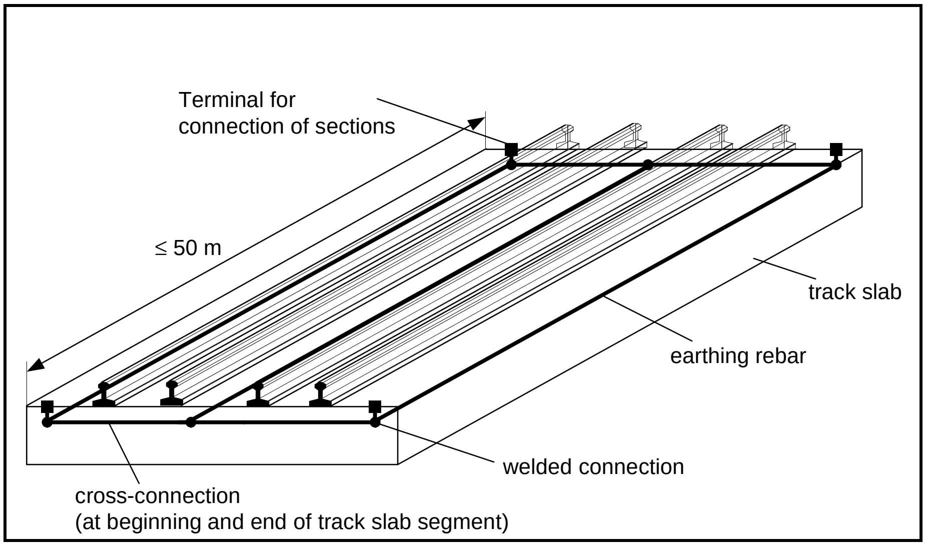


Figure 11.10 - Example of Earthing Connections in Unballasted Paved (Slab) Track

The detailed arrangement of earthing connections in the track bed depends on the type of reinforcement construction. In general, the topmost layer of the reinforcement shall be used for earthing measures.

Cable conduits with a minimum diameter of 50mm shall be provided at each earth wire support fitting or mast location. The conduit shall terminate adjacent to the earth wire support fittings or masts.

For structures besides the track such as emergency walkways or cable troughs, cable conduits with a minimum diameter of 50mm through the structures are to be provided. They shall be located in the immediate vicinity of the earth wire support fittings.

Rail fastenings on concrete slabs shall be carried out with insulating pads between rails and sleepers. The minimum permissible (ballast) resistance between rails shall be assigned by the Senior Project Manager Signals and Communications.

The detailed arrangement of earthing connections in the track bed depends on the type of reinforcement construction. In general, the topmost layer of the reinforcement shall be used for earthing measures.

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For structures besides the track such as emergency walkways or cable troughs, cable conduits with a minimum diameter of 50mm through the structures are to be provided. They shall be located in the immediate vicinity of the earth wire support fittings.

Rail fastenings on concrete slabs shall be carried out with insulating pads between rails and sleepers. The minimum permissible (ballast) resistance between rails shall be assigned by the Senior Project Manager Signals and Communications.

11.10.1 Ballasted Track

For ballasted track sections with reinforced substructure the same provisions apply as described for un-ballasted track, refer to Clause 11.10.

In ballasted track sections without reinforced substructure no additional longitudinal earthing bars need to be embedded. Attention is required to conductive services and utilities crossing or running parallel to the track.

In line sections with ballasted track, the mast foundations form by far the most significant earth electrodes of the traction earth. Therefore, it is essential to connect all masts electrically to their foundations.

11.10.2 Railings and Noise walls

Metallic railings, noise walls, crash barriers within the OHCLZPZ are to be connected to traction earth. If railings continue outside of these zones, they shall be interrupted over a minimum length of 2.5m in order that the earthed and the non-earthed section cannot be bridged by hand and a potential transfer is excluded.

11.10.3 Cuttings

Typical earthing measures for the structure of a cutting segment are shown in Figure 8.11-2:

- longitudinal rebars below the two tracks
- welded cross-connections of the longitudinal rebars
- earthing plates at each side
- embedded attachments (i.e. C-rails, anchor bolts) shall be welded to the connecting rebars of the reinforcement.

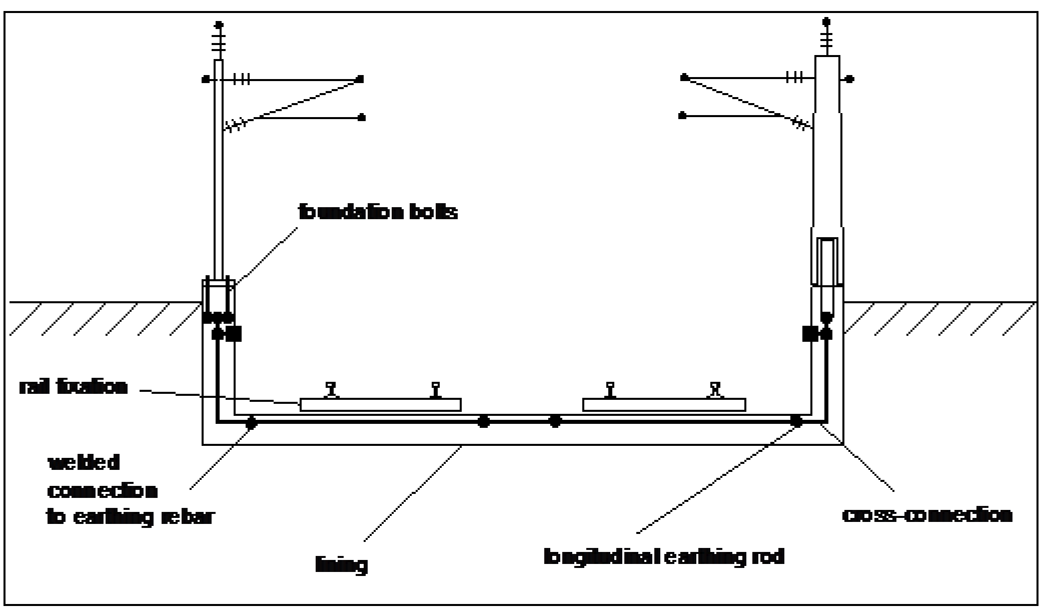


Figure 11.10.3 - Illustrates both typical steel and concrete masts.
Figure 11.10.3 - Example of Typical Earthing Measures for Cuttings with Masts

11.10.4 Wall and Deck Slab Elements

Within the top surface of the wall or deck slab, dedicated reinforcement bars are to be welded together and to earthing terminals, which as a minimum requirement, must be provided at each corner as shown in Figure 8.11-2. The remaining rebars are to be bonded thereto by wire-wrapping. At the earth terminals the bonding of single elements with jumper cables and to traction earth must be carried out (preferably at a mast).

The Technical Manager Electrification shall determine whether the requirements for earthing may be relaxed, e.g. less earthing terminals.

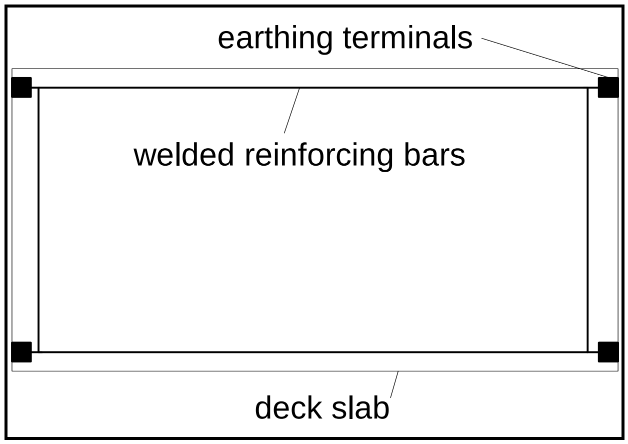


Figure 11.10.4 - Example of Earthing Measures for Precast Wall Panels or Deck Slabs

11.10.5 Deck Beams

This applies to deck slabs within the OHCLZPZ consisting of single pre-cast beams, which have reinforcing bars protruding at each end and where the ends will be embedded in the concrete top slab.

For earthing measures the reinforcement bars of all pre-cast slabs shall be bonded at their ends by a cross-bonding bar, which is embedded in the top slab as shown in Figure 8.11-3. At the ends of the cross-bonding bars earthing terminals are to be provided in order to bond to the earthing terminals of abutment walls and finally to traction earth.

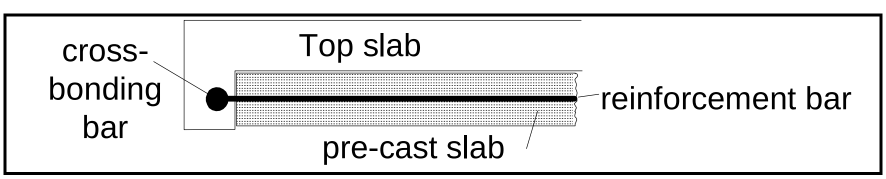


Figure 11.10.5 - Example of Earthing Measures for Precast Slab

11.11 METAL SERVICES ON, IN OR FORMING PART OF AN OVERLINE OR UNDERLINE BRIDGE

Where a bridge forms part of an installation which includes railway buildings or structures at the side of or over or under the tracks, e.g. a passenger station, exposed metal services shall be bonded to the metalwork of the installation and to the traction return rail or earth wire. The interconnections and bonding shall, so far as practicable, be arranged such that traction current flow through the services, bridge or installation metalwork is avoided.

Where the bridge is a separate entity:

1. the exposed metalwork of any electrical installation on the bridge shall be bonded to other metalwork within simultaneous touching distance;
2. other electrical services shall be insulated from the metalwork of the bridge and from any reinforced concrete or
3. where such electrical equipment is within touch distance of traction earthed metalwork, fed from an isolated supply – refer also to Clause 11.8.2.8
4. non-electrical metal services shall be bonded to the bridge metalwork except where bonding is impracticable or the owner of the service will not agree to bonding, in which circumstances the service shall be insulated.

Where the owner of a non electrical service wishes to insert insulation in the service at each end of the bridge, the section between the insulation shall be bonded to the bridge metalwork. The insulation shall be adequate for the voltage developed across it and of sufficient length, or other means shall be provided, to prevent adjacent metal parts of the service being touched simultaneously.

Where the service owner will not agree to bonding and flashover cannot be ruled out, a metal plate or similar conductive assembly shall be interposed between the service and live equipment to prevent fault current entering the service. The plate or assembly shall have a width at least that of the pantograph zone and extend by at least 500mm beyond the service. The metal plate or assembly shall be bonded to a traction return rail or earth wire and be adequately rated for fault current.

11.11.1 Passenger Stations and Depot Buildings

New station and depot buildings (referred collectively to, in this paragraph, as ‘station’) are to be provided with a structure earth, forming the station earth and forming part of the Common Bonded Earthing Network, as described in Clause 4.1.6. All station metalwork is to be bonded to the station earth which is in turn bonded to the traction earth at the PET such that excessive potential differences from accessible metalwork to traction structures and standing trains cannot occur under any circumstances. The traction earth connection shall be at a single point such that the building earth system cannot form a through path for traction return current.

Note: not withstanding the requirement for a single earth point at the PET, there may be instances where this is overridden by the requirement for a short low impedance earth connection to minimise potential differences, such as, for example, the bonding of overhead metalwork within the OHCLZPZ, which is better served by bonding to the closest traction return connection such as the earth wire. In cases where such an apparent conflict of requirements occurs, the matter shall be referred to the Technical Manager Electrification.

The traction earth shall be connected to the Common Bonded Earthing Network to avoid dangerous electrical potential differences. Station and depot building design requires close co-operation between all disciplines as there are frequently numerous systems within the such areas, each with individual earthing requirements, which must be integrated to ensure there is no accessible potential differences which represent a hazard to the general public or result in equipment failure or reduction in performance and/or reliability. Refer to Clause 11.20.2 for design principles for station and railway building power supplies.

