

Network Standard

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NS270 STRAY DIRECT CURRENT MANAGEMENT



ISSUE

For issue to all Ausgrid and Accredited Service Providers' staff involved with the design, installation, testing and review of components near external sources of stray Direct Current (DC) and is for reference by field, technical and engineering staff.

Ausgrid maintains a copy of this and other Network Standards together with updates and amendments on www.ausgrid.com.au.

Where this Standard is issued as a controlled document replacing an earlier edition, remove and destroy the superseded document.

DISCLAIMER

As Ausgrid's Standards are subject to ongoing review, the information contained in this document may be amended by Ausgrid at any time. It is possible that conflict may exist between Standard documents. In this event, the most recent Standard shall prevail.

This document has been developed using information available from field and other sources and is suitable for most situations encountered in Ausgrid. Particular conditions, projects or localities may require special or different practices. It is the responsibility of the local manager, supervisor, assured quality contractor, accredited service provider and the individuals involved to make sure that a safe system of work is employed and that statutory requirements are met.

Ausgrid disclaims any and all liability to any person or persons for anything done or not done, as a result of this Standard.

All design work, and the associated supply of materials and equipment, must be undertaken in accordance with and consideration of relevant legislative and regulatory requirements, latest revision of Ausgrid's Network Standards and specifications and Australian Standards. Designs submitted shall be declared as fit for purpose. Where the designer wishes to include a variation to a Network Standard, an alternative material or equipment to that currently approved, the designer must obtain authorisation from the Network Standard owner before incorporating the variation to a Network Standard in a design.

All designers, including external designers authorised as accredited service providers will seek approval through the approved process as outlined in NS181 Approval of Materials and Equipment and Network Standard Variations. Seeking approval will ensure Network Standards are appropriately updated and that a consistent interpretation of the legislative framework is employed.

Notes: 1. Compliance with this Network Standard does not automatically satisfy the requirements of a Designer Safety Report. The designer must comply with the provisions of the Workplace Health and Safety Regulation 2011 (NSW - Part 6.2 Duties of designer of structure and person who commissions construction work) which requires the designer to provide a written safety report to the person who commissioned the design. This report must be provided to Ausgrid in all instances, including where the design was commissioned by or on behalf of a person who proposes to connect premises to Ausgrid's network, and will form part of the Designer Safety Report which must also be presented to Ausgrid. Further information is provided in Network Standard (NS) 212 Integrated Support Requirements for Ausgrid Network Assets.

2. Where the procedural requirements of this document conflict with contestable project procedures, the contestable project procedures shall take precedent for the whole project or part thereof which is classified as contestable. Any external contact with Ausgrid for contestable works projects is to be made via the Ausgrid officer responsible for facilitating the contestable project. The Contestable Ausgrid officer will liaise with Ausgrid internal departments and specialists as necessary to fulfil the requirements of this Standard. All other technical aspects of this document which are not procedural in nature shall apply to contestable works projects.

INTERPRETATION

In the event that any user of this Standard considers that any of its provisions is uncertain, ambiguous or otherwise in need of interpretation, the user should request Ausgrid to clarify the provision. Ausgrid's interpretation shall then apply as though it was included in the Standard, and is final and binding. No correspondence will be entered into with any person disputing the meaning of the provision published in the Standard or the accuracy of Ausgrid's interpretation.

