SA Water

Engineering

Technical Standard

TS 0372 – Electrical Safety of Metallic Pipes

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Application and Interpretation of this Document

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Users of this Standard accept sole responsibility for interpretation and use of the information contained in this Standard. Users should independently verify the accuracy, fitness for purpose and application of information contained in this Standard.

Only the current revision of this Standard should be used which is available for download from the SA Water website.

Significant/Major Changes Incorporated in This Edition

Nil.

This is the first issue of this Technical Standard.

Document Controls

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1 Introduction

Metallic pipelines are frequently installed in locations or easements near overhead and underground high voltage transmission and distribution power lines, and other electrical infrastructure.

Pipelines and construction equipment located within an area of influence of these electrical sources can be subjected to hazardous voltages which may have the potential to cause injury or death.

The main circumstances that give rise to electrical hazards on pipelines are:

a. Low Frequency Induction (LFI) due to parallel or near parallel positioning of the pipelines to high voltage powerlines;

b. Earth Potential Rise (EPR) due to pipeline proximity to high voltage assets;

c. EPR due to lightning strikes adjacent to power lines;

d. Capacitive coupling of pipelines adjacent to high voltage power lines; and

e. Accidental direct contact of pipelines with electrical systems.

1.1 Purpose

The purpose of this document is to provide guidance for Designers in both performing the AS/NZS 4853 electrical hazard design process and the recommendation of LFI/EPR mitigation measures to SA Water requirements.

1.2 Glossary

The following glossary items are used in this document:

Term	Description
AC	Alternating Current
ALARP	As Low As Reasonably Practical
Appurtenance	An accessible accessory or adjunct to a pipeline, e.g., a valve or cathodic protection test point.
ARGON	A software tool created to assist utility staff in developing safety criteria to match actual risk profiles in relation to power system earthing. The software is designed to be used in conjunction with the ENA Power Systems Earthing Guide (EG-0) and is referenced by AS/NZS 4853. https://www.energynetworks.com.au/resources/guidelines/industry-guidelines/
CDEGS	SES and Technologies Limited computing package Current Distribution, Electromagnetic fields, Grounding and Soil structure analysis software
Constructor	The organisation responsible for constructing and installing infrastructure for SA Water, whether it be a third party under contract to SA Water or an in-house entity.
CP	Cathodic Protection
DC	Direct Current
Designer	The organisation responsible for designing infrastructure for SA Water whether it be a third party under contract to SA Water or a Constructor, or an in-house entity. A Designer is a person who effects design, produces designs or undertakes design activities as defined in the South Australian WHS Act and Regulations.
EHIMP	Electrical Hazard Integrity Management Plan (per section 7 of AS/NZS 4853)

Term	Description
ENA	Energy Networks Association
EPR	Earth Potential Rise
Hazard	A source of potential harm
HIFREQ	A computational module of CDEGS that can solve any electromagnetic problem concerning networks of arbitrarily oriented aboveground and buried conductors and any of a comprehensive array of components typically found in power systems.
HV	High Voltage
IJ	Insulating Joint
KMZ	Zip-compressed file that stores map locations viewable in various geographic information system (GIS) applications.
kV	Kilovolts
LFI	Low Frequency Induction
Location SA	Service locating tool for South Australia http://location.sa.gov.au/viewer/
NER	National Electricity Rules
SA Water Network	A series of pipelines that transport water or wastewater between SA Water assets
PPE	Personnel Protective Equipment
Risk	The effect of uncertainty on objectives
SA Water	South Australian Water Corporation
TS	SA Water Technical Standard

1.3 References

1.3.1 Australian and International

The following table identifies Australian and International standards and other similar documents referenced in this document:

Number	Title
AS/NZS 4853:2012	Electrical Hazards on Metallic Pipelines
AS 2225:1994	Insulating gloves for electrical purposes
AS 60903:2020	Live working – Electrical insulating gloves
ENA EG-0:2022	Power System Earthing Guide Part 1: Management Principles. (Energy Networks Association)
AS/NZS 3000:2018	Electrical installations "Wiring Rules"

1.3.2 SA Water Documents

The following table identifies the SA Water standards and other similar documents referenced in this document:

Number	Title
TS 0440	Cathodic Protection Part 1 - Pipelines

1.3.3 Other Documents

The following table identifies other documents referenced in this document:

Title
Australian Drinking Water Guidelines (2011) – Updated September 2022 https://www.nhmrc.gov.au/about-us/publications/australian-drinking-water-guidelines#download

2 Scope

The scope of this Technical Standard applies to determination of the electrical safety of metallic pipes, existing or planned, within the SA Water Network, where longer parallel pipe runs exposed to adjacent powerlines is most likely to occur in comparison to short metallic distribution pipes.

Guidance on SA Water's requirements in performing the AS/NZS 4853 electrical hazard design process is provided. It should be noted that the AS/NZS 4853 standard applies to all metallic Network pipelines and appurtenances only, and not metallic pipes within SA Water treatment and pumping plant locations.