Note: unless otherwise required, the requirements of Clause 11.16 for the isolation of incoming services does not generally require any special treatment for services, such as public telecommunications, which present a remote earth, as the EPR is generally within acceptable limits and the insulation of the connected devices (e.g. public telephones) provides sufficient protection. Where station or other buildings are very close to feeder stations which may suffer high values of EPR under earth fault conditions, incoming services must be isolated in the same manner as required for feeder stations – refer Clause 11.5.1

Moreover, all structural parts of station or other buildings, which are located within the OHCLZPZ are to be earthed similar to other structures. Continuous electrically conducting bars of adequate cross-sectional area, see Clause 13.2, are to be embedded parallel to the track or Guard Conductors installed as described below at all reinforced concrete structures.
The conducting bars have to be positioned as follows:

- above each overhead line
- in walls within the OHCLZPZ , or
- in floors adjacent to the tracks within the OHCZLPZ
- refer also to clause 11.11.3 for station platforms

Earth wires in station and depot areas shall be continuous and there shall be two alternative return paths for traction current, for example single earth wire and rails. All traction structures and metalwork liable to carry traction fault current as a result of, but not limited to, flashovers or broken Overhead Contact System conductors shall be bonded directly to the earth wire or closest accessible connection such as a traction mast.

The PET at stations and depot buildings in non track circuited areas may be connected to the mast or both rails, whichever is the most convenient.

A lockable enclosure (earth collector cubicle) shall be provided to enclose a disconnect link such that the Common Bonded Earthing Network earth value may be measured in isolation from traction earth. The enclosure shall:

- be constructed of insulating material
- be located such that separation is maintained from all exposed metalwork
- contain a link for disconnection of traction earth

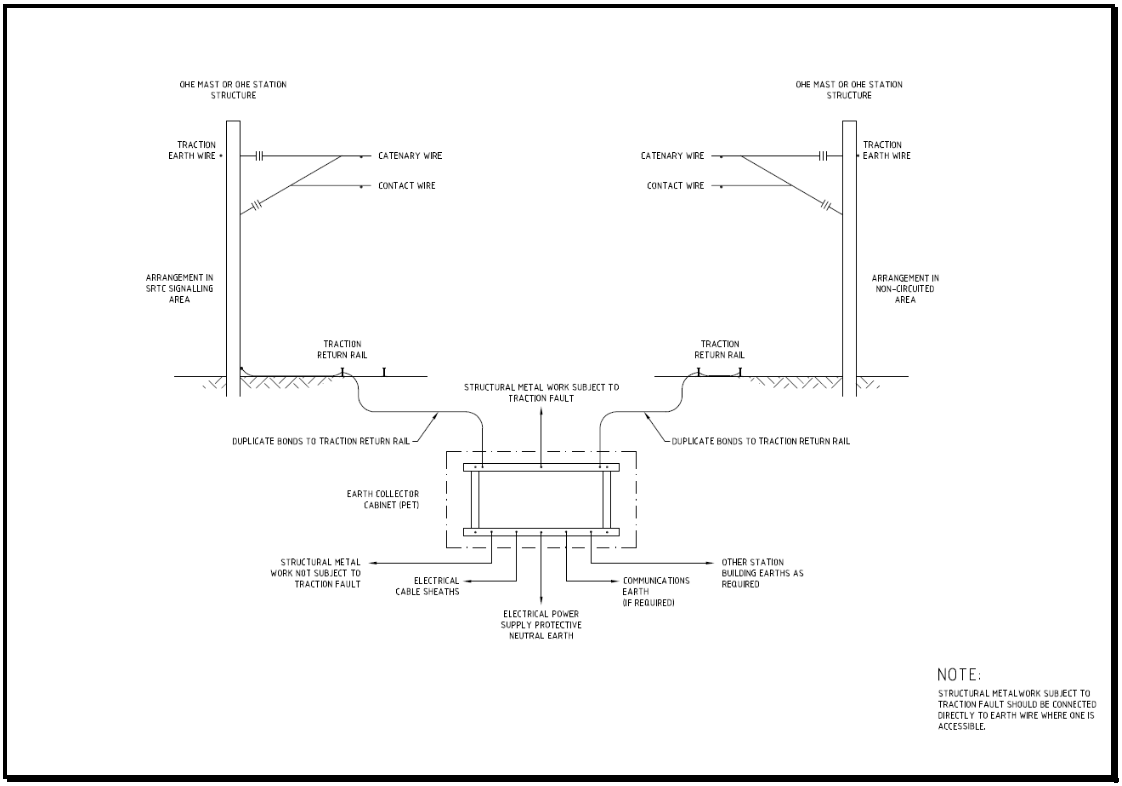


Figure 11.11.1 Typical Station or Depot Building Bonding

11.11.1.1 LV power rooms within stations or depot buildings

New Low voltage power supply rooms shall have a foundation earth electrode as specified in Clause 11.11.2

In rooms containing power transformers or switchgear the floor reinforcement shall be used for internal potential grading.

This is to be connected to the foundation earth electrode by welding.

Earthing terminals as described in section 13.4 shall be provided near to each corner of the rooms. Additional earthing terminals are to be provided at the outside of the building near to each corner of the building and according to the specification of the power supply contractor.

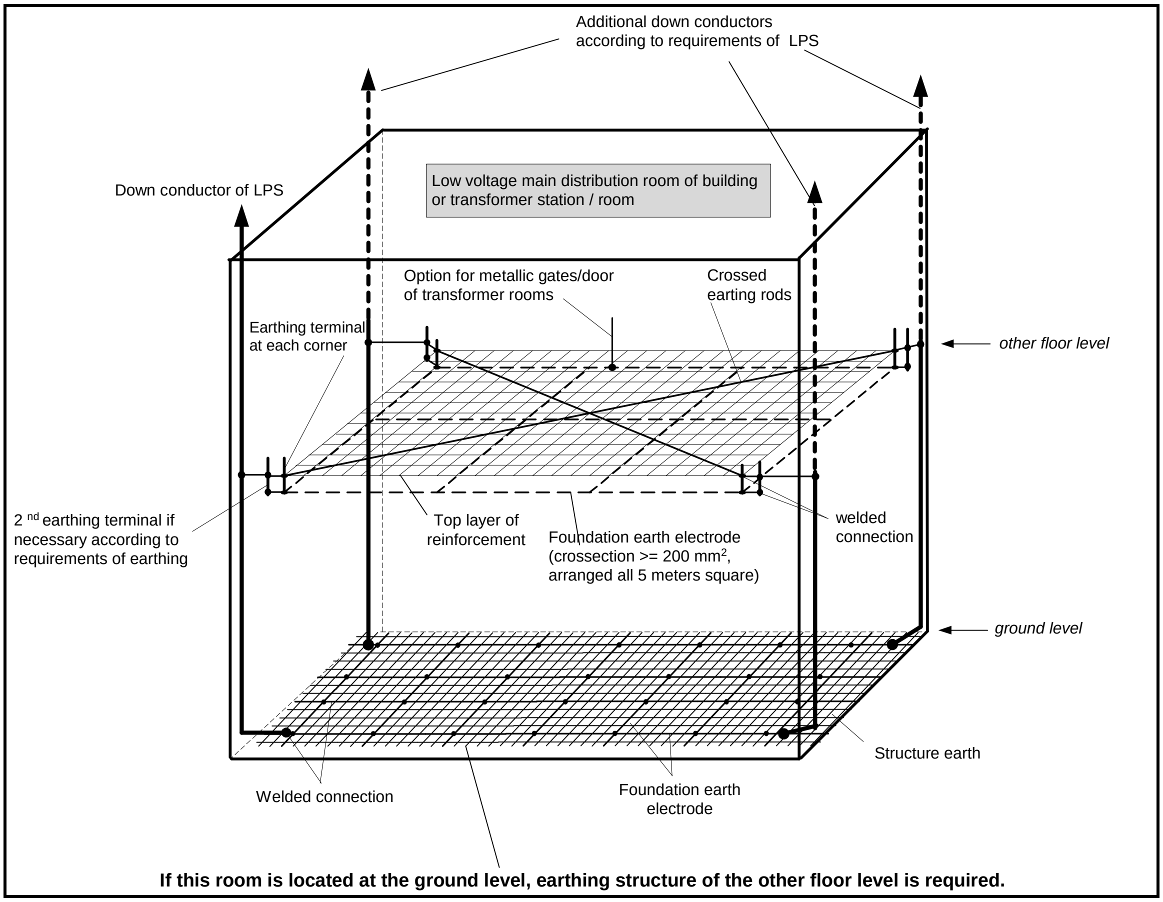


Figure 11.11.1.1 – Earthing & Bonding of Low Voltage Rooms

11.11.1.2 Equipment Rooms

The equipment rooms of each subsystem shall include at least one earthing terminal about 300 mm above surface of floor level.

The locations of earthing terminals are to be defined in the relevant detailed design drawings.

The equipment rooms of the subsystems signalling and telecommunication must have an arrangement of earthing terminals according to their specific requirements.

The requirement for separated earth terminals from the foundation earth electrode will be clarified during the detail design stage.

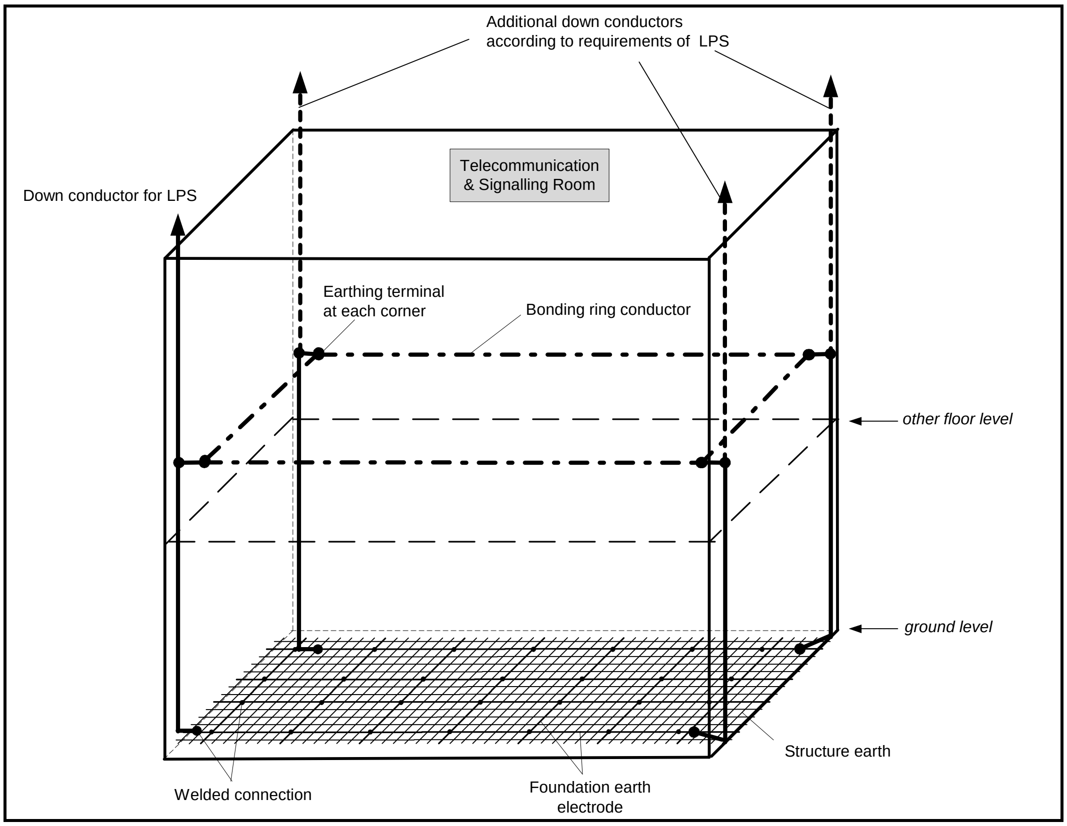


Figure11.11.1.2– Earthing & Bonding of Equipment Rooms

11.11.2 Structure Earth

All new buildings (made from reinforced concrete) shall have a structure earth including a foundation earth electrode. The structure earth functions both to dissipate traction currents and provide an equipotential zone within the building for the protection of the occupants and equipment within the building. Electrical rooms within the building may also require such an earth for compliance with IEC-60364. For this purpose, the foundation slab and the walls of the building require a reinforcing mesh equivalent to a minimum area of 10m by 10m. This mesh may be part of the reinforcement, or made from additional mild steel rods and wire-tied to the reinforcement at least every 400mm.

The foundation earth electrode shall be located 50-100 mm from the lower concrete surface (see Clause 13.1). For the welding of structure earth, see Clause 13.3.