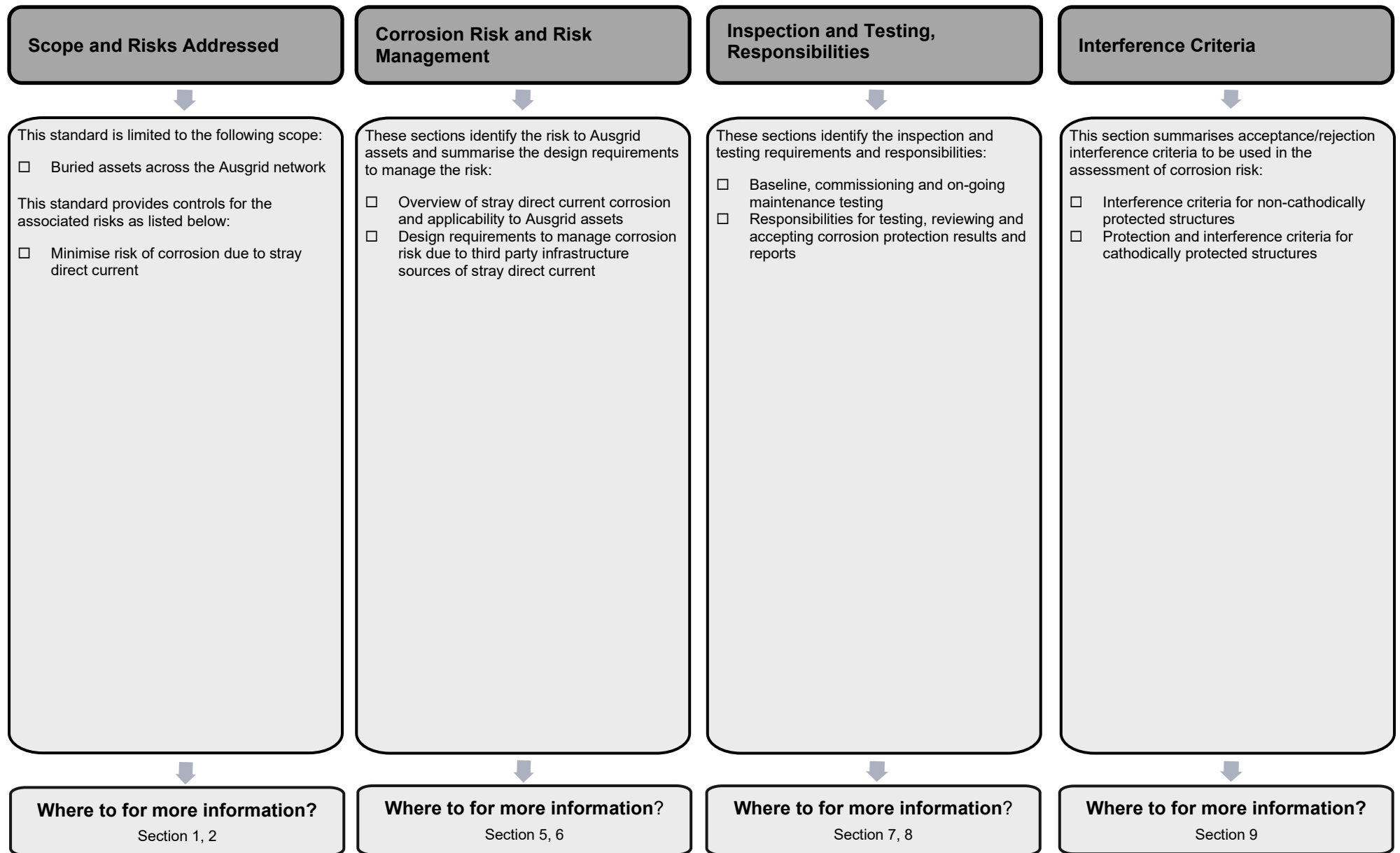
KEYPOINTS

This Standard has a summary of content labelled "KEYPOINTS FOR THIS STANDARD". The inclusion or omission of items in this summary does not signify any specific importance or criticality to the items described. It is meant to simply provide the reader with a quick assessment of some of the major issues addressed by the Standard. To fully appreciate the content and the requirements of the Standard it must be read in its entirety.

AMENDMENTS TO THIS STANDARD

Where there are changes to this Standard from the previously approved version, any previous shading is removed and the newly affected paragraphs are shaded with a grey background. Where the document changes exceed 25% of the document content, any grey background in the document is to be removed and the following words should be shown below the title block on the right hand side of the page in bold and italic, for example, Supersedes – document details (for example, "Supersedes Document Type (Category) Document No. Amendment No.").

KEY POINTS OF THIS STANDARD



Network Standard NS270 Stray Direct Current Management

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1.0 PURPOSE

The purpose of this document is to minimise the risk of corrosion to Ausgrid assets due to stray direct current. Sources of stray direct current are to be managed by specifying the minimum requirements for the following:

- Design
- Test and inspection
- Acceptance/rejection interference criteria

2.0 SCOPE

This document specifies high level requirements that apply to buried assets across the Ausgrid network subject to exposure from stray direct current from external parties, such as railway traction systems and cathodic protection systems.

3.0 RELATED DOCUMENTS

3.1 General

All work covered in this document shall conform to all relevant Legislation, Standards, Codes of Practice and Network Standards. Current Network Standards are available on Ausgrid's Internet site at www.ausgrid.com.au.

3.2 Ausgrid documents

- Ausgrid's Electrical Safety Rules
- Ausgrid Electricity Network Safety Management System Manual
- NS116 Design Standards for Distribution Equipment Earthing
- NS181 Approval of Materials and Equipment and Network Standard Variations
- NS222 Major Substation Earthing Design
- NS260 Sub-Transmission Feeder Earthing

3.3 Other standards and documents

- AS 2159:2009 Piling – Design and Installation
- AS 2832 (all parts) Cathodic Protection of Metals
- AS 3007:2013 Electrical equipment in mines and quarries – Surface installations and associated processing plant
- AS 3600:2018 Concrete structures
- AS 4036:2006(R2016) Corrosion of metals – Dissimilar metals in contact in seawater
- EN 13509 Cathodic Protection Measurement Techniques
- EN 50122-2:2010 Railway applications – Fixed installations – Electrical safety, earthing and the return circuit – Part 2: Provisions against the effects of stray currents caused by d.c. traction systems
- EN 50162:2004 Protection against corrosion by stray current from direct current systems
- Guide for Measurement of Interference Caused by Cathodic Protection and Railway Drainage Systems (the Red Book), 1998, NSW Electrolysis Committee
- Railway MAD Agreement
- ASTM C876-15 – Standard Test Method for Corrosion Potentials of Uncoated Reinforcing Steel in Concrete

3.4 Acts and regulations

- Electricity Supply (Corrosion Protection) Regulation 2014 (NSW)
- Electricity Supply (General) Regulation 2014 (NSW)
- Electricity Supply (Safety and Network Management) Regulation 2014 (NSW)
- Work Health and Safety Act 2011 and Regulation 2017 (NSW)