In some instances, short metallic distribution pipes may be close to electricity infrastructure, such as substations, which may have a high enough occurrence of fault frequency in combination with high EPR to require AS/NZS 4853 assessment. In such instances, discretion and professional judgement will be needed to determine if the aspects of this Technical Standard apply.

2.1 Technical Dispensation

Departure from any requirement of this Technical Standard shall require the submission of Technical Dispensation Request Form (TDRF) for the review and approval (or otherwise) of SA Water Principal Engineer, on a case-by-case basis.

The Designer shall not proceed to document/incorporate the non-conforming work before the Principal Engineer has approved the proposed action in writing via the Technical Dispensation Request Form (TDRF).

SA Water requires sufficient information to assess dispensation requests and their potential impact. The onus is therefore on the proponent to justify dispensation request submissions and provide suitable evidence to support them.

Design works that are carried out without being appropriately sanctioned by SA Water shall be liable to rejection by SA Water and retrospective rectification by the Designer/Constructor.

2.2 Design Criteria

The design criteria must be ascertained and agreed with SA Water or its representative during all stages of investigation, concept design and detailed design in order to achieve a value-for-money installation that is fit for purpose and with minimum or negligible risks to SA Water. The design criteria should consider the following aspects:

1. Life Cycle Costs

Designs should be innovative and incorporate the appropriate techniques and technology, in conjunction with the selection of appropriate equipment, to minimize the life cycle costs, while satisfying operation and maintenance requirements. Energy consumption must be given particular attention in this respect.

2. Security of Operation

Designs should take into account the failure of a single item of equipment or a fault in a particular area of an installation is confined to the associated part of the installation and does not affect the continuous operation of the remaining parts of the installation, where possible.

3. Reliability

The installations are to be designed to minimize the likelihood of a failure, taking into consideration the electricity supply characteristics, ambient conditions, load characteristics and operation and maintenance requirements.

4. Upgradability

The installations are to be designed to facilitate future upgrades where applicable.

5. Interchangeability

The installations are to be designed to maximize the interchangeability of components and assemblies as far as practical to improve flexibility and reduce the spare parts inventory.

6. Operation, Maintenance and Fault-Finding Facilities

The installations are to be provided with suitable and adequate facilities to allow ease of operation, maintenance and fault finding.

7. Environmental Considerations

The installations are to be designed and suitable equipment selected to avoid or minimize unacceptable impact on the environment as far as possible.

8. Safety Considerations

The installations are to be designed with the safety and welfare of construction, operation and maintenance personnel and the general public in mind, complying with statutory regulations. Wherever possible, electrical equipment and wiring should not be located in areas classified as hazardous.

3 Types of Hazards

There are two main mechanisms that voltages can transfer from a power system to a metallic pipeline: the Low-Frequency Induction (LFI) mechanism and the Earth Potential Rise (EPR) transfer mechanism.

LFI and EPR voltage transfer mechanisms occur both during normal load conditions of the power system and during earth fault conditions. Generally, it is only during fault conditions that voltage transfer creates public or personnel voltage hazards, whereas during normal three phase load conditions, it is generally only a corrosion concern, as opposed to a safety concern.

All the mechanisms that create a voltage hazard at one location of a pipeline can transfer potential along the pipeline where it may not be expected.

3.1 Low-Frequency Induction

Any power system involves both an electrical current and an electrical voltage on a conductor. Electrical current and voltage of an AC power system produces both magnetic and electric fields around the conductor; otherwise known as electromagnetic fields. When another conductor (such as a metallic pipeline) is within the power system magnetic field, a voltage is induced onto the adjacent pipeline, which may drive a current, if the pipeline has any connection to earth. Low-frequency induction refers to such induction specifically from a low-frequency such as 50 Hz electrical power. Figure 3-1 illustrates the LFI mechanism.