Existing buildings, in which the reinforcing is not accessible, shall be protected by a perimeter earth encircling the building and bonded to traction earth, in accordance with Clause 11.16.5.

11.11.3 Platforms

Steel reinforced concrete platforms shall be fitted with a steel edge cap, acting as guard conductor, and, where required, wire mesh close to the surface. This mesh shall be connected to traction system earth at least every 50m. A 50mm angle iron edge cap is preferred however, for existing platforms where this may be difficult and expensive to achieve; a flat steel strip, of the required minimum cross-sectional area as specified in Clause 11.8, on the vertical edge of the platform, installed in such a manner as to provide a target for a falling contact wire, is acceptable.

Concrete platforms with a surface dressing which does not provide a high level of insulation and without accessible reinforcement shall be protected against excessive step potentials by means of a copper mesh laid 50-100mm under the surface dressing and connected to traction earth (or the edge cap) every 50-60m. The purpose of this mesh is to provide potential equalisation and is supplementary to guard conductors to carry and divert fault currents required by Clause 11.11.1.

Note: ceramic tiles or an impervious surface treatment such as bitumen are considered to provide a suitably high level of resistance, provided that the resistivity exceeds 3 000 Ohm-m, however, in all cases, a steel edge cap or functionally equivalent guard conductor shall be provided.

All measures for trackside structures and installations described in the other paragraphs of this Clause 11.8 are valid for platforms.

11.12 SELF SUPPORTING METAL PIPES AND PIPES CARRIED ON BRIDGES

Self supporting metal pipes crossing over the track do not require to be bonded if flashover can be ruled out and it is not possible to touch simultaneously the pipe and traction earth.

In any instance where a cathodic protection system is applied to the pipe or conduit, special precautions may be taken by the owner of the cathodic protection system which in turn may influence any bonding procedure (refer to Clause 11.14.2).

Note: Bonding and sectionalisation may require to be modified to also meet requirements of the service provider having jurisdiction over the pipeline.

Metal pipes, conduits and the like (other than electrical conduits) carried on bridges shall preferably be bonded to the metal parts of the bridge, subject to the consent of the owner where they are not railway owned. Where necessary, the requirements of Clause 11.16 for isolation from the electricity service provider's MEN system or any other separate earthing system shall be observed.

If consent to bond to the bridge is not given, the owner may insulate the pipe or conduit from the bridge metalwork or may insert insulation in the pipe or conduit either side of the bridge. In the latter case, the section between the insulating joints shall preferably be bonded to the bridge metalwork but, if the owner objects to this, it shall be insulated from the bridge.

In all cases, the insulation or insulated joints shall be applied or installed as specified in Clause 11.16.3.

When the pipe or conduit is insulated from the bridge and the disposition is within the OHCLZPZ, a metal screen shall be provided between the live traction overhead wiring equipment and the pipe or conduit. This screen shall be bonded to the bridge metalwork or, if the bridge is not constructed of metal, to traction earth. Where alternate and approved non metallic screens are installed, a conductive rail, of cross-sectional area as specified in these Guidelines as adequate to carry full traction fault current, shall be installed along the top of the screen.

When the pipe or conduit is insulated from the metal parts of the bridge and insulation is not inserted in it on each side of the bridge, even when there is no possibility of contact with live traction overhead wiring equipment, there may still be a hazard because of potential difference between the pipe or conduit and the bridge metalwork. If calculations and/or measurements show that this hazard exists, action may be taken as follows:

- the abovementioned screen shall be arranged to prevent persons from making simultaneous contact with the pipe or conduit and the bridge metalwork or the screen; or
- the pipe or conduit shall be wrapped with insulating material in accordance with the requirement of Clause 11.16.2.

These precautions may be omitted if the location of the pipe or conduit precludes simultaneous contact between the pipe or conduit and bridge metalwork while the traction overhead wiring equipment is energised.

11.12.1 Electrical Metal Conduits and Metal-Sheathed Cables

Electrical metal conduits and metal-sheathed cables shall be insulated from any metalwork of the bridge which is connected to the traction earth unless the conduit or sheath has sufficient cross-sectional area and/or is not connected to the MEN then it may be bonded to the traction earth.

When the conduit or sheath is insulated from the metalwork, the requirements of Clause 11.8.2.1 for screening and insulating shall apply.

11.13 METAL SERVICES EMBEDDED IN CONCRETE BRIDGES

Any metal pipes, conduits or cables shall be drawn into a tube of insulating material (such as PVC cast into the concrete) or the pipes or conduits shall themselves be of insulating material cast directly into the concrete. Cables with insulating sheaths drawn into metal tubes are not acceptable.

In the case of services embedded in the reinforced or pre-stressed concrete of bridges existing at the time of electrification which do not have such insulating tubes and which do not have a clearance of 300mm or more from the catenary wire, or any other live traction supply conductor, to the underside of the bridge, consideration shall be given to the diversion of the services either into the road surfacing or to the parapets. If the parapets are of reinforced concrete, any service mounted on them shall be insulated from them and the requirements of Clause 11.12.1 shall in any case be met. If diversion in either of these ways is not acceptable, a separate trackside structure shall be constructed for the support of the services.

The requirements of this Clause do not apply to situations where a trench is formed in the upper surface of a reinformed or pre-stressed concrete bridge to accommodate services, provided that the services laid in the trench are clear of reinforcing or metalwork which is connected to traction earth. In such cases, no further action is necessary.

11.14 METAL SERVICES ON RAILWAY PROPERTY RUNNING PARALLEL TO THE LINE

Where metal services run parallel to the line and are within the OHCLZPZ, the services shall be bonded to the traction return rail or earth wire.

Where metal services run parallel to the line and come close to the track but are outside the OHCLZPZ, measures shall be taken to ensure that exposed metalwork of the service cannot be touched simultaneously with traction earth.

11.14.1 Pipes and Conduits

This Clause applies to metallic pipes, conduits, cable sheaths, etc which run parallel to the track for 200m or more and which may therefore have a longitudinal potential gradient induced in them by traction current flowing in traction overhead wiring equipment or in the traction return rail. The maximum level of induced voltage permitted shall be in accordance with AS/NZS 4853 or as agreed with Asset Owners.

This Clause does not apply to 25kV A.C. incoming or track feeder cables or communications and signalling cables which are covered by separate Clauses, nor to pipes, conduits or cables which are not parallel to the track for 200m. In such cases, no action is necessary apart from that required by other Clauses of these Guidelines relevant to the particular situation.

The action required by this Clause is additional to any action which may be necessary under any other relevant Clause of these Guidelines.

Where the pipeline is within the railway reserve and has a metallic outer surface liable to become bare, this metallic outer surface shall be earthed to earth electrodes of a separate earthing system at intervals of approximately 200m, or at such greater intervals as the Technical Manager Electrification may determine. The maximum level of induced voltage permitted shall be in accordance with AS/NZS 4853.

The resistance of each earth connection shall not exceed 200 Ohms. The traction earthing system shall not be used as the earth electrode. In cases where a cathodic protection system exists incorporating sacrificial anodes, and in accordance with the requirements of AS/NZS 4853, the sacrificial anodes may be adequate to meet this earthing requirement.

Where the pipeline is within the railway reserve and has a metallic outer surface liable to become bare, but is unlikely to be influenced by traction earth, the Technical Manager Electrification, in accordance with the requirements of AS/NZS 4853, shall determine whether the above earthing requirements may be relaxed.

Where the pipeline is within the railway reserve and has a metallic outer surface liable to become bare and is likely to be influenced by traction earth, the Technical Manager Electrification shall arrange for calculations, in accordance with the requirements of AS/NZS 4853, and/or tests to be carried out to determine the maximum voltage induced in such pipe, conduit, cable sheath, etc. If it is found that an existing installation requires remedial action, earth connections shall be earthed to earth electrodes of a separate earthing system (as defined by Clause 11.16.1) at intervals of approximately 200m, or at such greater intervals as the Technical Manager Electrification may determine.

Where the pipeline is not bare, but is covered permanently by insulating material, the Technical Manager Electrification shall determine what action is necessary at the ends of the installation to guard against a hazardous situation.

Any new pipelines or conduits which are to be installed in the ground shall be treated in accordance with installations above ground. The maximum level of induced voltage permitted shall be in accordance with AS/NZS 4853.

Pipelines crossing under the track shall be installed as close as possible at right angles to the track and, if metallic, shall be insulated from the surrounding subsoil within the limits of the railway alignment by means of an insulating coating.

In the case of a metallic pipe, conduit, cable, etc which is existing at the time of electrification, the Technical Manager Electrification shall arrange for calculations, in accordance with the requirements of AS/NZS 4853, and/or tests to be carried out to determine the maximum voltage induced in it. If it is found that an existing installation requires remedial action, earth connections shall be applied to the installation at intervals of approximately 200m, or at such greater intervals as the Engineering Interface Manager may determine.

11.14.2 Cathodic Protection Systems

If a pipe or conduit within the railway reserve is provided with a cathodic protection system, a metallic connection from such pipe or conduit to traction earth may adversely affect the cathodic protection system. The maximum level of induced voltage permitted shall be in accordance with AS/NZS 4853.

The owner of services which are so protected may therefore elect to insulate the pipe or conduit or to insert insulated joints in locations, such as on bridges, where contact with traction earth would otherwise occur. Where the pipe or conduit has already been insulated for cathodic protection purposes, this shall be considered acceptable, provided the pipe or conduit is insulated to 600 Volts or more.

The owner of a pipe or conduit which is provided with a cathodic protection system which would be affected by electrification should be consulted and given the opportunity to decide the preferred action from these alternative procedures.

Where the pipe or conduit outside the railway reserve is provided with a cathodic protection system, and is likely to be influenced by traction earth, the Technical Manager Electrification shall arrange for calculations, in accordance with the requirements of AS/NZS 4853, and/or tests to be carried out to determine the maximum voltage induced in such pipe or conduit. If it is found that an existing installation requires remedial action, the owner of the pipe or conduit should be consulted and given the opportunity to decide the preferred action from these alternative procedures.

Where cathodic protection is required for reinforced concrete structures the reinforcing metalwork cannot be bonded to traction earth and the risk shall be assessed, in accordance with the requirements of AS/NZS 4853, to determine if personnel protective measures are required to guard against excessive potential gradients and provide alternate paths for leakage currents which could otherwise result in concrete damage or interference with the operation of the cathodic protection system under fault or normal operation.

11.14.3 Cables

Exposed metal outer surfaces of cables installed above ground shall be dealt with in the same way as pipes and conduits. Buried cables shall not be provided with intermediate earths.

11.14.4 Cables Abandoned

The maximum length of wayside cables is determined by the length at which, in the worst case, the induced voltage reaches the maximum permitted values of 430V under normal operation or 60V under normal operation, whichever is the shorter length. This length is 2 000m.

Any abandoned cable which does not exceed 2 000m requires no special treatment to avoid a hazardous touch potential from the exposed ends of such a cable. Any abandoned cable exceeding a length of 2 000m shall:

- be cut into lengths not exceeding 2 000m; or
- be insulated at the ends using a waterproof and abrasion resistant treatment such as a heat shrink cable cap to prevent physical contact with the conductor and (where applicable) armouring and any other metallic component of the cable

11.15 INTERFACES WITH D.C. ELECTRIFIED LINES AND OTHER ADMINISTRATIONS' RAILWAYS

In general the E&B requirements for A.C. railways differ from those of D.C. railways (including tramways) in that the rails of D.C. systems are not deliberately earthed to minimize ground currents and subsequent corrosion effects.

Note: although not deliberately earthed, the rails are connected, at the D.C. feeder station, to an earth electrode system by means of a Rail Earth Contactor if the rail EPR exceeds specified limits and this condition must be included when estimating and/or measuring D.C. potentials on 25kV A.C. rail circuits.

These Guidelines do not cover any future work which requires bonding or any rail continuity between A.C. and D.C. systems which results in a proportion of the return currents flowing in the other system. This requires close attention by the Senior Project Manager Signals and Communications into the effects of return current into track circuits of both systems, requiring these to be immune to the effects of both A.C. and D.C. currents over an area generally of at least 5km either side of any point of common connection. Attention is also required by Technical Manager Electrification to ensure that bond cable sizes are adequate for fault currents from either traction supply system.