4.0 DEFINITIONS

| | |
|------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Accredited Service Provider (ASP) | An individual or entity accredited by the NSW Department of Industry, Division of Resources and Energy, in accordance with the Electricity Supply (Safety and Network Management) Regulation 2014 (NSW). |
| Anode | An electrode through which direct current enters an electrolyte allowing oxidation reactions to take place. |
| Cathode | An electrode through which direct current leaves an electrolyte allowing reduction reactions to take place. |
| Cathodic Protection (CP) | The prevention or reduction of corrosion of metal by making the metal the cathode in a galvanic or electrolytic cell. |
| Contestable Work | Contestable work is work such as the design, construction and installation of electricity works that are required to connect a customer's installation to an electricity distributor's network. Customers are required to fund the cost of contestable work and they have the choice of selecting the ASP to carry out the work. The legislation relevant to contestable work is the Electricity Supply Act 1995 (NSW) and Electricity Supply (Safety and Network Management) Regulation 2014 (NSW). |
| Corrosion | The deterioration of metal caused by its chemical, electrochemical or both reactions with its environment. |
| Designer | An Ausgrid employee, contractor to Ausgrid or ASP/3 who is duly qualified to produce design plans. |
| Electrolyte | A liquid or liquid component in composite material such as soil, in which electric current may flow by movement of ions. |
| Exposure Classification | Designation indicative of the most severe environment to which a concrete member is to be subjected during its lifetime (refer AS3600) |
| Half Cell | <p>An electrode which has a stable potential in one or more electrolytes at a given temperature, thus enabling it to be used for the measurement of other electrode potentials.</p> <p>The potential between the anode and cathode can be measured using a Half Cell. The Half Cell is a reference electrode that can measure the potential of electrodes when placed in the same medium.</p> |
| Interference | A change in potential to earth of a foreign structure as a consequence of the operation of a CP system applied to a primary structure. |
| Low Voltage TT | A power system having the earthable point directly connected to earth, the exposed conductive parts of the installation being connected to earth electrodes which are electrically independent of the earth electrodes of the power systems (refer A3007) |
| Passivity | The state of the surface of a corrodible metal or alloy where its electrochemical behaviour becomes that of a less reactive metal and its corrosion rate is reduced. |
| Polarisation | The change in the potential of an electrode (e.g. structure) as the result of current flow to or from that electrode. |
| Quiescent potential | The average potential between a buried asset and the reference half-cell at a time when no rail vehicles are operating. |

| | |
|------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Structure Potential | The potential of a structure relative to that of a specified reference electrode situated in the electrolyte immediately adjacent to the structure. |
| Traction power system | The electrical infrastructure required to convert the incoming AC supply from the supplying HV network to the DC traction voltage and deliver that supply to the rail vehicles. |
| VLD | Voltage Limiting Device. Protective device connected at each rail traction substation or stop between the earth and the traction negative to provide protection against hazardous potentials occurring on the rail. |
| VTD | Voltage Triggering Device. Protective device connected between conductive structures and the rail in the vicinity of the overhead catenary system to prevent hazardous potentials developing on conductive infrastructure in the event of overhead wiring insulation failure. |

5.0 STRAY DIRECT CURRENT CORROSION OVERVIEW

There are two significant types of stray direct current sources that may cause corrosion of Ausgrid buried assets:

- DC cathodic protection systems (non-fluctuating DC)
- DC traction systems (fluctuating DC)

5.1 DC cathodic protection systems

Critical pipelines or telecommunications cables with metal sheaths buried in the soil have a natural tendency to react with the environment because they span long distances through a variety of soil types. Localised corrosion at a small insulation coating defect on a pipeline can result in a major pipeline failure. To prevent such failures, an appropriate direct current is applied flowing in opposition to the original corrosion current (e.g. using an impressed current cathodic protection system). This cathodic protection (CP) current shifts the potential of the structure to be more negative (cathodic) to the surrounding environment. This may result in surrounding infrastructure such as Ausgrid buried assets becoming more corrosive (anodic) if located within the zone of influence of either the protected structure or the anode bed.

DC CP systems apply a constant DC (constant current mode) or slowly changing DC current (constant voltage mode). Signature switching of the CP system between on and off states facilitates the assessment of the level of polarisation/depolarisation of the Ausgrid asset to determine the risk of corrosion due to CP interference.

5.2 DC traction systems

DC traction substations supply current via an overhead contact wire or charge bar through the train pantograph to the traction motors or a third rail is used to supply the traction current on catenary designs. The current returns to the source via the train wheels, running rails and dedicated conductive paths. The supply side of the traction motor is positive with respect to the rails. The return metallic paths, particularly the running rails, are intentionally insulated from earth to minimise the stray current flow through earth.

Due to imperfections in the track to earth insulation some current leaks into the soil and enters and exits Ausgrid buried structures and earthing in close proximity to the rail tracks. This stray traction current can cause corrosion where it exits Ausgrid buried structures, for example steel reinforced footings, exposed metallic cable armouring or sheaths or copper earthing systems. The stray current fluctuates rapidly due to nature of the contact system with the magnitude varying due to the location and acceleration state of the trains.

5.3 Asset exposure to stray direct current

Assets on the Ausgrid Network at risk of corrosion from stray current include:

- Structure footing steel reinforcement where the concrete cover has been compromised. Typically, in the form of steel tower legs encased in concrete or earthed with galvanised steel strap, concrete poles with stainless steel butt plates, steel poles with reinforced concrete footings and embedded earthing associated with foundations of buildings.
- Metallic cable sheaths/armouring: Exposed cable armouring or sheaths are prone to the effects from stray current, particularly, aluminium or lead sheaths which dissolve at higher rates than steel or copper and are also sensitive to elevated negative current flow which leads to hydrogen embrittlement. A localised cable serving defect site may also result in accelerated cable failure due to concentrated corrosion current.
- Buried earthing systems: Typically made of copper in the form of solid or copper clad steel electrodes, stranded conductors or strap.