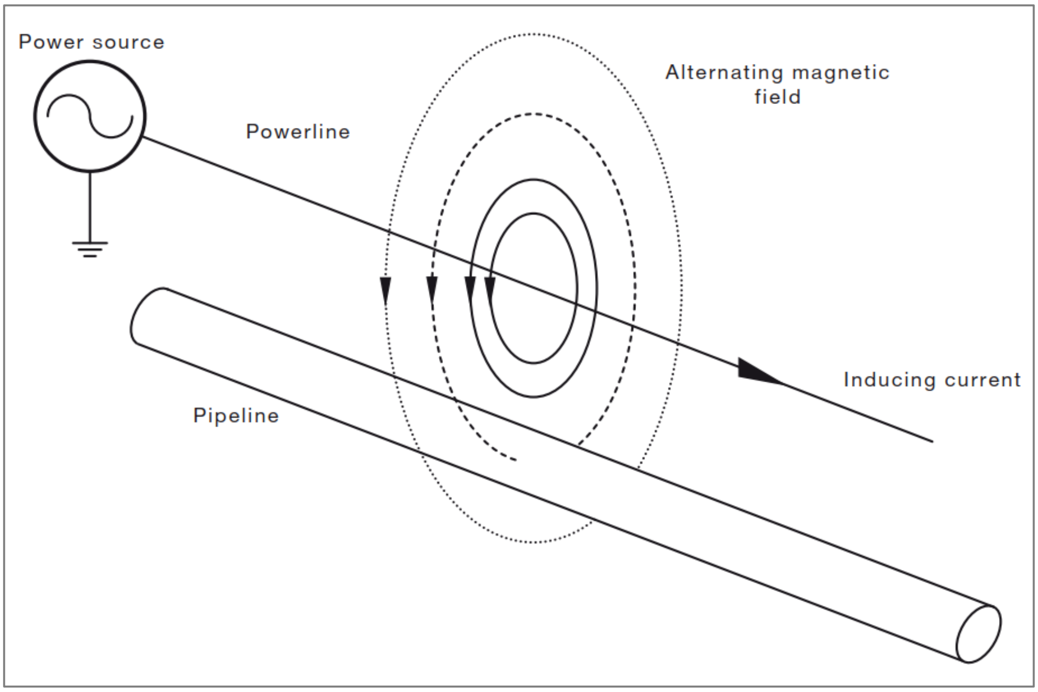

Figure 3-1 - LFI Mechanism (Excerpt Figure 3.2(a) of AS/NZS 4853)

The distance that the powerline and pipeline are parallel with one another creates an accumulative voltage to the pipeline, and the closer the powerline is to the pipeline, the greater the magnetic field, and hence a greater pipeline voltage that builds up.

3.2 Earth Potential Rise

During certain abnormal power system events, the power system may short-circuit to ground. In doing so, power may return through various conductive return paths, including powerline earth wire(s), metallic pipelines, and the soil.

Regardless, current will inevitably return through the soil, which firstly involves entering the soil at the location of earth-fault, such as a powerline pole. At the location of the fault, the current entering the soil creates a spike of voltage rise across the soil, which decreases with distance from the fault. This rise of soil voltage is driven by the 'Earth Potential Rise' (EPR) at the faulted location and is dependent on both the soil electrical resistivity properties at various depths of the soil, as well as the magnitude of fault current. As a prime example, when a pipeline traverses through an EPR region, the voltage of the pipe will be different to the voltage of the soil, and therefore a voltage difference between the soil surface and pipeline occurs. If a person was to touch the pipeline at this point, a 'touch voltage' will be experienced.

3.3 LFI at Normal Load Conditions

During normal operating power system conditions, only the LFI mechanism is relevant. The induced pipeline voltage is relatively small, but always present. Investigations can be conducted to confirm that the pipeline is not exceeding the 50V safety limit. (Refer AS/NZS 3000 S1.5.5.3, Appendix B.)

The key cause for concern is typically for the small, but constant current, creating current leakage on the pipeline, giving rise to corrosion. Since the normal load conditions occur somewhat constantly, pipeline voltage loggers can be used to accurately quantify voltage levels induced onto the pipeline. Whilst this is a recommended practice for quantification of corrosion issues, it is outside the focus of this document which focusses on voltage hazards which are greater than 50 V.

3.4 Earth-Fault Conditions

During abnormal power system conditions, as described in Section 0, EPR at the faulted location may occur. Additionally, LFI can also occur due to the fault current flow, and to a much greater extent than during normal load conditions, because of significant electrical fault current.

The time duration of a power system fault is generally very short, the frequency of fault is typically rare, and the probability of someone touching the pipeline during these conditions is also very low, which is why a probabilistic assessment process is adopted by AS/NZS 4853 to quantify the risk.

3.5 Transferred Voltage Along Pipeline

It is possible that hazardous voltages may extend well beyond the physical area in which it is expected to occur. This is because voltage can transfer along the pipeline. The extent to which the voltage transfers will depend on the integrity of any earthed points that may exist, the integrity of insulative coatings on the pipeline (if they exist), and the electrical resistivity of the soil. Hence, pipeline voltages may rapidly decay to negligible/safe voltages in short distances, or conversely, may extend for relatively long distances.

Transferred voltages, coupled with hazards induced from long parallel lengths of powerline, together with HV below-ground electrical cables, can become unexpected sources of voltage and pose hidden risks.

3.6 Lightning

A pipeline may, on rare occasions, experience a direct lightning strike, regardless of any electricity infrastructure. Even a below-ground pipeline is susceptible to transferring voltage from lightning along the pipeline. While this is less likely to be direct hazard for people, it can exceed pipeline insulation ratings and damage the coating or equipment on a pipeline.

3.7 Capacitive Coupling

Sections of longer metallic objects under a powerline which are poorly earthed, may become capacitively charged due to the electric field of the powerline. In this case, touch contact of the object may cause a minor capacitive discharge shock.