In general the bonding requirements for adjacent non-electrified lines of other rail administrations shall be in accordance with Clauses 11.1.6 and 11.1.7 for DTEI owned lines.

11.15.1 Glenelg Tramway

The existing crossing of the Glenelg Tramway is at right angles and well outside of the OHCLZPZ thus there are no problems with induced voltages into the tramway and no requirements for bonding between the two systems.

D.C. track circuits cannot be used in close proximity to D.C. tramway substations and where there is any of possible leakage currents affecting such track circuits, the Senior Project Manager Signals and Communications will arrange for calculations and, if necessary, tests to be carried out to determine if replacement of D.C. track circuits is required.

11.15.2 ARTC

ARTC lines within the OHCLZPZ or running parallel for an extended distance, as defined by Clause 11.1.7, require to be bonded to traction earth. Design measures, as specified in Clause 11.1.6 to track circuit equipment and, as determined by the Senior Project Manager Signals and Communications, to ensure A.C. immunity will be required for these sections of the ARTC tracks. In addition, for ARTC tracks with extended parallelism to electrified tracks, the lengths of ARTC signalling circuits and immunity of equipment connected thereto will be required to meet the same standards required for DTEI electrified tracks.

11.16 NON TRACTION ELECTRICITY SUPPLIES AND OTHER SERVICES TO RAILWAY PREMISES INCLUDING HIGH VOLTAGE SUBSTATIONS

It is a requirement that there shall be no interconnection between traction earth and the electricity service provider's MEN system or any other separate earthing system.

This necessitates careful consideration of every instance where earth electrodes or exposed metalwork which is directly associated with traction earth comes into contact with or is in proximity to earth electrodes or exposed metalwork of the electricity service provider's MEN system or any other separate earthing system to ensure that effective isolation of traction earth from the electricity service provider's MEN system or any other separate earthing system is maintained.

It is also necessary to ensure that no hazardous situation is created because of the proximity of the traction earthing system or any other separate earthing system. This is to avoid situations where persons can touch bare exposed metalwork of the two systems simultaneously.

While the action to be taken to achieve these objectives in some particular situations is set out in specific Clauses of these Guidelines, the following general practice is to be observed.

11.16.1 Separation of Earth Electrodes

To ensure touch separation, a minimum separation of 2.5m (5m preferred) shall be maintained between all metalwork bonded to the traction earthing system and that of the electricity service provider's MEN system or any other separate earthing system (see Clause 11.16.2). For the purpose of this Clause, earth electrodes include any bare buried pipes, conduits, cables or any other buried metal connected thereto.

To minimise resistive coupling, a minimum separation of not less than double the average depth of the two closest earth electrodes shall be maintained between earth rods and/or underground structures and/or foundations bonded to traction earth and those of the electricity service provider's MEN system or any other separate earthing system.
Where it is shown, by testing, that the maximum voltage developed between traction earth and the electricity service provider's MEN system or any other separate earthing system under any traction current or weather conditions exceeds a level which is acceptable (the electricity service provider's MEN system is influenced by traction earth), then the following actions shall be taken:

- relocate the earth electrode of the electricity service provider's MEN system or any other separate earthing system to a position outside the sphere of influence of the traction earthing system; or
- isolate the electricity service provider's MEN system or any other separate earthing system from the traction earthing system in accordance with the requirements of these Guidelines by means of an isolating transformer and creating an alternate earth system bonded to the traction earth.

Note: Any metallic object supplied by a station power supply which is within the OHCLZPZ at a station or within touch distance of structural steelwork which is deliberately bonded or fortuitously connected to traction earth must have the supply neutral bonded to traction earth and thus cannot be bonded to the electricity service provider's MEN as the traction EPR design maximum of 60V is in excess of the maximum allowable voltage of 50V permitted by EN 50122-1 Clause 6.2.4.2.2. for a TN system. Thus except, in unusual circumstances, station and depot power supplies shall always require an isolating transformer. The isolation function may be performed by an HV distribution transformer however the sheaths of the incoming HV cable shall be gapped – see Clause 11.20.2.3 for more details.

11.16.2 Separation of Exposed Metalwork

A minimum separation of 2.5m shall be maintained between readily accessible bare exposed metalwork which is connected to the traction earthing system and readily accessible bare exposed metalwork which is connected to the electricity service provider's MEN system or any other separate earthing system.

Where this separation cannot be achieved, suitable insulation shall be applied to the bare exposed metalwork of one or both installations to prevent persons inadvertently touching both earthing systems simultaneously. The insulation level of such insulation shall be a minimum of 1000 Volts A.C.; alternatively, a suitable physical barrier shall be provided to eliminate the risk of simultaneous contact.

Where the provision of insulation or barriers is not practical, all accessible bare exposed metalwork within the 2.5m separation limit shall be bonded together, and the electricity service provider's MEN system or any other separate earthing system shall be isolated in accordance with the procedures detailed in the appropriate Clauses of this Section of these Guidelines. Particular care must be taken when bonding exposed metalwork to traction earth to ensure that all metalwork is electrically continuous. Where exposed metalwork is not electrically continuous, a separate bond shall be used between individual parts of exposed metalwork or each item shall be directly bonded to traction earth.

Any exposed metallic or conductive part for electrification works within the OHCLZPZ, as defined by Clause 4.1.27.6 shall be connected to the traction system earth and the earthing system of that installation shall be capable of carrying full traction fault currents or be protected by a suitable physical barrier to eliminate the risk of simultaneous contact.

11.16.3 Elimination of Direct Connections

Where direct metallic contact between traction earth and the electricity service provider's MEN system or any other separate earthing system exists (i.e. by pipes, conduits or fences which are in contact with both earthing systems), lengths of insulated pipe, conduit or insulated flanges shall be inserted in all connections to provide effective isolation of traction earth from the electricity service provider's MEN system or any other separate earthing system.

Insulated sections shall not be less than 2.5m in length and, if an insulated joint is used, an insulating sheath shall be applied over the flange and along the pipe to achieve a separation of 2.5m between bare metal on each side of the flange, as required by Clause 11.16.2. Insulating flanges shall be adequate for the voltage which may be developed across them.

The intent of these Clauses is that it shall not be possible for a person to be able to come into contact with, and form a bridge between, metalwork at different potentials under both normal and traction fault conditions. 2.5m is the minimum distance to avoid touch contact unless insulation or a barrier at the same potential is installed to prevent contact. In the case of insulated sections in pipelines between pipe sections at different potentials, additional length may be required to limit current though fluids carried by pipes. Insulated section lengths shall be calculated where such current may flow to demonstrate that such current flow is within the permitted limits required by the service provider having jurisdiction over the pipe.

11.16.4 Not Used

11.16.5 Perimeter Earth

A perimeter or counterpoise earth is required to provide touch and step potential protection where fault levels are high.

11.17 EXPOSED METALWORK IN BUILDINGS AND OTHER PLANT AND EQUIPMENT CLOSE TO THE TRACK

This Clause does not apply to underbridges or overbridges or other trackside structures over the track, traction overhead wiring structures, substations, switching stations or signal or communications structures and equipment, for which separate Clauses are included in these Guidelines.

The purpose of this Clause is to establish the traction bonding procedures for all installations where exposed metalwork and conductive elements in buildings and installations adjacent to the track is located within the OHCLZPZ or where persons may simultaneously touch exposed metalwork or conductive elements in the building or installation and exposed metalwork which is connected to traction earth (i.e. trains, wagons and traction overhead wiring structures).

Steel reinforcement in a concrete structure which is accessible or connected to accessible metalwork and within the OHCLZPZ shall be bonded to traction earth. If the reinforcement is not accessible and/or for structural reasons the reinforcement bars and/or mesh are not welded together, Guard Conductors shall be installed and bonded to traction earth. For details refer to Clause 11.8 for *Protection of Reinforced Concrete Structures using Guard Conductors*.

Guard Conductors would generally be the preferred solution except where connection to the reinforcement is required to provide the functionality of a structure earth – see Clause 11.11.2.

Note: where bonding of the reinforcement is required to provide structure earth to increase the conductance to earth in order to reduce EPR to specified levels but for structural or other reasons cannot be achieved, additional earth conductors may be required. Such measures may be required at workshops or, for example, at passenger stations situated close to feeder stations. See also Clause 11.11.2.

11.17.1 General Requirements

Any exposed metalwork or conductive elements of a building or installation within the OHCLZPZ shall be connected to the traction system earth or protected by a suitable physical barrier to eliminate the risk of simultaneous contact. These protective provisions avoid excessive touch voltages in case of insulator flashovers, short-circuits and other faults which do not occur directly to the running rails or traction earth wire. It is important that each situation be assessed to ensure that there is no undue risk of simultaneous contact.

Due regard shall be paid in all cases to the possibility of bonds carrying traction return or traction fault current and, where necessary, their sizes shall be increased accordingly. Traction bonds which may carry the full traction fault current shall be a standard traction bond as specified in these Guidelines.

It is not necessary, except where structures have been pre-painted prior to erection, to bond across bolted, riveted or welded joints in trackside structures, nor to bond window frames and similar small items. Bolted pre-painted surfaces within the OHCLZPZ shall employ a minimum of two bolts per joint fitted with stainless steel star washers at each surface to ensure electrical continuity. After installation suitable approved measures shall be used to prevent long term degradation of the paint and/or electrical contact area. Refer also to Clause 11.1.2.1.

Structural metalwork, steel pipes, the metal enclosures of all electrical equipment, machines, gas and water services in metal pipes, other services in metal pipes, conduits or sheaths (except electrical cable sheaths which are connected to the electricity service provider's MEN system or any other separate earthing system) and fences within 2.5m of traction earth shall be bonded together and connected to traction earth.

Note: light fittings and/or other equipment required to be bonded directly to traction earth must not also be connected to the earth bar at the power distribution board – see Clause 11.20.6.

Insulation shall be inserted in any incoming or outgoing services and fences (as detailed in Clause 11.16.3) as near as possible to the boundary of the installation. In applying this rule, a passenger station, for instance, shall be regarded as one entity.

In accordance with Clause 11.16.2, a minimum separation of 2.5m shall be maintained between accessible bare exposed metalwork which is connected to the traction earthing system and accessible bare exposed metalwork which is connected to, or is likely to come into contact with, the electricity service provider's MEN system or any other separate earthing system. It shall be considered possible for persons to touch exposed metalwork simultaneously, unless there is a suitable barrier or a clear separation of 2.5m.

General light and power supplies provided to buildings or installations adjacent to the track shall be treated in accordance with Clause 11.20.1.

11.17.2 Freight and Maintenance Sheds

11.17.2.1 Sheds Served by Wired Connections to Electrified Lines

The traction return rail(s) of the tracks serving such sheds shall be bonded to the traction earth of the main electrified lines. Traction return rail to rail and track to track cross bonds shall be provided, as detailed in Clause 11.1.3.3, for wired sidings and a dedicated earth wire shall be run through sheds and maintenance facilities.

Any exposed metalwork in the building or installation associated with the shed which may accidentally become electrically connected to live traction overhead wiring equipment shall be bonded together and to traction earth, in accordance with the requirements of Clause 11.17.

If the shed has an electrical installation for lighting or power, or is served by metallic pipes or conduits for water or gas, etc, the precautions of Clause 11.16 regarding isolation for the electricity service provider's MEN System or any other separate earthing system shall be observed.

Note: EN 50122-Part 1, Clause 7.2.3. requires a lower permanent voltage of 25V in workshop areas compared to the maximum rail EPR of 60V required elsewhere. While the low speed would generally enable this reduced voltage to be met, a higher than normal conductance to earth may be required where the workshop or depot is close to a feeder station and this would require the reinforcement of floor slabs to be bonded to traction return to provide a structure earth to achieve this. See also Clause 11.11.2. and Appendix D.

11.17.2.2 Sheds Served by Unwired Connections to Electrified Lines

Where a shed is served by unwired connections from an electrified line and is so remote from the electrified line that there is no reasonable possibility of accidental electrical connection between exposed metalwork in the building or installation and the traction overhead wiring equipment, two sets of insulated rail joints shall be provided in the connections to the electrified line to prevent traction earth potential being transferred into the shed, in the manner prescribed in Clause 11.1.3.4.

The requirements of Clause 11.17 regarding exposed metalwork and/or Clause 11.16 regarding isolation from the electricity service provider's MEN System or any other separate earthing system are not relevant in this case.