These buried assets can corrode themselves or contribute to the corrosion of other buried objects by transferring stray direct current.

5.3.1 Assets within 10m of a source of stray direct current

For any part of a buried structure or earthing installed within 10m of a source of stray current, the following requirements apply to minimise the impact of electrolysis:

- **Earth electrodes**

Corrosion resistance earth electrodes shall be made of solid copper or bare stranded copper conductor. Stainless steel is not recommended for electrodes as stainless steel varieties can corrode in environments lacking oxygen.

- **Reinforced and prestressed concrete structures**

Concrete properties, particularly the cement content, water to cement ratio and concrete cover are the major factors in providing corrosion resistant properties. A high level of crack control, especially in flexural elements is also important. For normal conditions, corrosion of reinforcing steel in concrete structures can be prevented by producing low permeability concrete that maintains high alkaline conditions at the metal surface. An increase in concrete coverage will provide a greater resistance between steel and earth which ensures less leakage current penetration (or pickup) and a greater distance for the migration of chloride products.

To minimise the risk of corrosion, the concrete coverage of embedded steelwork shall be determined by following the process of Exposure Classification in AS3600 and/or AS2159. Where the exposed concrete surface is within 10m of a source of stray direct current this coverage shall be enlarged by increasing the Exposure Classification one grade where the potential risk is reviewed to determine the minimum Whole of Life cost.

6.0 INTERACTION WITH UTILITY INFRASTRUCTURE

6.1 Telecommunications

6.1.1 Corrosion risk

Telstra uses a positive earthed network whereby the Telstra Exchange equipment and earthing system is directly bonded to the DC positive.

Telstra assets include bare lead sheathed cables which are usually cathodically protected using impressed current or galvanic systems. In metropolitan areas, or where impressed current cathodic protection is unsuitable, a negative battery bond originating from the exchange is used to protect the lead sheath.

When Ausgrid's MEN has a common bond to the exchange earth grid, then Ausgrid's MEN network becomes interconnected with Telstra's positive circuit and is at risk of accelerated corrosion.

6.1.2 General requirements to manage corrosion risk

The earthing design for a distribution substation supplying telecommunications infrastructure shall consider the impact of any cathodic protection system that is associated with the exchange.

Where a Telstra Exchange utilises cathodic protection connected to their earth grid, then the Telstra earth grid should be separately earthed from Ausgrid's MEN via a segregated earthing design, polarisation cell or isolation transformer for the LV feed.

A distance of 3m is required for separation of Telecommunications earthing from Ausgrid earthing.

6.2 Rail

6.2.1 Corrosion risk

The risk of corrosion due to the proximity of Ausgrid assets to the DC rail corridor is increased by common earthing of HV supplies to rail assets. With common earthing, there is a direct conductive

path between the rail asset earthing and Ausgrid's MEN. This results in a significantly lower stray current circuit resistance which increases the magnitude of stray current flow.

Operation of rail network safety devices can also significantly increase the stray direct current. Typical safety devices include rail earth contactors (REC), short circuit devices (SCD) or voltage limiting devices (VLDs) that operate (closes and short-circuits two systems) when the DC negative to earth potential becomes excessive. DC spark gaps or voltage triggering devices (VTD) are placed between key rail structures and the running rail in case of overhead catenary insulation failure or lightning event. When any of these devices operate, the stray current is increased significantly until they are reset or replaced.

6.2.2 Requirements to manage corrosion risk

For new rail projects corrosion risk is best managed at the design stage to minimise leakage current from the rail. This is done through Whole of Life assessment which includes appropriate selection of asset site and proximity to other assets, materials used and associated plant. During the design stage the following recommended practices to manage corrosion risk should be considered:

- Low rail resistance and cross bonding along the running rails
- High rail to earth insulation
- Stray current collection system
- Proximity and criticality of Ausgrid assets to the rail
- Number and operational characteristics of rail to earth safety devices (e.g. VLDs and VTDs)
- Provision for future stray current drainage systems

Ausgrid requires any assets located within 10m of a DC rail corridor boundary to be identified in associated corporate systems SAP and GIS. Key locations for stray direct current test points shall be identified by the approved Ausgrid authorised person. These test points and their associated provisions shall be negotiated with the associated railway entity. For example, test point provisions may include access for Ausgrid staff and two connections to the rail (one for allowance of connection of a drainage bond and one for a rail reference potential to carry out testing).

Where earthing electrodes are installed within 10m of the rail corridor, direct buried copper clad steel electrodes are susceptible to severe pitting corrosion when exposed to excessive stray traction current. Solid copper electrodes or bare 70mm² stranded copper conductors installed in predrilled holes shall be specified for corrosion resistance. In known high stray traction current areas such as near stabling yards or train maintenance facilities the Ausgrid authorised person shall be consulted as part of the earthing design and for coordination with the NSW Electrolysis Committee.