Capacitive coupling can also occur during construction/installation (i.e., suspended pipe lifted beneath or nearby a HV powerline by a vehicle on rubber tyres with no trailing earth forming capacitive plates and the person comes into contact with the vehicle may get electric shock).

4 Design Expectations

4.1 Overview of AS/NZS 4853

The Australian Standard AS/NZS 4853:2012 'Electrical Hazards on Metallic Pipelines' serves to provide the framework for assessing the safety of metallic pipelines with prospective voltage hazards from electricity infrastructure.

The standard identifies the responsibilities to pipeline owners, the voltage hazard sources and mechanisms, how the risks can be quantified (via calculations or computer modelling), and how the risks can be controlled (by using the Hierarchy of Controls).

The standard adopts the ALARP (As Low As Reasonably Practical) risk assessment methodology which is referred to in ENA EG-0 Power System Earthing Guideline.

Given that the risk quantification process can be arduous, AS/NZS 4853 provides three levels of voltage hazard assessment, to determine whether further consideration/remediation are required:

- **Level 1:** Using AS/NZS 4853 lookup tables, it can be quickly ascertained whether the length of parallel exposure or distance from the powerline- is sufficient to require further assessment or not. This is a first-pass assessment, adopting typical powerline fault levels and fault clearing times (for both EPR/LFI), and line loadings (for LFI), based on whether it is a 'distribution' or 'transmission' powerline.
- **Level 2:** Using calculations or computer modelling, the probabilistic risk assessment is performed based on pre-determined contact and fault frequencies outlined in the AS/NZS 4853 standard.
- **Level 3:** Further to Level 2 assessment, custom contact scenarios and fault frequency are considered in the analysis to further assess the risk probability and adopt any voltage hazards mitigations if deemed necessary.

It is important to keep in mind, that a Level 3 AS/NZS 4853 study showing safety compliance only shows that for any given contact with an asset, the probability of fatality is less than 1 in a million. Based on the ALARP principle, it is best-practice for workers to use/implement risk control measures where practicable, even when AS/NZS 4853 compliance is achieved for the pipeline.

4.2 Risk-Based Assessment Approach

An assessment shall be undertaken for all new pipelines, pipelines that are modified or pipelines where a review is warranted due to a change in local electrical conditions, for example, where a new powerline or substation has been installed in the vicinity. Notwithstanding the obvious changes, a review of the electrical hazards for all such pipelines should be revisited not more than every five (5) years.

4.2.1 Level 1/2/3 Expectations

SA Water expect the AS/NZS 4853 methodology process to be followed, as much as practicable and sensible to do so, in terms of the methodology and general intent to achieve a safe outcome.

Where general uncertainty exists regarding a metallic pipeline, a Level 1 study should be conducted. However, where it can be readily demonstrated that a pipeline is already non-compliant or that a Level 1 study would not result in compliance, proceeding directly to a Level 3 study may prove to be prudent, particularly if there is a need for speeding up the process to achieve a safe outcome.

Whilst AS/NZS 4853 suggests a Level 2 assessment is appropriate, due to excessive conservativeness with Level 2 assessments, and the lack of availability of relevant information from local electricity utilities, the Level 2 study should be omitted. A Level 3 study should be conducted with the best information and assumptions available.

Contact frequencies which form the AS/NZS 4853 Level 2 safety limits are generally considered an acceptable basis from which to calculate the Level 3 safety limits. This is considered 'pre-approved', unless stipulated otherwise, providing there are no obvious anomalies, such as where human contact would be significantly more probable than standard/typical pipeline and/or appurtenance locations. However, different contact scenarios based on the consideration of the locality of the pipeline/appurtenances may be proposed for such site-specific concerns.

Where the likely outcomes of assessments are indeterminate, both Level 1 and Level 3 studies shall be quoted as separately executable options.

4.2.2 Pipeline Modifications

Where an existing pipeline is modified, any electrical hazard studies previously performed should be sought from SA Water. Such studies need to be determined as appropriate to current installation/conditions, and whether the proposed modification will have any material impact on the safety of the asset (based on length, insulation joints, coating, appurtenances, displacement from existing route towards powerlines, etc).

If no existing study is available for the pipeline, then an electrical safety study for the entire pipeline should be performed.

If a comprehensive study of the pipeline is available, and a routine maintenance pipeline replacement section needs to be performed, then it should be assessed as to whether the replacement section has any material safety impact. For example, relocating closer to electricity infrastructure, or removal of earthed locations of the pipeline, would increase the risk. These aspects should be considered in context with the risks presented by the previously completed comprehensive study for the pipeline.

If a comprehensive study for the entire pipeline is not available, then the study to be performed for the section that is to be modified must extend to a logical boundary condition where the effects of EPR/LFI past such location cease to influence the section under study.

For any emergency replacement sections where a study does not exist, safe work practises will need to be employed. Concurrently, or within a reasonable timeframe after completion of emergency works, it shall be similarly assessed as per above.