If there is a possibility of accidental contact between exposed metalwork in the building and live traction overhead wiring equipment, the provisions of Clause 11.17 shall be observed.

11.17.2.3 Electrical Cable Sheaths (Excluding Traction Feeder Cables)

Where an isolating transformer has been installed within the electrified area (refer to Clause 11.20.2.2), the sheath or armouring of any cables from the secondary of the isolating transformer to electrical equipment in the building or installation shall be bonded to all other metalwork mentioned in Clause 11.17.1 and to traction earth. At the transformer end, the sheaths or armouring of these secondary cables shall be connected to the transformer case or tank which shall be connected to traction earth. The sheath of incoming electricity service provider's cables shall be double insulated and armouring insulated from the transformer case or tank and connected only to the inter-winding screen. No connection shall be permitted from traction earth to the sheath or armouring of the incoming electricity service provider's cables which supply the primary of the isolating transformer.

Where the electrical power supply originates from a railway HV distribution transformer (refer to Clause 11.20.2.3), the sheaths or armouring of these secondary cables shall be bonded to all other metalwork referenced in Clause 11.17.1 and to traction earth. The treatment of the incoming cable sheath or armouring at the isolating transformer shall be approved by the Technical Manager Electrification.

11.18 LINESIDE SIGNALLING AND TELECOMMUNICATIONS EQUIPMENT

Where required by the signalling and telecommunications design, bonds shall be connected via a discharge device in order to protect signalling and telecommunications equipment.

11.18.1 Signal Bridges, Cantilever Signal Gantries, Bracket Signals, Straight Post Signals, Ground Signals Etc.

These structures shall be bonded to a traction return rail or earth wire

11.18.2 Fixed Radio Aerial Structures, CCTV Camera Masts (except at Level Crossings) and Monitors

Exposed metalwork which could become live from a broken overhead line conductor or a broken, or dewired pantograph or from flashover or short circuit or is within simultaneous touching distance of other metalwork connected to traction earth, shall be bonded to a traction return rail or earth wire.

Fixed radio aerial structures attached to a tunnel wall or mouth shall be bonded to a traction return rail or earth wire.

11.18.3 Radiating Cables for Fixed Radio

The outer conductor of a radiating cable attached to a tunnel wall or mouth installed within the OHCLZPZ shall be terminated in a suitable interface bond to traction earth, prior to entry to the communications room to ensure that any voltage rise occurring during a traction fault to the cable is within permitted limits. The bond shall be duplicated.

11.18.4 Level Crossings

This section is intended primarily to cover pedestrian crossings within station areas and does not cover comprehensively the earthing and bonding works for associated signalling equipment, such as level crossings, or which may be associated with the control of such installations.

11.18.4.1 General

All exposed metalwork, such as fences and pedestrian mazes, associated with level and pedestrian crossing installations shall be bonded to the traction earth using a standard traction bond (refer to Clause 13.4.1) unless there is a 2.5m separation from such exposed metalwork and the traction earthing system.

All other metal fences and pedestrian mazes associated with level and pedestrian crossing installations which are 2.5m or more from other fences or rail which are bonded to traction and have no deliberate or fortuitous metallic connection to such metalwork, do not require to be bonded unless calculations indicate and/or tests show the presence of touch and step potentials under both normal operating or traction fault conditions in excess of that defined in Appendix B. In such cases, the fence shall be earthed as necessary to reduce the voltage to a safe value.

Insulation shall be inserted in any fences and pedestrian mazes associated with level and pedestrian crossing installations, as detailed in Clause 11.16.3, as near as possible to the boundary of the installation. In applying this rule, a passenger station, for instance, shall be regarded as one entity.

If the exposed metalwork of a fence and pedestrian maze associated with level and pedestrian crossing installations is connected to, or is likely to come into contact with, the electricity service provider's MEN system or any other separate earthing system, a separation of 2.5m from exposed metalwork connected to traction earth shall be maintained (refer to Clause 11.16.2). Generally, it shall be considered likely for exposed metalwork of a fence to come in contact with the electricity service provider's MEN system or any other separate earthing system when such exposed metalwork of a fence is within 300mm of an exposed metalwork connected to the electricity service provider's MEN system or any other separate earthing system.

11.18.4.2 Spark Gap Arrester

In electrified areas with single rail track circuits, spark gap arresters shall be installed on each electrified track at every level crossing. These spark gap arresters shall be installed to afford protection to the signalling equipment in the event of fallen traction overhead wiring equipment contacting the signalling rail.

It shall be connected between the traction return rail and the signalling rail, on each side of the level crossing, and be located between the nearest insulated rail joint required for signalling track circuit purposes and the edge of the level crossing.

11.18.4.3 Barrier Arm Structures

A continuous copper strip conductor of 19 x 2.5mm shall be provided along the length of the boomgate arm and shall be bonded, together with the supporting mast, to the traction return rail in SRTC and non track circuited areas. All metalwork on the boomgate arm, including the boomgate arm lights, shall be bonded to this copper strip conductor.

Insulation shall be inserted in rodding and signal wires which are connected to or pass a level crossing. The total isolated length shall not exceed 200m.

Where it is possible for any part of a lifting barrier, if capsized, to come closer than 150mm to live overhead equipment including bare return conductors, or if the barrier could become live from a broken overhead line conductor or a broken or dewired pantograph the barrier shall be bonded to a traction return rail or earth wire.

Where it is possible for any part of lighting columns or CCTV camera masts associated with level crossings, if collapsed, to come closer than 150mm to live overhead line equipment including bare return conductors, or if they could become live from a broken overhead line conductor or a broken or dewired pantograph, they shall be bonded in accordance with Clause 11.17.

11.18.5 Signalling and Telecommunication Cable Sheaths, Screening Conductors, Lineside Apparatus Cases and Lineside Fixed Radio Equipment Accommodation

11.18.5.1 General

S&C equipment generally requires a low earth with impedance minimum cabling distance for lightning or low noise reasons and is thus generally provided with a dedicated earth system. The earth connection of all S&C equipment within the OHCLZPZ or equipment which could reasonably be expected to come into contact with the OCLS must also be bonded to traction earth. Equipment within the railway alignment but not within the OHCLZPZ, unless it is feasible to prevent simultaneous contact with traction earthed metalwork, shall also be bonded to traction earth. At passenger stations, such preventative measures (to prevent simultaneous contact) are not considered feasible at S&C equipment rooms and the S&C earthing systems are provided by the Common Bonded Earthing Network which is bonded to traction earth at the PET.

These Guidelines specify only the requirements for the bonding of S&C earthing systems to traction earth and exclude the requirements for the provision, installation and maintenance of S&C earthing systems.

11.18.5.2 Lightning and Transient Surge Protection

The protection of an S&C installation from the effects of direct lightning strikes is achieved by means of a lightning protection system. Even though an installation may be protected against a direct lightning strike, severe damage to electrical and particularly electronic equipment can result from a direct strike or induced surge on power, signalling and communications cables and other conductors such as metallic pipes entering the installation. Protection is achieved by fitting transient surge protection to incoming cables and bonding directly to the S&C earthing systems.

The wavefront of lightning impulses is steep and the impedance of the earthing cable at a frequency of 50kHz to 1MHz must be considered. This requires very short cables and the impedance of the traction earthing system at 50Hz is too high for such surges and is unsuitable for lightning and surge protection.

Care needs to be taken to establish a star topology for earthing in S&C equipment rooms to prevent high differential voltages appearing across equipment from a lightning strike or for an unacceptable proportion of traction fault currents to flow in S&C earth conductors of inadequate cross-section for such currents.

11.18.5.3 Earthing and Bonding of Lineside Cabinets

Any Lineside Cabinet, location case or mast to which S&C equipment is mounted, such as a wayside telephone, which is within the OHCLZPZ, shall be bonded to traction earth. Trackside equipment outside the OHCLZPZ but within 2.5m of traction earth bonded metalwork shall also be bonded to traction earth or simultaneous contact prevented by means of an insulating screen. Trackside equipment outside the OHCLZPZ, but in which cables terminate which are connected to the rails, (e.g. track circuit connections), shall be bonded to traction earth.

Signalling equipment connected to the rails, such as points machines through actuating rods, or any other means shall be bonded using a standard traction bond.

11.18.5.4 Cable Screen Earths (where applicable)

Electrostatic screens, such as the moisture barrier on communications cables, shall be earthed at one end only, generally at the communications equipment room or the end closest to the communications equipment room. If earthed at the remote end, the screen shall be insulated at the communications room end.

11.18.5.5 S&C Power Supplies

Power supplies to S&C equipment rooms, if not fed from the isolated railway supply, shall be isolated from the electricity service provider's MEN in accordance with Clause 11.20.1.

To avoid circulating currents and consequential voltage regulation problems, trackside signalling distribution power supplies shall be earth free or earthed at the supply end only.

11.18.5.6 Earthing and Bonding of Radio Towers

Radio towers will normally have an earthing system for lightning protection. Where there is a reasonable possibility of the radio tower falling onto the OCLS, the tower itself shall be bonded to traction earth.

Radio towers connected to equipment within the electrified railway environment will generally be bonded by default to traction earth via the outer connection of the antenna cable (note that this is of insufficient cross section to carry traction fault current). Radio towers outside the railway alignment can thus export traction system EPR beyond the railway alignment and the requirements of Clause 11.16.1 for isolation of traction earth from other earthing systems such as the electricity service provider's MEN and any hazards arising from the consequent touch potential to the radio tower must be considered and appropriate action taken.

11.18.6 Lever Frames, Ground Frames, Point Rodding and Mechanical Signal Wires

Where such items are within simultaneous touching distance of metalwork connected to the traction earth or trains, they shall be bonded to a traction return rail or earth wire.

11.19 POINT HEATERS, RETARDERS AND OTHER METALLIC APPLIANCES CLOSE TO RUNNING RAILS AND CONNECTED BY PIPEWORK OR CABLES

11.19.1 Incoming Pipework

Pipework from a source of gas, air, oil or other liquid, shall be either non conducting, or otherwise have a length of non conducting section of minimum length 2.5m inserted as required by Clause 11.16.

11.19.2 Appliances Connected To Water Supplies

Appliances connected to water supplies shall be bonded to the traction return rail or earth wire and shall be either non conducting, or otherwise have a length of non conducting section of minimum length 2.5m inserted as required by Clause 11.16.

11.19.3 Electric Points Heaters

The main electrical earthing terminal of the installation shall be securely bonded to traction earth.

11.20 AUXILIARY AND POWER SUPPLY TRANSFORMERS

11.20.1 General Light and Power Supplies

General light and power supplies shall be installed generally in accordance with the requirements of AS 3000.

Note: Conflict may exist with AS 3000 with regard to such issues as the requirement for neutral earthing which can be provided by the traction earth or structure earth without dedicated earth rods. Any such apparent conflicts shall be submitted to the Technical Manager Electrification.

11.20.2 Supplies from electricity service provider's mains

Where an electrical power supply for general light and power is taken from the electricity service provider's 240V single-phase or 415V three-phase systems for use in an area where the isolation requirements of Clause 11.16.1 cannot be achieved, an isolating transformer shall be installed in the incoming supply:

11.20.2.1 External to the electrified area

An isolating transformer, in accordance with AS/NZS/IEC 61558.2.4, shall be installed in an enclosure adjacent to the point of attachment or entry. No part of the transformer metalwork, including fences or other metalwork connected to the transformer, shall be within 2.5m of traction earthed metalwork, or shall be installed with barriers to prevent simultaneous contact between them. The enclosure shall have a Degree of Protection of IP54 in accordance with IEC 62528. Where convenient, the main switchboard may be located within this enclosure.

The isolating transformer case, screen and enclosure shall be electrically bonded to the electricity service provider's MEN system at the isolating transformer location. The sheath or armouring and the conductors of the cables supplying the installation from the secondary of the isolating transformer shall be double insulated from the transformer case, the enclosure and the electricity service provider's MEN system. An isolating switch breaking phase, neutral and armouring continuity (if applicable) or double insulated plug coupler with female socket shall be provided to the secondary of the isolating transformer and shall be located within the enclosure. The sheath or armouring of traction earth cables connected to the male pins of the plug coupler shall be connected to the installation earthing system which will then become the protective earth for the installation supplied from the isolating transformer.