Where special earthing arrangements are required for traction substations these will be assessed on a case by case basis by the Ausgrid officer responsible for facilitating the contestable project and dispensation may be given by following the Ausgrid Network Standards variation process (NS181).

An Ausgrid officer or representative shall be given the opportunity to witness the commissioning of non-standard traction supply earthing systems. For example, where an Ausgrid substation is located within the rail traction substation compound and the kiosk and traction substation earthing systems are combined.

6.2.3 Traction substations - HV supply requirements

The HV earthing shall be proved compliant with the relevant criteria Refer to earthing Network Standards NS116, NS222 and NS260 for details. An integral part of ensuring electrical safety is consideration of the electrolysis corrosion risks to the primary earthing system and the subsequent consequences of failure of the earthing system. In addition to the safety of people and correct operation of protection schemes, inadequate earthing performance due to excessive electrolysis corrosion can also lead to direct and indirect safety risks to other critical infrastructure such as HV cables, Water mains; Gas and Fuel pipelines.

To minimise stray DC traction current, separation of Ausgrid and rail earthing systems is the preferred configuration.

Where earthing compliance cannot be achieved with a segregated earthing design then the two earthing systems shall be common bonded via dedicated earthing connections with facility for testing and monitoring.

A third option is the installation of a stray DC current blocking device (e.g. rated voltage limiting device or polarisation cell) in the cable screens. Any DC blocking device selected shall be rated for the conduction of asymmetrical earth fault current to backup clearing times. Typically, this is an option for high impedance fault limited systems.

Where the HV cable screens are bonded to the local earthing system (e.g. to Traction substation earth grid) then the following corrosion risk management requirements apply:

- Access shall be made available to the Ausgrid cable screen connection in the traction substation for routine inspection and testing
- Provision shall be made in the cable screen bond for the application of a DC tong ammeter and/or shunt for routine testing
- Remote stray DC current monitoring (with telemetry warnings of thresholds being reached) of Ausgrid HV supply cable screens.
- Provision for future installation of stray current mitigation such as conduit for polarised resistive drainage bonds or cathodic protection systems and an electrolysis test strategy in place to manage corrosion risks.
- Separation / Isolation of the Traction Substation earth grid from the DC Negative is important and failure modes such as VTD or VLDs shorting to the traction substation earth grid should be minimised.

6.2.4 Traction substations - LV supply requirements

Ausgrid LV supplies shall be separated from DC Traction networks where practicable. The neutral conductor shall not be connected to a rail overhead wire support structure.

Separation is achieved via a segregated earthing design or isolation transformer. In either case, adequate separation is typically achieved by positioning the Ausgrid earth electrodes outside the zone of influence of the rail earthing system and track formation e.g. > 3m from the boundary of the rail corridor. In some situations, a separated LV TT earthing system will be used instead of a conventional LV MEN earthing system. LV TT earthing configurations are typically limited to smaller installations (e.g. LV supply for lighting) located within the confines of the rail corridor and will be assessed on a case by case basis by an Ausgrid Earthing Engineer.

The track slab shall be proven isolated from the MEN network with a measurement of >2 ohms.

6.2.5 Mitigation measures

Over the lifetime of a DC rail system there will be changes in the leakage of stray current. If abnormal measurements are found on Ausgrid assets then the following shall be requested from the operator of the rail:

- Fault detection of the track insulation:
 - Check operation of rail safety devices and replace damaged ones
- Check rail insulation and clean if polluted (e.g. dirt or salt near coastal areas) and ensure good drainage
- If stray current collection system exists, consider reconfiguration until primary rail insulation is rectified (i.e. traction substation polarised resistive drainage bond to stray current collection system in the section where the problem exists). This option may have system

wide implications and should only be done as a last resort in consultation with the NSW Electrolysis Committee to manage interference.

If the above fails to bring the stray current to within acceptable levels then the following control measures are to be implemented.

6.2.5.1 Isolation

- Relocating structures away from the source of interference
- Excavating and insulating/coating the structure to be protected – generally not applicable to structures that form part of the earthing system as the coating would insulate the protected structure from the soil.

6.2.5.2 Drainage bond

A drainage bond may guide the stray current out of the asset via a metallic path.

The need for drainage bonds and/or other special earthing requirements for substations within 200 metres of electrified rail lines will be assessed and required works specified by Ausgrid.

Drainage bonds shall be designed in accordance with the Australian Standard on Cathodic Protection AS2832.1 with reference to the NSW Electrolysis Committee Guide.

Drainage bonds shall be located where:

- The railway and structure to be protected cross or where they are closest together.
- The maximum adverse structure potential changes due to stray currents are measured. This may require assisted drainage bonds such as transformer rectifier assisted drainage.
- Where agreed by NSW Electrolysis Committee which takes into consideration the interference affects to other foreign assets.

6.2.5.3 Cathodic protection

Cathodic protection (CP) systems are a strategic application of negative polarity DC current to the targeted asset. They can be either galvanic anode or impressed current system.

The practicality of conducting more frequent testing of earthing electrodes, specification of copper electrodes and replacement of deteriorated or corroded electrodes is to be reviewed for suitability. The use of cathodic protection on earthing electrodes is generally the option of last resort due to initial expense and ongoing maintenance requirements.

Impressed current cathodic protection systems are an effective corrosion mitigation method but are more expensive to install and maintain than galvanic anodes. Any CP design needs to consider the risk of causing interference on neighbouring third party assets. Effective mitigation requires a tailored solution in cooperation with the NSW Electrolysis Committee to prevent adverse effects on neighbouring assets.