Ultimately, the outcome of any pipeline section replacement is that it should not negatively impact on the voltage safety level of the pipeline.

4.3 Scope of Calculations

Pipeline start and end points, of which the assessment is to gauge compliance of the safety limits for the pipeline, and all appurtenances along the pipeline, are to be defined in the scope of any studies.

The design scope must specify whether it is just the voltage safety assessment that is required, or whether normal electricity load conditions and corresponding normal load induced LFI voltages for corrosion control purposes are to also be calculated.

Once the scope has been defined, the applicable electricity assets of relevance to the Level 1 or Level 3 study need to be determined.

The following information will be required from the electricity utility, which may include, but is not necessarily limited to, the following:

- Fault levels at source substation(s) or at particular points along powerline, projected for 5 years from present (or just for present if not available),
- Applicable powerline clearing times for each LFI powerline exposure being assessed,
- Normal load conditions projected for 5 years from present (or just for present if not available),
- Powerline route,
- Overhead earth wire types and bonding arrangement,
- Phase and earth conductor heights and geometries relative to the pole,
- Pole or tower earth resistances, and
- If any nearby substations are identified, earth resistances or system impedance, and fault level to determine EPR.

Reasonable assumptions are expected to be made for any information not able to be easily obtained, provided best-efforts have been given.

The following information will be required from the water utility, which may include, but is not necessarily limited to, the following:

- Pipeline extents,
- Pipeline wall thickness, diameter, material,
- Any anode or voltage safety earths,
- Design or test resistance values of any earthing,
- Earth resistance values of major assets, if known,
- Pipeline nominal burial depth,
- Construction or electrical properties of above mounted pipelines,
- KMZ or other format of route and asset/appurtenance locations,
- Pipeline coating type and thickness,
- Coating resistivity if known,
- Coating condition,
- Insulating joint locations and relevant details,
- Appurtenances, including: valves (including air valve, scour valve), CP test points, take-offs, meter sets,
- Any pipeline-specific contact scenarios to be considered,
- Any soil electrical resistivity data associated with, or nearby, the pipeline, and
- Any previous design reports which might have relevance.

Notwithstanding the above, the Designer is to communicate to SA Water if any information regarding SA Water assets is not provided which is pertinent, or could become pertinent, during the assessment.

All information requests of electricity utilities are to be managed by the Designer.

4.4 Minimum Calculation and Testing Requirements

4.4.1 Outcomes

A Level 1 study is to determine whether the Level 3 study is required. The Level 1 study must identify all possible LFI and EPR hazard sources and identify which ones pass and which ones do not. The hazard sources which do not pass will then become the scope of the Level 3 study.

A Level 3 study needs to assess:

1. Contact scenario safety limits for appurtenances as per AS/NZS 4853 Appendix K tables.

   K1 – Contact Scenarios that affect the public,

   K2 - Contact Scenarios that affect pipeline operators,

   K4 - Contact Scenarios that affect pipeline maintenance workers.

2. Metallic pipeline potential of the pipeline for each relevant power system LFI earth fault scenario assessed,
3. Corresponding touch voltages with 1 m reach distance from pipeline/appurtenances,
4. Plot of regions of pipeline/appurtenances where any safety limits do not comply,
5. Details or a plot highlighting how much the safety limits are exceeded, and
6. If safety limits of appurtenances are not complied with, details of calculated safety limits using surface treatments, as required, highlighting whether these surface treatments would provide compliance.

Note that if additional pipeline or appurtenance earthing is considered as a mitigation, additional modelling or calculations would be required. This may have implications on the overall scope of the study and the ensuing mitigation measures.

4.4.2 Calculation Tools

Hand-calculations alone are generally not considered as acceptable or transferrable for future computer modelling.

CDEGS HIFREQ module and relevant CDEGS tools specific to LFI studies which incorporate magnetic field calculations are endorsed by SA Water.

Other software may be used for the assessment, providing that the input files can be provided to SA Water. Alternative software must be readily available such that others are able to later inspect the model files.

4.4.3 Presentation of Raw Data/Model Data

Key data pertinent for replication of the study is required to be maintained in a clearly presented manner in the report, including referencing where such parameters are sourced from, and whether any assumptions are made. The modelling files used for the assessment are to be included with the final report when submitting to SA Water, unless otherwise agreed with SA Water.

4.4.4 Soil Electrical Resistivity Testing

Soil electrical resistivity testing shall be performed by trained personnel using the Wenner method, unless justification to use another method is presented for acceptance.

Only reputable equipment shall be used for soil electrical resistivity testing which is purpose-built, and capable of longer test spacings required for the task. The equipment should be able to provide the user with stake/loop resistance values so that the operator can reliably diagnose erroneous test measurements due to high stake resistances, which would otherwise lead to inaccurate data.

Equipment must be calibrated as per manufacturer requirements and as appropriate to a documented policy or process of the equipment owner.