The neutral of the isolating transformer secondary shall be isolated from the transformer case and extended into the electrified area where the neutral earth link shall be connected to traction earth.

The feed from the isolating transformer secondary shall be protected by a 2-pole (single phase) or 4-pole (3-phase) 500mA RCD such that, should an earth fault occur on the secondary windings, the electricity service provider's MEN is automatically isolated from traction earth.

Note: It is essential that the double insulation of the cables from the secondary is maintained so that there is no possibility of physical contact between the installation fed from the isolating transformer and its earthing system and the electricity service provider's supply and its associated MEN system.

The isolating transformer shall carry in a prominent position alongside the secondary terminals a permanently affixed warning sign reading:

"**WARNING - ISOLATE POWER AND DISCONNECT PLUG BEFORE WORKING ON SECONDARY TERMINALS**"

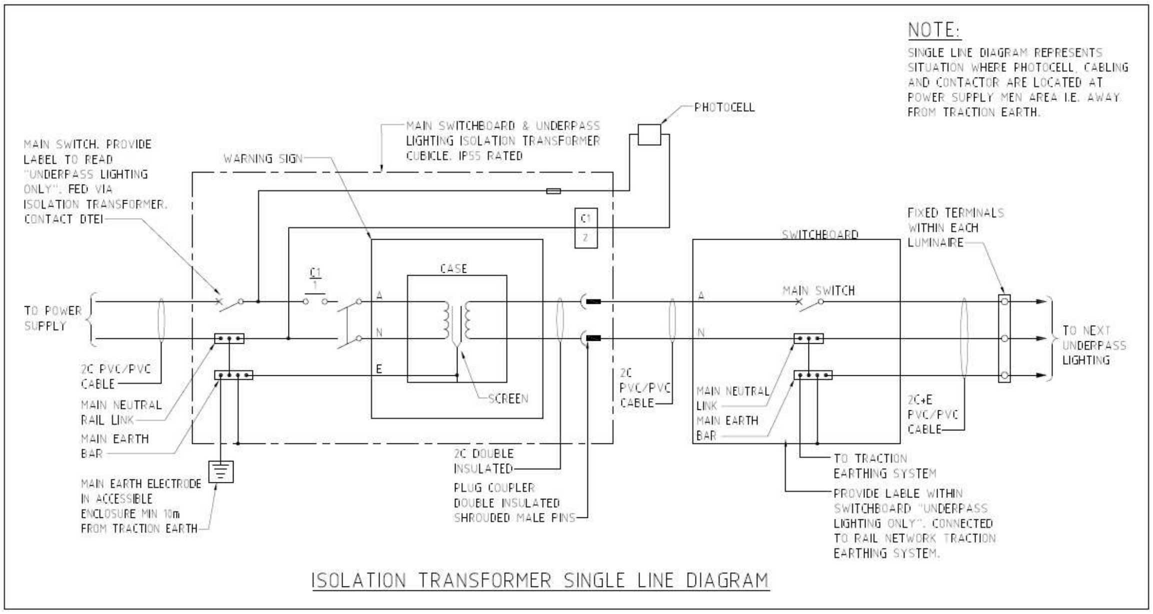


Figure 11.20.2.1 - Typical isolating transformer arrangement for overbridge lighting

11.20.2.2 Within the electrified area

An isolating transformer, in accordance with AS/NZS/IEC 61558.2.4 shall be protected on the primary side by a 2-pole (single phase) or 4-pole (3-phase) 500mA RCD at the supply end, such that, should an earth fault occur between the primary winding and the transformer case or laminations, the electricity service provider's MEN is automatically isolated from traction earth.

The transformer isolating screen shall be electrically bonded to the electricity service provider's MEN system and the isolating transformer case and frame to traction earth. The supply cables to the isolating transformer shall be terminated such that a length of armour and screen is made off as a bonding tail and double insulated and connected to the transformer screens. The TX case shall be treated as a live part with respect to this screen. The sheath or armouring and the conductors of the cables supplying the primary of the isolating transformer shall be double insulated and connected to the screen and at termination points within the transformer enclosure treated as a live conductor.

Note: It is essential that the double insulation of the cables to the primary of the isolating transformer is maintained so that there is no possibility of physical contact between the installation supply and its earthing system and the electricity service provider's supply and its associated MEN system.

The sheath or armouring and the conductors of the cables supplying the installation from the secondary of the isolating transformer shall be connected to the traction earth which will then become the protective earth for the installation supplied from the isolating transformer. Earth fault protection for the incoming cables is provided by the armouring back to the electricity service provider's MEN. Earth fault protection for the transformer primary winding is provided directly through the earth screen back to the electricity service provider's MEN and indirectly through the low impedance of the traction earth back to the electricity service provider's MEN. All normally accessible metalwork is connected to traction earth.

The isolating transformer shall carry in a prominent position alongside the secondary terminals a permanently affixed warning sign reading:

"WARNING - ISOLATE POWER BEFORE OPENING TRANSFORMER CASE"

A switchboard shall be installed adjacent to where the secondary cables of the isolating transformer enter the installation. This switchboard shall be regarded as a main switchboard for the purpose of effecting the earth connection of the installation and shall be termed the "Isolated Railway Supply Main Switchboard". The switchboard shall contain a main switch, main neutral link and main earth bar. The main switch shall be marked "Isolated Railway Supply Main Switch". Where convenient, this switchboard may also serve as the distribution board for the general light and power supplies.

11.20.2.3 Supplies from Railway-Owned Distribution Transformers

Where the electrical power supply for general light and power originates from a Railway-owned distribution transformer for use in an area where the isolation requirements of Clause 11.16.1 cannot be achieved, a separate isolating transformer is not required, but the distribution transformer and the installation supplied from it shall be treated generally in accordance with the provisions of Clause 11.20.2.2 above. Refer to EN 50122-1 Section 6.2.4 Figure 28.

HV cable screens must be gapped and/or made off and insulated at the transformer end such that the remote supply authority HV earth is not accessible to meet the touch distance separation of Clause 11.16.1. The tank of the transformer shall be bonded to the traction earth and the LV star point and thus carries HV earth fault current via the traction earth and the total earth fault path shall be of low enough impedance to permit operation of HV protective circuit breakers under earth fault. This will generally require earth fault protection. Maintenance operations on HV feeder cables may require special measures, including isolation of the traction supply, to ensure that safety earthing requirements are met without transferring traction voltage rise to the HV supply infrastructure provider and shall be referred to the Technical Manager Electrification for resolution.

11.20.3 Neutral Earthing of Isolating Transformers

The neutral shall be connected to traction earth at the Primary Earth Terminal (PET). The requirements for the PET are specified in Clause 11.11.1.

Where the distribution of an isolated railway supply covers a large geographic area such that sub-mains would extend in excess of 500m parallel to electrified tracks, a high value of induced voltage will occur under traction fault in the protective earth conductor. This will result in a potential difference between metalwork connected to this protective earth and local metalwork connected to traction earth which in turn can result in a consequential hazard. This requires that a separate isolated supply with a neutral earth connection to the local traction earth is provided where sub-mains would otherwise exceed 500m parallel to the track.

11.20.4 Supplies from Stand-By Generator Sets and EST's

General light and power supplies will not normally be provided with an auxiliary power supply. Where a general light and power supply requires an auxiliary power supply, this may be derived via an automatic selection and changeover system from two or more alternative sources:

- one originating from the electricity distributor or railway-owned system, and
- the other originating from an automatic-start diesel engine-driven stand-by generator supply; or
- the other originating from an Emergency Supply Transformer (EST) from the 25kV OCLS

The incoming electricity service provider's or railway-owned electrical distribution supply shall be routed via the Stand-By Generator Room through the stand-by generator mains power cubicle to a 240/415 Volt distribution board, feeding:

- light and power circuits; and
- secure signalling and communications supplies.

The neutral of the standby generator shall be connected to the neutral busbar of the Isolated Railway Supply main switchboard. Where standby generators are installed as a packaged unit external to the switchroom, care shall be exercised to maintain isolation from external earths as required by Clause 11.16.1.

The supply originating from the electricity distributor or railway-owned electrical distribution system shall be treated in accordance with the requirements of Clauses 11.20.2 – 11.20.2.3 above.

11.20.5 Signalling & Communications Power Supplies within Station or Depot Buildings

Where a signalling power supply is required to be provided from an isolating transformer, in accordance with Clause 11.16.1 it shall be permissible to provide the general light and power supply from the main switchboard at the point of attachment or entry. The main switchboard shall be provided with separate circuits for the general light and power supply and the signalling room power supply and communications room power supply. Each circuit shall be separately protected at the main switchboard by a suitably rated circuit breaker.

11.20.6 Earthing of Installations Close to Traction Earth

Where an installation or portion of an installation has equipment required to be earthed which is located

- within the OHCLZPZ (e.g. lights in tunnels or maintenance facilities)
- within 2.5m of any earth electrode or exposed metalwork bonded to or forming part of the traction earthing system, and where the installation is influenced by the traction earthing system or it is necessary to avoid excessive touch and step potentials (e.g. vending machines close to structural steelwork)

then:

- an isolating transformer shall be provided, in accordance with Clause 11.20.2.1 11.20.2.2 unless functionally isolated as described in Clause 11.20.2.3 above, and the installation shall be earthed in accordance with Clause 11.20.3
- to prevent circulating currents and traction fault currents flowing in it, the protective earth conductor from the switchboard shall not be connected to the case metalwork on which the power supply terminates i.e. the power supply earth fault path is via traction earth and not via the earth conductor in the supply cable (refer Figure 11.20.6

)

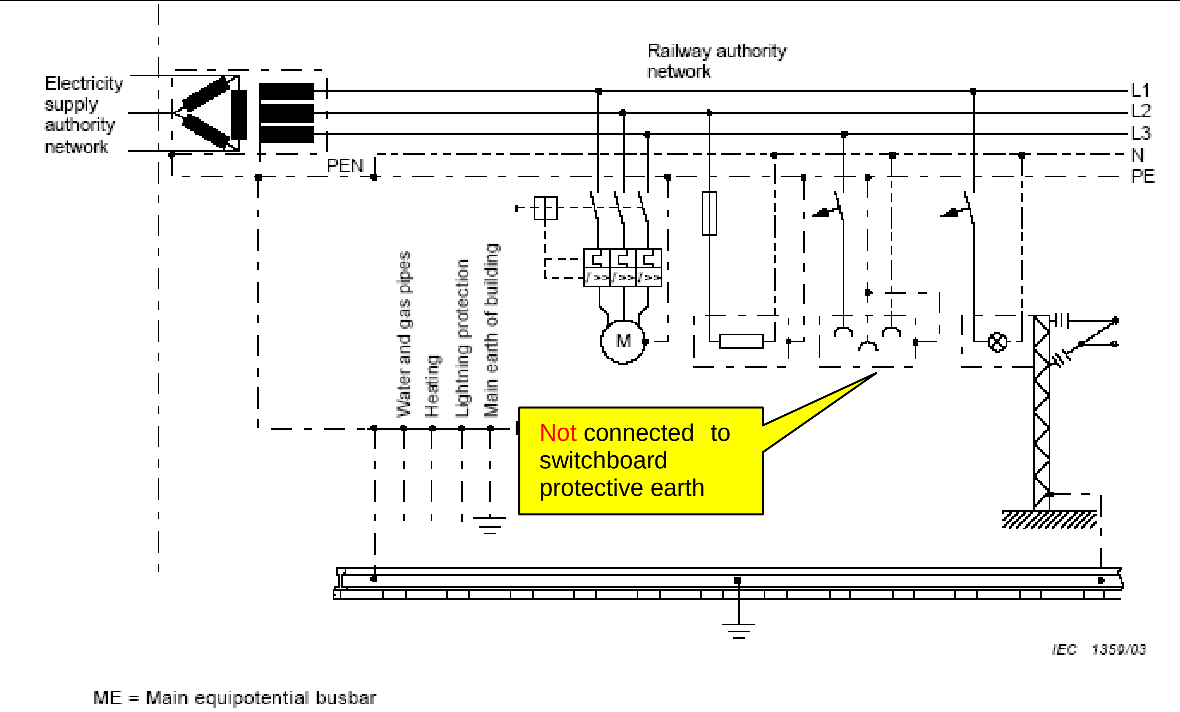


Figure 28 – Example for protective provisions of exposed conductive parts for a.c. traction systems by electrical isolation from the power supply system by means of a separate high voltage station or a transformer with separate windings (see 6.2.4.2.4.2)

Figure 11.20.6 - Typical Railway Isolated Supply (EN 50122-1)

11.20.7 Stageworks

Clauses 11.20.1 to 11.20.5 apply only to the final situation in which all OCLS has been completed and the requisite very low value of traction earth has been achieved, thus providing a low value of neutral earth to all railway isolated supplies. All supplies at stations or other railway installations brought into service prior to this time shall comply fully with AS 3000 but shall be constructed to facilitate reconfiguration of bonding arrangement prior to energization of the OCLS.