6.2.6 Shared building requirements

Shared buildings occur when a distribution substation is installed in a multipurpose building for example a kiosk supplying a building located directly above a rail station.

Minimisation of stray DC traction current leakage onto the Ausgrid network can be difficult when the two earthing systems are directly adjacent or located in the same building. However, separation may be possible by implementing one of the following:

- Separating the Ausgrid substation earthing from the rest of the building. This is achieved by earthing all HV equipment in the Ausgrid substation to the 11kV cable screens and to a set of local electrodes installed outside the rail corridor. The HV earthing within the Ausgrid substation will need to be insulated from the rest of the building. This can be achieved by consideration of insulating matting beneath HV equipment, earthing the LV neutral separately to the HV earthing and supplying any services in the room by an isolated supply

and/or appropriate insulation. Provision shall be provided for future installation of a possible DC blocking device.

- Separation of the building earthing from the rail earthing. Installation of heavy plastic membrane under or behind all reinforced concrete slabs and/or piers to electrically isolate the slabs and/or piers from soil and stray currents where practical to install. The impact of any impermeable or membrane layers on the earthing system performance shall be considered by the responsible person. An alternative to using plastic is to increase the concrete durability as per Clause 5.3.1.

The use of plastic rather than metal should be used for buried pipework where possible. In the event buried metallic pipework and/or cables are installed within the property, it is recommended to install within sealed non-metallic conduit.

6.3 Pipelines

Pipelines owned by other utilities are typically cathodically protected. CP systems in NSW need to comply with the NSW Electricity Supply (Cathodic Protection) Regulation with most requiring registration. Details on existing registered CP systems owned by third parties can be obtained through the NSW Corrosion Protection System – Online Register. Further information can be requested through the NSW Electrolysis Committee.

Where pipelines are in close proximity to power lines, the cathodic protection of the pipelines are not permitted to cause excessive interference to towers, poles or associated earthing systems (including metallic cable sheaths).

The anode beds associated with the cathodic protection system of the pipeline should be located away from tower, pole and earth pit locations. Adequate separation is to be proven by interference assessment.

7.0 INSPECTION AND TESTING

Visual inspections are made on above ground connections while interference measurements and correlation tests are required for assessing the corrosion effect on buried structures.

Procedures and techniques for measurement of interference shall refer to the NSW Electrolysis Committee's Guide for Measurement Techniques.

The locations of test connections to the structure and any reference electrode shall be documented to facilitate repeatability of measurements.

7.1 Baseline testing

Baseline testing shall be conducted to establish the level of interference on Ausgrid assets due to existing sources (e.g. existing heavy rail) prior to a new rail line, significant upgrade of rail facilities or pipeline cathodic protection system being installed.

7.2 Commissioning testing

Commissioning testing shall be conducted to prove compliance with design criteria of each element of a new rail line or pipeline cathodic protection system. Typical corrosion commissioning tests include:

- Structure-to-soil potential survey at all test points.
- Continuity or resistance checks (e.g. prove separation between Ausgrid MEN and Rail earthing)
- Insulating joint effectiveness checks
- Measurement of system resistance to earth to determine adequacy of coatings

- Correlation testing between Ausgrid assets and a new rail line.

7.3 Maintenance testing

Stray current patterns in railway transit areas can be subject to change by a number of different factors including sub-station scheduling, sub-station repairs, and deterioration of below pavement bonds and ties, and rearrangement of other underground structures as well as soil moisture content variations. A proposed electrolysis testing program is produced at the regular meetings of the NSW Electrolysis Committee and updates are circulated to each of the organisational representatives for consideration.

Potential tests on Ausgrid assets in the vicinity of or affected by a corrosion protection system, including any anode beds and the associated structure that is being protected. Ausgrid assets include:

- Metallic cable sheaths/armouring
- UGOH earths
- Substation earth grids
- Light column earths
- Water services (on the customer side of the meter – bonded the LV neutral)
- LV neutrals
- Sub-Transmission feeder earthing e.g. tower earthing, concrete poles and link box earthing

7.3.1 Test intervals

Maintenance and routine inspections on Ausgrid drainage bonds are currently performed by the respective Rail Operator.

Determination of test intervals to consider areas where stray current leakage is increased due to the large concentration of installed rail and/or sub-standard rail insulation or when the train drives (or parks) over the insulated joint (IJ) separating the stabling yard track from the main line e.g. Flemington and Mortdale Stabling.

8.0 RESPONSIBILITIES

8.1 Cooperative administration of electrolysis mitigation

Control of stray direct current corrosion problems may involve many operators of underground plant. For example installation of a drainage bond between one structure and the transit system negative, generally affects the condition of other underground structures in the vicinity. An arrangement that is mutually satisfactory is usually achieved through the NSW Electrolysis Committee to facilitate appropriate outcomes. This eliminates duplication of effort and ensures that any control measure will not jeopardise other structures as a result of protective measures applied.

Galvanic anode CP systems with output > 150mA or protecting a structure > 500m in length and all impressed current CP systems are required to be registered with the Department of Planning and Environment, the regulatory body administering the Electricity Supply (Corrosion Protection) Regulation 2014. Each CP system registered attracts an annual fee payable to the Department.