Soil test spacings to include suitable spacings to determine the surface layer resistivity but also for profiling the deeper layer depths. Minimum of 6 x Wenner spacings from 1 m up to at least 32 m are desirable. Where physical space permits, greater spacings are preferable to ascertain the deeper layers most relevant to LFI studies with long parallel exposure LFI systems. Larger test spacings may need to be performed at distance from the pipeline to ensure the pipeline itself is not distorting test results.

When performing soil resistivity tests, spacings must continue to increase until a resistivity plateau is achieved, or justify why spacings are not continued. This is to ensure the resistivity spacings do not cease just as a major change in lower depth resistivity is being discovered in the testing process.

Reasonable efforts must be made to ensure the soil resistivity testing is performed away from the influence of buried metallic services.

4.4.5 Applied Electrical Earth Fault Level

ElectraNet publish ‘Connection Point Data’ for substation bus earth fault levels on their website. Depending on the arrangement of where the parallel exposure is, and the electricity transmission network, only a fraction of the substation earth fault level might be applicable to the LFI parallel exposure section. ElectraNet maintain KMZ data of their powerline network which may be useful for importing into software, although these files are not publicly accessible.

SA Power Networks do not publish earth fault levels on their website, although do publish an interactive map with capacity.

Location SA also publishes mapping information of electricity infrastructure.

Additional required information must be requested directly from these electricity utilities by the Designer on behalf of SA Water.

Earth fault levels should be based on values projected for 5 years from the present, or, apply a 10% allowance for future increase.

4.4.6 Calculation of Safety Limits

Calculation of safety limits for Level 3 assessments refers to ENA EG-0, which in turn refers to the use of Argon software, readily downloadable from the ENA website.

A key parameter is the primary clearing time of the earth fault. The National Electricity Rules (NER) publishes guidance on what the maximum acceptable clearing times for various voltage levels can be, although only for voltages of 100 kV or greater. Consequently, the NER can be applied for all ElectraNet clearing times, although is not applicable for any SA Power Networks clearing times. Care must be applied to use the remote-end powerline clearing time, where applicable, for powerline clearing times.

When using the Argon tool, it can be a common practise to round up the clearing time to the nearest 0.1 second increment, which can add unnecessary conservativeness. It should be noted that the Argon tool provides the ability to plot the design curve and obtain safety limits for clearing times with additional decimal places.

Contact scenarios and applied footwear are a dominating factor in calculation of safety limits. Footwear and contact scenarios are provided in AS/NZS 4853 Tables K1 K2 K3 K4 for Level 2 safety limits. These contact scenarios may be applied for the Level 3 assessments. Where footwear is not defined by AS/NZS 4853, 'Standard' footwear in Argon shall be assumed for public, and 'Electrical' footwear assumed for personnel.

Crushed rock and asphalt surface treatments should only be considered in calculation of safety limits if there are found to be compliance issues, and the surface treatments are being considered as a mitigation option. Alternatively, if the calculated touch voltages are relatively high, albeit still below the safety limit, they might be presented within the assessment for consideration and reference only.

Fault frequencies for calculating safety limits are to be in accordance with utility data and/or assumptions of ENA EG-0, of which a table of standardised fault level rates per 100 km lengths of powerline are provided, for various voltages, and overhead earth wire conditions. Consideration of lightning frequency in various regions of Australia is a contributing reason for varying powerline fault rates, as also is vegetation areas (falling limbs). South Australia is generally a lower lightning probability, and therefore if not a dense vegetation powerline, a fault level on the lower end of the fault rate can be applied. It should be noted that EPR transfer from electricity substations may require consideration of appreciably higher fault frequencies where multiple feeders can create EPR hazards at that substation.

4.4.7 Corrosion Assessment

AS/NZS 4853 not only considers voltage hazards, but also induced voltages from normal powerline load conditions, which may be cause for corrosion concern. The purpose of this assessment is not as an exhaustive corrosion impact assessment, but for the scenario where a new powerline or new pipeline may provide insight as to whether there is cause for concern.

The Designer must ascertain whether the relevant AS/NZS 4853 corrosion limit (4 VAC or 10 VAC) applies, (based on the soil electrical resistivity of the region) and identify any areas of corrosion protection non-compliance. The Designer should use average load values applicable over the year from each relevant powerline (where possible, not an overly conservative maximum conductor capacity), but also allow for some future increase. An appropriate current imbalance shall be considered in accordance with the NER balancing requirements, to ensure a conservative outcome.

It should be kept in mind that this assessment is somewhat irrelevant, if pipeline voltage logging has already been performed on the pipeline, and there are no changes to the pipeline or powerline systems.

The assessment should be based on load values projected for 5 years from the present, and if not available, based on the present load value with a 10% allowance for future increase.

4.5 Modelling Guidelines

In general, EPR/LFI modelling can be complex due to many parameters of a complex system, and information from multiple asset owners can be hard to obtain. Assumptions may be made after reasonable effort to obtain information has been made and documented, and it can be certain that using the assumed information will, based on judgement of the Designer, result in a conservative outcome.