11.21 METALLIC FENCING

Any exposed metalwork or conductive elements of a fence within the OHCLZPZ shall be connected to the traction system earth or protected by a suitable physical barrier to eliminate the risk of simultaneous contact. These protective provisions avoid excessive touch voltages in case of insulator flashovers, short-circuits and other faults which do not occur directly to the running rails.

Affected wire-mesh fences, which would have insufficient cross-sectional area to carry the specified fault current, shall be protected by a guard conductor. This may utilise a hot dipped galvanised steel wire of 12mm minimum diameter which shall be connected to the traction earth at catenary masts or to terminals of the track substructure, as appropriate, at not less than 300m intervals. This measure also applies to plastic covered fence poles. It is important that each situation be assessed to ensure that there is no undue risk of simultaneous contact.

Exposed metalwork of a fence within 2.5m of traction earth (i.e. traction rail, mast or other metalwork bonded to traction earth) shall be bonded together and connected to traction earth. All other metal fences do not require to be bonded unless induced voltage calculations indicate and/or tests show the presence of a touch and step potential, under either normal operating or traction fault conditions, in excess of that defined in Appendix B. In such cases, the fence shall be earthed as necessary to reduce the voltage to a safe value.

Note: steel fencing posts will provide adequate safety earthing for metallic fences provided that electrical continuity between the fence and the fence posts can be ensured.

Insulation shall be inserted in any fences (as detailed in Clause 11.16.3) as near as possible to the boundary of the installation. In applying this rule, a passenger station, for instance, shall be regarded as one entity.

If the exposed metalwork of a fence is connected to, or likely to come into contact with, the electricity service provider's MEN system or any other separate earthing system, a separation of 2.5m from exposed metalwork connected to traction earth shall be maintained (refer to Clause 11.16.2). Generally, it shall be considered likely for the exposed metalwork of a fence to come in contact with the electricity service provider's MEN system, or any other separate earthing system, when such exposed metalwork of a fence is within 300mm of metalwork connected to such an independent earthing system. E.g. a fence bonded to traction earth next to a water tap fed by a copper or galvanized iron pipe.

11.22 RED BONDS

In general, traction bonds are not marked, but in any situation where removal of a traction bond may create an electrical hazard, generally due to interruption of the traction current return path, the end of the traction bond adjacent to any lug which may be inadvertently removed is to be marked by red PVC tape or sleeving or painted over, and a 200mm area of the traction return rail web or traction overhead wiring structure, as appropriate, surrounding the studs or bolts by which the traction bonds are connected, is to be painted red.

Examples of situations where the removal of a traction bond could create an electrical hazard and where marking is required are:

- the return current connection to traction earth of the HV winding of the power transformer;
- both ends of the MPC between the RC and the ACI (or rails in axle counter or non-signalled areas)
- the return current connection of an Emergency Supply Transformer (EST)
- both ends of the traction overhead wiring structure to rail at for structures which support isolating switches;
- the rail end of bonds which connect feeder stations and track sectioning cabins to any traction return rail(s) in SRTC or non track circuited areas.
- any rail continuity bond bridging out an insulated joint.
- transposed continuity bonds between rails at a set of insulated joints
- both ends of bonds between SRTC and DRTC transition

11.23 SPIDER PLATES

Where a number of bonds are required to be commonly connected to the traction return rails, a robust spider plate of adequate rating for its duty shall be used. A bond shall be provided from the spider plate to each of two separate tracks. Each spider plate shall be given a unique identity code.

11.24 WARNING NOT TO DISCONNECT BONDS

Where the earthing and bonding of services at stations and similar installations depend upon the integrity of connection to the traction return circuit, warning signs shall be displayed to ensure that electrical safety is not jeopardised by unauthorised disconnection.

11.25 PHYSICAL PROTECTION OF BONDS

Where bonds are liable to physical damage e.g. across roadways or platforms they shall be adequately protected.

Wherever possible, the traction bonds shall be routed and arranged as shown on the appropriate design drawings included in the traction overhead system design. The traction bonds shall be buried below the surface of the ballast, formation or ground level unless otherwise approved by the Technical Manager Electrification. Traction bonds shall be supported where necessary to avoid damage or movement.

In areas with jointless track circuits, bonds which pass beneath a running or conductor rail shall be encased in orange coloured plastic tube such that inadvertent contact between the bond and the rail is prevented even if the bond insulation becomes damaged.

12.0 EARTHING AND BONDING SYSTEM DESIGN

12.1 POWER SUPPLY, OVERHEAD LINE, RETURN CONDUCTOR AND SIGNALLING CONSIDERATIONS

During the course of the development of the earthing and bonding system, a continuous review shall be carried out to achieve the most effective and economic earthing and bonding system design. The review shall take into account the developing system designs for the traction power supply, the overhead line, the return conductors and signalling.

The correct application of earthing and bonding at all installations is essential to ensure the safe operation of traction power and overhead wiring equipment within 25kV ac electrified area. The earthing system shall ensure the safety of staff and members of public from the effects of transferred voltages and high potential gradients during both traction fault and normal traction load conditions, dangerous induced voltages caused by high voltage power lines, by 25kv ac traction systems and from high potential gradients caused by lightning discharges. It is therefore essential that earthing and bonding of all traction power and overhead wiring equipment is installed in accordance with the requirements of these Guidelines.

The following table provides an overview of contact personnel for planning, inspection and maintenance of railway installations. Refer to standards and codes of practice for responsibilities and contacts for planning, inspection and maintenance for further details of these responsibilities.

12.1.1 Planning, Commissioning and Maintenance Responsibility Matrix

		planning				commissioning				maintenance			
	Contact / Parts	E	C	S	T	E	C	S	T	E	C	S	T
1	Earth Wire (on overhead)	r	-	-	-	r	-	-	-	r	-	-	-
2	Return Current Rail Bonds to Feeder Station or Earth Wire	r		i		r		i		i		r	
3(i)	Earthing Conductors (all except to S&C equipment)	r	-	i	-	r	i	i	-	r	-		-
3(ii)	Earthing Conductors (S&C equipment)	r	-	i	i	r	-	i	i	i		r	i
4	Earthing of steel and reinforced concrete constructions	r	i		-	r	i		-	r	i	-	-
5	Earthing and Bonding of catenary masts	r	-	-	-	r	-	-	-	r	-	-	-
6	Earthing of 25 kV cable screens	r	-	-	-	r	-	-	-	r	-	-	-
7	Equipotential Bonding of platforms	i	r	-	-	r	i	-	-	r	i	-	-
8	Earthing of reinforced tracks slabs, underbridges and tunnels	i	r	-	-	r	i	-	-	r	i	-	-
9(i)	Earthing of wayside S&C cable screens	i	-	r	r	i	-	r	r	i	-	r	r
9(Ii)	Earthing of wayside Traction and general electrical power cable screens	r	-	-	-	r	-	-	-	r	-	-	-
10	Signalling Rail Bond	i	-	r	-	i	-	r	-	i	-	r	-
11	Traction Bonds (non-track circuited areas)	r	-	i	-	r	-	i	-	r	-	i	-
12 (i)	Traction Bonds (track circuited areas)	i		r		i		r		i		r	
12 (ii)	Primary Earth Terminal	r	-		-	r	-		-	r	-		-
13(i)	Voltage fuses and spark gaps connected to rail	i	-	r	-	i	-	r	-	i	-	r	-
13(iI)	Voltage fuses and spark gaps connected to Traction Earth Wire or other traction equipment	r	-	-	-	r	-	-	-	r	-	-	-
14	Bonding of Wayside Equipment and Structures (Structure & equipment Bonds)	r	i	i	i	r				r			

Explanations:

1. Contact
   - E = Technical Manager Electrification
   - C = Civil Work Manager
   - S = Senior Project Manager Signals and Communications
   - T = Senior Project Manager Signals and Communications
2. Activity:
   - r = responsible
   - i = involved

12.2 EARTHING AND BONDING SYSTEM DESIGN DOCUMENTATION

All individual traction return current and fault current path bonding necessary to meet the requirements of these Guidelines is specified on the following drawings:

12.1.2 Signals Bonding Plans;

- all return current bonding paths along and between rails with track circuits installed
- all return current bonding paths along and between rails in non-track circuited (and axle counter) areas
- all fault current path bonding connections to signals equipment (signal masts, level crossing alarm masts, points machines, signals locations)
- all fault current bonding to railway communications equipment
- all insulation joints installed for electrical power supply separation purposes
- mast or other references for demarcation points for all bonding from rails back to the traction earth wire and traction equipment

12.1.3 Traction Bonding Plans

- the installation of all traction earth wire segments and cross interconnections between mast runs
- all return current bonding connections from rails to traction feeder stations, track sectioning locations, etc
- all return current bonding to traction equipment and the traction earth wire.
- all fault current path bonding connections to structures, protection screens, station buildings, other equipment in the rail corridor and miscellaneous items such as corridor fencing

13.0 BONDING CONDUCTORS

Each bond shall have an electrical rating adequate for its duty:

- for traction return current conductors: capable of carrying the maximum traction load current indefinitely within the allowable temperature rise for the type of enclosure and maximum operating environmental temperature
- for all other bonds: capable of carrying the maximum traction fault current for the worst-case fault clearing time including reclosures. For this project this is established as 6 000A for 550ms

13.1 EARTHING CONDUCTORS (UNENCLOSED)

Any exposed metalwork, at risk of contact with the OHCLZPZ, must be earthed in such a manner that it is capable of carrying maximum traction fault current.

These conductors, where required, shall be a minimum of 50mm^2 copper or equivalent aluminium conductor. A 50mm^2 copper conductor is capable of carrying the full 6 000A maximum traction fault current for the maximum fault clearance time and fault cycle of the traction protection system.

13.2 EMBEDDED EARTHING CONDUCTORS

Earthing conductors for all purposes, including lightning protection, shall be designed according to IEC standards to withstand mechanical and thermal stress for the required fault current/time profile. This also applies to earthing conductors embedded in concrete, which may be part of the reinforcement or additional mild steel rods.

The minimum cross section of earth electrodes with regard to corrosion and mechanical strength shall be determined and shall comply with appropriate IEC standards. The minimum cross-section depends on the material and shape of the electrode.

The thermal design of the earthing system shall be based on the IEC relevant fault current and tripping time of the power supply system installed as shown in Table 13.2-1

Type of system	Relevant current for thermal design of earthing conductor
Systems with isolated neutral	Double earth fault current
Systems with resonant earthing	Double earth fault current
Systems with low-impedance neutral earthing (MEN)	Initial symmetrical line-to-earth short-circuit current

Table 13.2-1 Relevant currents for thermal design of earthing conductors and concrete embedded earth conductors

13.3 WELDING REQUIREMENTS FOR REINFORCEMENT BONDED TO TRACTION RETURN

Figure 13.3-1 shows examples for welded connections. The minimum length of two opposite welded seams shall be 50mm. To ensure a fully electrical conductive length of 50mm, a welding length of at least 55mm is recommended. For single side welding a minimum length of the seam of 100mm is required.