Notification is made for the following cases:

- Direct current traction system operators inform the sub-soil users of every alteration and extension likely to change the protection conditions of buried metallic structures in the vicinity of the traction system installation.
- The owner of a cathodically protected pipe or cable who becomes aware of changes to the electrical conditions of that pipe or cable, or who makes modifications to their protection

system must inform the owners of any neighbouring structures that may be involved, and proceed to make an investigation into any adjustments necessary to the protection system. All corrosion protection systems are not permitted to operate beyond the registered current for that particular system.

8.2 Ausgrid CP assets

Ausgrid CP assets such as drainage bonds, cathodic protection systems shall be stored in Ausgrid corporate systems SAP and GIS.

9.0 INTERFERENCE CRITERIA

All interference potential limit criteria stated in the following subsections are with respect to a copper/copper sulphate (Cu/CuSO_4) reference electrode unless specified otherwise. Silver/silver chloride (Ag/AgCl) reference electrodes shall be used in saltwater conditions.

All pertinent interference criteria listed in the subsections below shall be complied with. In exceptional circumstances dispensation may be given by the Ausgrid Corrosion Technologist.

9.1 Structures without cathodic protection

Non-cathodically protected assets affected by interference are subject to the limits in Table 1. Where there is evidence that the structure is already being corroded no positive potential change shall be permitted.

Table 1: Interference limits for non-protected structures

| Asset Type | Maximum Anodic Shift | Maximum Cathodic Shift |
|-----------------------------------------------------------------------------------|----------------------|------------------------|
| Cast iron and carbon steel structures, not embedded in concrete | 20mV | -200mV |
| Stainless steel structures not embedded in concrete | 20mV | -200mV |
| Carbon steel structures, embedded in concrete (including IR drop ^[1]) | 200mV | -200mV ^[2] |
| Copper structures, not embedded in concrete | 20mV | -200mV |
| Aluminium sheath | 20mV | -200mV |
| Lead sheath | 20mV | -200mV |

^[1] Refer of EN 50162:2004.

^[2] Cathodic shift greater than 200mV (usually) implies that there exist other parts which are subjected to anodic interference

For assets affected by non-fluctuating interference (i.e. pipeline CP system stray current) structure to electrolyte potentials shall be measured with the stray current source in and out of operation. The measured values during these two conditions shall be compared with each other. If the stray current source cannot be temporarily switched off, the interference should be extrapolated from tests made under different stray current operation conditions.

For assets affected by fluctuating interference (i.e. stray traction current) measurements for the evaluation of average interference values shall be taken over a 24-hour period as a minimum less

the quiescent period. The average shifts in the potential for buried structures relative to the natural potential shall not exceed the interference limits in Table 1.

For assets where the potential measurement is found to exceed the maximum cathodic limits in Table 1 then it is recommended to reduce the CP system output to bring the interference levels back to within the defined limits. Where CP system adjustments cannot be made such as when protection levels will be compromised, then anodic zones on the affected asset are to be identified and assessed for compliance.

On the MEN network greater changes in potential may be accepted provided the current discharge caused by the interference to any single electrode is < 1mA.

9.1.1 Assets without CP affected by fluctuating stray traction current

For assets affected by fluctuating interference (i.e. stray traction current) determination of the "average anodic" interference and "average cathodic" interference shall be taken over a 24-hour period as a minimum. The average shifts in the potential for buried structures relative to the natural potential shall not exceed the limits defined in Table 1. Note infrequent excursions less than 500ms may be excluded from the evaluation if they are not considered to be a corrosion risk.

The quiescent potential is determined as being the average value recorded during the period of least train movements. The average anodic potential is determined as the average of all excursions more positive than the natural potential. The average cathodic potential is determined as the average of all excursions more negative than the natural potential.

9.2 Structures with cathodic protection

The structure material establishes the criteria used for determination of a corrosive or protective state of a buried asset. The structure is considered cathodically protected if all parts of the structure maintain a potential equal or more negative than listed in column 2 (Maximum allowed Structure Potential) of Table 2. The maximum cathodic shift allowed before overprotection issues can occur is listed in column 3 of Table 2. Cathodic overprotection may cause accelerated disbondment of insulation coatings or hydrogen damage such as embrittlement or cracking of the metallic structure.

Table 2: Potential criteria for protected structures

| Structure Material | Maximum Allowed Structure Potential (Instant Off) | Maximum Cathodic Shift Acceptable To |
|-----------------------------|---------------------------------------------------|-------------------------------------------------|
| Ferrous | -850 mV | -2500 mV |
| Copper/copper alloy | -300 mV | -2500 mV |
| Lead (aerated conditions) | -650 mV | -1450 mV |
| Lead (anaerobic conditions) | -800 mV | -1450 mV |
| Mixed metal | As per the criteria for the most anodic metal | As per the criteria for the most affected metal |

9.2.1 -100mV polarisation shift criteria

Another criterion for protection is all parts of a structure shall be able to maintain an instantaneous off-potential which is at least 100mV more negative than the depolarised potential as shown in Figure 1. This criterion is not applicable if the structure is affected by stray current or significant galvanic corrosion effects.