By way of EPR/LFI assessment for SA Water assets, pipelines should be modelled using correct representations of the following:

- Outer diameter and metallic wall thickness,
- Impedance per unit length, or resistivity/permeability, representative of the pipeline metallic wall,
- Coating resistance or resistivity with thickness, with consideration of the age and condition (if known),
- Depth of pipeline,
- Height of powerline conductors, and
- Electrical equivalent resistance of earthed anodes, pipeline earthing, and earthed locations such as facilities, pumping stations, reservoirs, or where it is confirmed that large, earthed points occur.

Powerlines should be modelled using as accurate as practicable routes, with correct relative distance to the pipeline. The pipeline and powerlines are not likely to be a constant separation distance, and this shall be reflected in the modelling.

Consideration should be given to the location of an earth fault along the powerline, the length of exposure, and the fault level. A conservative assessment of the highest fault level at any point of the powerline and the longest parallel exposure distance, if providing a favourable outcome to AS/NZS 4853 compliance, is considered acceptable.

The height of the powerline conductor should be factored into the model. The magnetic field shielding effect of the earth wire must be included in the model; unless it is demonstrated that full AS/NZS 4853 compliance is achieved without including the earth wire. If an earth wire is included in the model, then the pole or tower earthing must also be considered.

Note that some SA Water facilities (such as pump stations) are bonded directly to adjacent power substations. If there is a possibility that a reasonable current return of the fault loop may occur through the pipeline, or the EPR of the source substation will impact the outcome of the assessment, then this should also be reflected in the modelling. Additionally, it should be noted that an earth fault of the lower voltage supplied to the pumps, with the source power substation in close proximity, if not directly bonded, can result in greater voltage hazards between the pump station and substation than voltage hazards of other earth fault scenarios from the substation. This is due to the mutual earth resistance, with overlapping zones of earth influence.

The pipeline voltages can be used to represent touch voltages and should be plotted as either a plan-view with colour representations of the voltage, or as a chainage plot.

Where non-compliant voltages on the pipeline occur, relative to the safety limit, then it should be listed in table form, or clearly shown diagrammatically, where the non-compliant assets or sections of assets are.

When mitigations are suggested as an outcome to a study, all parties shall be given the opportunity to discuss all inputs and assumptions, so the agreed level of conservatism is applied before mitigations are specified.

Surface treatment mitigations for any non-compliant appurtenances should be considered in the first instance. If increased safety limits of crushed rock or asphalt surface treatments suffice, then general details for required application/installation of such surface treatments should be provided. If, however, equipotential mats/mesh or pipeline earthing is required to meet compliance, or it can be demonstrated that surface treatments alone are not satisfactory or not cost effective, then this should also be documented, as required.

Modelling the normal load conditions for corrosion considerations should be done on a similar basis. The voltage difference between phases, as permissible by National Electricity Rules for voltage levels, should be factored into the model by way of imbalanced load currents, or as appropriate, to model the resulting increase of magnetic fields due to imperfect load balance.

Power cables should also be considered, and where applicable, include details of screen return currents (which can offset magnetic fields), trench configuration (flat or trefoil), screen bonding arrangements, earth continuity conductor, earth resistance values at either end of the cables, and any other detail as required which would determine whether or not AS/NZS 4853 compliance is achieved, and if not, what mitigations might be required. If compliance can be demonstrated by a simplified model of a cable without a screen and the magnetic field shielding effect, then this is a satisfactory approach.

4.5.1 Consideration of Insulating Joints (IJs)

Aside from their use in cathodic protection and decoupling of dissimilar metals, Insulating Joints (IJs) can reduce the voltage transfer along the pipeline. Modelling of IJs can be useful for demonstrating the reduced voltage hazards transferred along a pipeline. If proposed for use as a voltage safety mitigation measure, they must be modelled to demonstrate effectiveness.

For water pipelines, use of a value of 150 µS/cm (taken from the Australian Drinking Water Guidelines, and equivalent to 66.7 Ω.m) can apply to the resistance through the IJ from pipeline section to pipeline section. In the absence of more exact data, this value may be applied as a lumped resistance or conductor with set resistivity in the pipeline model. This does need to be converted to a resistance or resistance per unit length as per the below formula, which relates resistance to the resistivity, length and cross-sectional area of the IJ.

$$R = \frac{\rho l}{A}$$

Where: R is the calculated resistance for the given length l (Ω)
l is the length of the IJ (m)
ρ is the resistivity of the water (Ωm), and
A is the surface area of the pipe (m^2) and equal to πr^2 r being the radius of the pipe (m)

5 Design Report Requirements

Design reports submitted to SA Water shall be clearly presented with the following minimum information:

- Relevant project and scope information;
- An executive summary;
- Battery limits on the assets that have been included in the study (per section 4.2.2);
- Site plans, including asset details, age, location, earthing layouts and electrical infrastructure (or references to the specific drawings and revisions used for assessment);
- All relevant electrical data and modelling parameters;
- Soil test equipment, method, and test locations;
- Soil test results and computed models;
- Pipeline and power asset model and calculation details, including assumptions, and plots of the model, such that a knowledgeable reader can understand the specifics of how the model is prepared;
- Hazard scenario details, including asset lists and maps;
- Parameters for calculating safety limits, and applicable safety limits for various hazard scenarios and different asset contact scenario types;
- Options and recommendations for standardised mitigations/equipment modifications;
- Ongoing maintenance and testing recommendations or requirements; and
- Recommendations of further studies, if relevant.