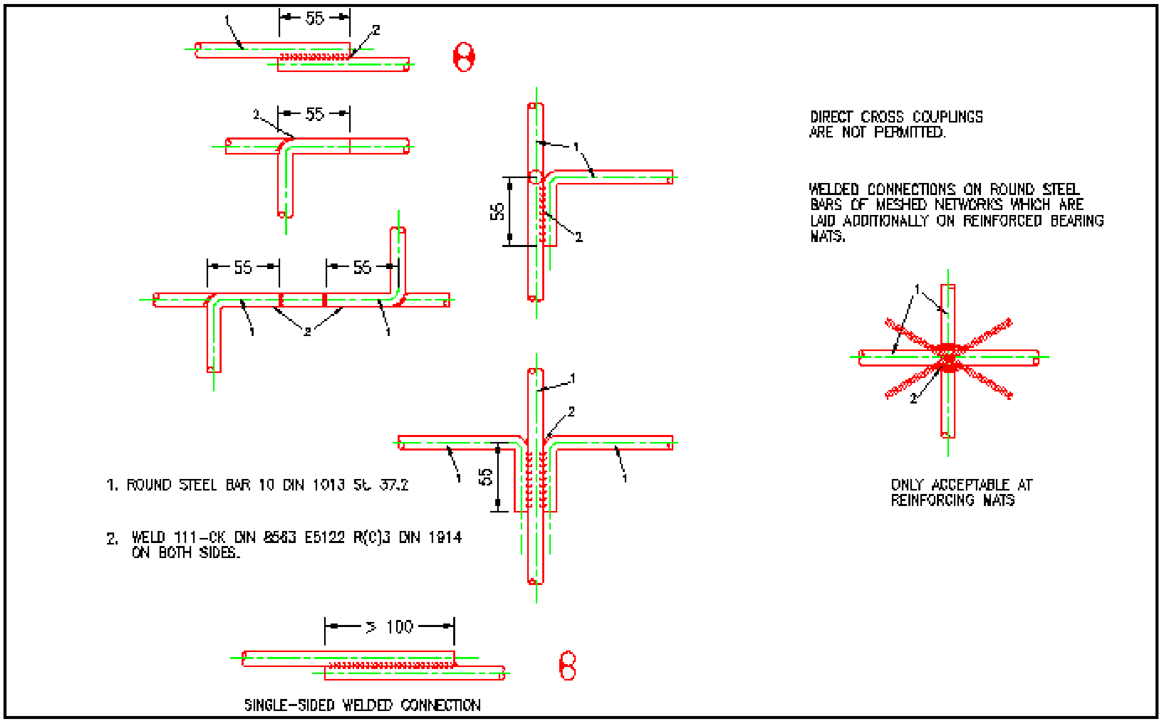


Figure 13.3-1 – Example of Welded Earthing Connections

13.4 TERMINALS TO REINFORCEMENT BONDED TO TRACTION RETURN

Terminals for the connection of embedded parts to other parts of the earthing systems are required.

Inside buildings, and other closed structures, contact tongues made from hot dipped galvanised flat steel or embedded terminals for bolted connections are to be used.

For connections outside of buildings and for open structures, embedded terminals for bolted connections made from stainless steel or galvanised steel (suitable corrosion protection for the environment) are to be used, only. These terminals are furnished with an internal thread for 1 x M16 bolt.

Earthing terminals are to be welded to the earthing bars according to the welding requirements above using an approved process.

The earthing terminals shall be accessible at a height of 300 to 500mm above concrete floor or final ground level.

The required cross section of the earthing conductors shall be calculated for the system and compared with the above minimum cross sections. The larger cross sections are to be applied.

Based on a maximum short-circuit current of 6kA a cross-section of 100 mm^2 steel is sufficient for this purpose, because it provides the thermal capacity for carrying the short-circuit currents. This cross-section shall also be applied for concrete embedded earthing conductors if no other information is available.

Note: a fault current of greater than 6kA could occur from a grid substation or the utility power supply to a building, the neutral of which may be required to be effectively bonded to the traction earth and reinforcement.

The cross-section of earthing wires is the subject of detailed design.

All embedded earthing conductors must be covered by at least 50mm of concrete for corrosion protection.

Conductors, which are part of an earth electrode or are located within the OCLS or pantograph zone, shall not be covered by more than 100mm of concrete. This is necessary to ensure sufficient contact to the soil or to a fallen overhead contact line respectively.

The down conductors inside walls shall be connected to the reinforcement at intervals of 400mm by means of wire wrapping.

13.4.1 Standard Traction Bond

The standard traction bond for all applications except traction return rail joint bonds is to be a 19/3.25mm stranded hard drawn aluminium conductor with a general purpose PVC sheath of 1.6mm nominal thickness provided with aluminium compression lugs at one or both ends as necessary. These lugs shall be suitable for termination onto 16mm stainless steel bolts, studs or terminals.

14.0 TESTING OF THE EARTHING AND BONDING SYSTEM

Testing of the electrification system when installed will be carried out, at the time of commissioning, under traction load and short circuit conditions, to verify that the design complies with the requirements of this specification.

14.1 TESTS DURING CONSTRUCTION PHASE

14.1.1 Soil Resistivity

At some selected locations, to be defined during basic design, the soil resistivity shall be measured with the Wenner method (4 electrodes) as basis for earthing calculations. The measurements shall be made at the correct electrode spacing and soil depths as described in Work Instruction No AR-EL-WKI-0101.

14.1.2 Certificate of Embedded Conductors

Civil Works and Track work shall certify that all measures defined in Clauses 11.8 are implemented completely, especially visual inspections of welded connections to ensure electrical continuity. Refer to the Work Instruction No. AR-EL-WKI-0100

14.1.3 Resistance to Earth

The resistance to earth of completed earth electrodes shall be measured at one reference terminal to ensure required values for safety of persons. Procedure shall be according to the 3 electrodes method as described in the Work Instruction No. AR-EL-WKI-0099.

14.1.4 Test of Continuity and Completeness of Terminals

Tests shall be conducted to ensure all required terminals are provided and have low impedance connection to the reference terminal. Procedure will be according to the
4-terminal resistance method as described in Work Instruction No. AR-EL-WKI-0098

14.2 TESTS DURING COMMISSIONING PHASE

14.2.1 Certificate of Bonding of Trackside Installations

Checks shall be conducted to ensure that all equipment according to the E&B concept located along the track is bonded to traction system earth.

14.2.2 Certificate of Bonding for LPS

Checks shall be conducted to ensure appropriate measures for external and internal lightning protection are applied.

14.3 SHORT CIRCUIT TESTS

The short circuit test takes place with a short circuit between contact wire and the outer rail or between contact wire and earth wire, as determined as the worst case situation for each specific test. Tests will include, but are not limited to:

14.3.1 Measurement of remote rail potential and induced voltages

Memory Recorder connected to:

1. outer running rail and earth spike at least 10m at right angles from running rail
2. (at stations) voltage between station metalwork and station power supply MEN and incoming telephone circuit earth
3. induced voltage in longest signalling cable between the feeder station and short circuit site (earth reference at remote end of cable and memory recorder earth spike 10m at right angles from track)

14.3.2 Measurement of touch voltage (measurements repeated for short circuits with all bonds intact and with rail bonds, as nominated, removed

Memory recorder connected to:

1. outer running rail and earth spikes 1m (rail touch potential) and 2m (rollingstock touch potential) at right angles from running rail
2. traction mast to earth stake 1m away
3. traction mast to closest rail
4. track to track (inner rails)
5. rail to rail
6. (at station) rail to station metalwork e.g. end of platform fence
7. (at feeder station) touch potential to station fence

14.3.3 Measurement of short circuit currents and voltages at feeder station

1. short circuit current in feeder
2. return current from rail(s) to return current bus
3. busbar VT voltage

Both measurements take place close to short-circuit location at running rails of the track where short circuit test is done and at mid-point between rail to earth wire bonds.

Appendix A: Referenced Documents

AS/NZS 3000	Wiring Regulations
IEC 62305:2006	Lightning Protection
AS/NZS 4853 (2000)	Electrical Hazards on Metallic Pipelines
IEC 60364	Electrical installations of buildings – Part 1: Fundamental principles, assessment of characteristics, definitions
IEC 60502-1	Power cables with extruded insulation and their accessories from rated voltages from 1kV up to 30kV Part 1 Cables for rated voltages for 1kV and 3kV
IEC 60913	Electric traction overhead lines
AS/NZS/IEC 61558.2.4 (2001)	Safety of power transformers, power supply units and similar - Particular requirements for isolating transformers for general use
IEC 62529	Degrees of protection provided by enclosures for electrical equipment (IP Code)
EN 50122-1 Part 1	Railway Applications. Fixed Installations. Protective Provisions Relating to Electrical Safety and Earthing

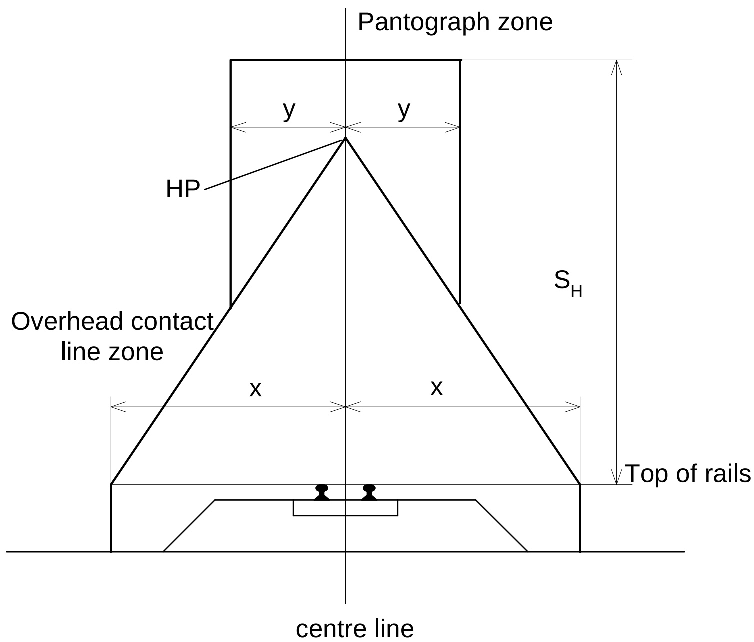
Appendix B: Maximum Permissible Touch and Accessible Voltages and 25kV Service Voltages

Unless protected by earthed screens, all metalwork within the OHCLZPZ shall be connected to the traction earth. The impedance of the traction return circuit must be sufficiently low to achieve the following criteria:

- the potential of exposed metal parts shall be held to a value not exceeding 60 Volts under normal operating conditions or 430 Volts under traction system fault conditions, measured to the general mass of the earth; and
- the correct operation shall be ensured of any system electrical protection equipment associated with the traction system.

Note 1: A relaxation of the 430V limit under fault conditions to 670V is permitted under failure of the most critical rail bond in the fault circuit. A further relaxation may be applied, subject to agreement by Technical Manager Electrification, for induced voltages from high security lines which parallel the railway. The maximum allowable voltage shall be in accordance with EN 50122-1 Clause 7.2.1 Table 2 for the guaranteed tripping time of the external power line for an earth fault.

Appendix C: Overhead Contact Line Zone and Pantograph Zone Dimensions



x: Width of overhead contact line zone to the centre of track
y: Width of pantgraph to the centre of track
S_H: Height of overhead contact line zone
HP: Highest point of the overhead contact line.

The parameters x and y are defined by DTEI to be x = 4.0m (extended to 5.0m for track with curves less than 1000 m) and y = 2.0 m. The total height Sh is defined to be 8.0m above top of the rails.

Note: It may be investigated if dimension X = 5m for curves with radius less less than 1000 m can be reduced (but not less than 4m), on a site specific basis, with approval of the Technical Manager Electrification.

Appendix D: Table Of Impedance Bond/Aci Rail Connection Intervals And Track Conductance Design Requirements

System Conductance		
From (line/km)	To (line/km)	Conductance (S/km)
Workshops		
Earth wire size		
From (line/km)	To (line/km)	CSA (mm^2)
Marginal masts		
Centre masts		
Average Mast Foundation Resistance/km		
From (line/km)	To (line/km)	Resistance (Ohms)
Supplementary Earthing System		
From (line/km)	To (line/km)	Conductor size (mm^2)
Rail Bond Interval		
From (line/km)	To (line/km)	Bond separation (M)
Additional Bonds for SRTC/DRTC transitions		
SRTC/DRTC at (line/km)	Additional bond at (km)	Separation (m)
Feeder Station EPR		
25kV Traction fault (V)	66 kV earth fault (V)	Isolate comms circuits (Y/N)
FS		
TSC EPR		
25kV Traction fault (V)		Isolate comms circuits (Y/N)
TSC		

ALL VALUES *TBA – subject to Earthing and Bonding Study*