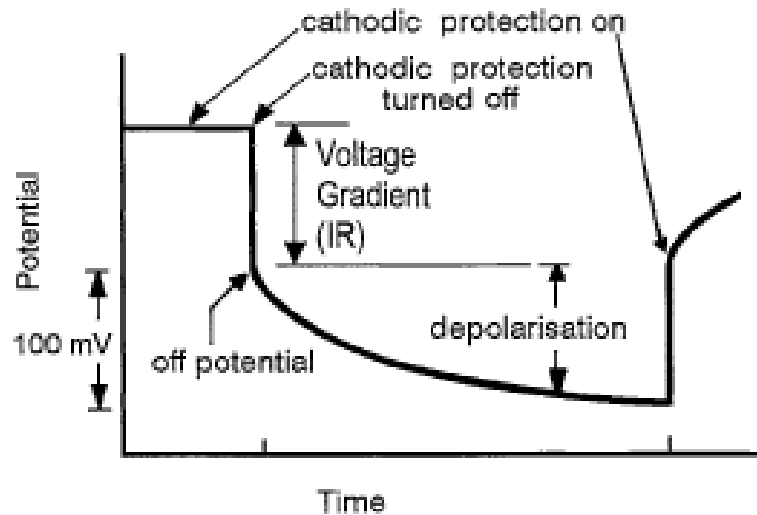


Figure 1: 100mV polarisation decay criteria

9.2.2 Concrete with embedded steel reinforcing

Concrete structures such as footings, retaining walls and concrete poles that have steel embedded reinforcing shall have a potential not more negative than the criteria in Table 3 to prevent catastrophic failure due to hydrogen embrittlement.

Table 3: Potential criteria for reinforced concrete

| Structure Material | Min Allowed Structure Potential |
|------------------------------------------------------|---------------------------------|
| Concrete with embedded reo (plain reinforcing steel) | -1166mV (Cu/CuSO4) |
| Concrete with embedded reo (prestressing steel) | -966mV (Cu/CuSO4) |

In addition to the criteria in Table 3, a concrete reinforced structure shall meet at least one of the following criteria to be considered as not at risk from corrosion: average of all excursions more negative than the natural potential.

9.2.2.1 Structures with cathodic protection

- a) Potential decay criterion (refer section 9.2.1). A potential decay over a maximum of 24-hour period of at least 100mV from the instantaneous off potential.
- b) Absolute potential criterion. An instantaneous off potential (measured between 0.1s and 1s after switching the DC circuit open) more negative than -786mV with respect to Cu/CuSO4.

9.2.2.2 Structures without cathodic protection

- c) Refer to ASTM C876 for concrete reinforcement potential measurement techniques and criterion for assessment for concrete structures without cathodic protection.

9.2.3 Assets with CP affected by fluctuating stray traction current

For assets affected by fluctuating interference (i.e. stray traction current) determination of the “average anodic” interference and “average cathodic” interference shall be taken over a 24-hour period as a minimum. The average shifts in the potential for buried structures relative to the quiescent potential shall not exceed the limits defined in Table 1. Note infrequent excursions less than 500ms may be excluded from the evaluation if they are not considered to be a corrosion risk.

The quiescent potential is determined as being the average value recorded during the period of least train movement. The average anodic potential is determined as the average of all excursions more positive than the natural potential. The average cathodic potential is determined as the average of all excursions more negative than the natural potential.

9.2.3.1 Structures with short polarisation time

The structure potential shall not be more positive than the criteria in Table 4. These criteria shall be applied to structures which have a short polarisation time.

Table 4: Criteria for structures affected by stray traction current with short polarisation time

| Structure Material | Criteria Description | | | |
|-----------------------------|-----------------------------------------------|-----------------------|-----------------------|-------------------------|
| | for 5% of test period | for 2% of test period | for 1% of test period | for 0.2% of test period |
| Ferrous | -850mV | -800mV | -750mV | 0mV |
| Copper/copper alloy | -300mV | -250mV | -200mV | +550mV |
| Lead (aerated conditions) | -650mV | -600mV | -550mV | +200mV |
| Lead (anaerobic conditions) | -800mV | -750mV | -700mV | +50mV |
| Mixed metal | As per the criteria for the most anodic metal | | | |

9.2.3.2 Structures with long polarisation time

For structures with a long polarisation time, depending on the size of the structure, the following criteria apply:

- Long buried structures: the potential shall not be more positive than the criteria shown in Table 2 for more than 5% of the test period.
- Compact buried structures: the potential shall not be equal to or more positive than the criteria shown in Table 2 for more than 10% of the test period.

10.0 RECORDKEEPING

The table below identifies the types of records relating to the process, their storage location and retention period.

Table 5 Recordkeeping

| Type of Record | Storage Location | Retention Period* |
|--------------------------------------------------------------------|----------------------------------------------------------------------------------------|-------------------|
| Approved copy of the Network Standard | Document repository Network sub process Standard – Company | Unlimited |
| Draft Copies of the Network Standard during amendment/creation | Records management system Work Folder for Network Standards (HPRM ref. 2014/21250/218) | Unlimited |
| Working documents (emails, memos, impact assessment reports, etc.) | Records management system Work Folder for Network Standards (HPRM ref. 2014/21250/218) | Unlimited |

* The following retention periods are subject to change e.g. if the records are required for legal matters or legislative changes. Before disposal, retention periods should be checked and authorised by the Records Manager.

11.0 DOCUMENT CONTROL

Document Owner : Head of Asset Engineering Policy & Standards

Distribution coordinator : Manager Asset Engineering Standards