A results summary table should include as a minimum:

- Contact scenarios considered;
- Maximum pipeline voltage as a percentage of allowable limit;
- If any allowable limit is exceeded, what mitigations are required, or if further studies are required to address; and
- Maximum pipeline voltage as a percentage of the corrosion voltage limit for normal load conditions.

In addition to the above, any pertinent information to summarise the AS/NZS 4853 compliance may be included. All relevant information shall be neatly presented in the report in a methodical manner.

All assumptions are to be noted in the report, and the Designer must have reasonable grounds to make them.

All LFI and EPR scenarios are to be documented, and where a scenario such as a powerline or nearby Stobie pole or substation is not considered, it must be documented as to why, with justifiable grounds.

6 Hazard Control Mechanisms and Standardised Mitigations

Hazards on pipelines should not pose a greater than negligible risk to people. If they do, we need to apply controls to achieve an ALARP risk.

It is the preference of SA Water to implement the various methods of mitigating voltage hazards on metallic pipelines in accordance with the Hierarchy of Control. The acceptance of all mitigation measures shall be gained from consultation with key stakeholders inside and external to SA Water prior to any implementation.

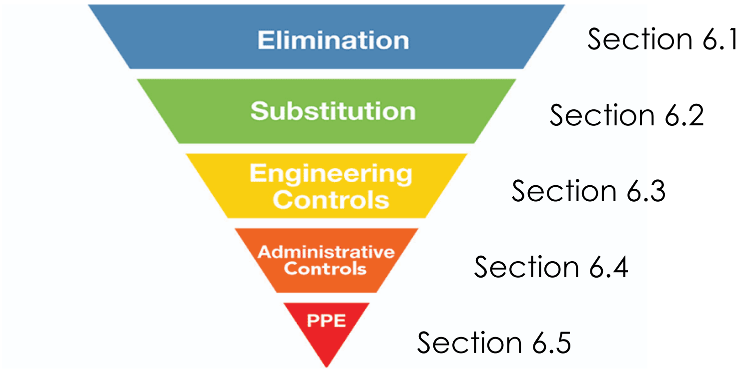

Figure 6-1 – Hierarchy of Control for Pipeline Hazards

6.1 Elimination

It is generally not practicable to eliminate the hazard source, as there is rarely an opportunity to relocate a powerline or SA Water infrastructure, however, temporary de-energisation of a powerline or HV asset in the region of a metallic pipeline could eliminate the hazard during construction activities.

Breaking the pipeline into smaller exposure lengths can be effective in eliminating a sufficient build-up of voltage, provided an appropriate level of insulation can be achieved between each section. This can be a costly option for an in-service pipeline.

6.2 Substitution

It is generally not practical to substitute a metallic water pipeline, however, use of a non-conductive pipe would remove LFI/EPR risks. This should be considered during pipeline replacement works or new installs, where project requirements can otherwise be met.

For the case of appurtenances or valves accessed on the pipeline, it may be possible to substitute a conductive appurtenance such as:

- CP test points – substituting test terminals for IP terminals, shrouded from contact,
- Valves in pits – where these require a rod to operate, a non-conductive tool may be used to operate the valve.

It may be appropriate to request a utility to temporarily implement faster protection settings during times of heightened risk, thereby substituting the risk of the longer fault duration with that of a shorter duration.

6.3 Engineering Controls

Engineering control measures are frequently adopted for LFI-borne voltage hazards. This can include pipeline grading control wires, IJs, earthed points, grading rings around the points of concern, equipotential pads, or impedance pads (surface treatments).

Engineered hazard control options, involve either creating resistance between the person and the pipeline (surface treatments), or decreasing the voltage between the ground that the person stands on (earthing), and the pipeline. Additional considerations and expenses associated with voltage control measures (additional computer modelling, etc) warrant careful consideration of whether such controls are desirable over convenient (high impedance) surface treatments.

Options for decreasing the voltage between ground and pipeline inevitably involve an earth, which leads to corrosion, if directly bonded, and is often in direct conflict with the design of the pipeline corrosion prevention systems or the engineered cathodic protection systems. Therefore, before implementation of any earthing mitigations, the aspects of cathodic protection must be considered.

Any earthing of pipeline/assets creates a step voltage hazard that would otherwise not occur. However, this trade off of risks is immaterial in any risk assessment, since touch voltages are always more of a safety concern than step voltages.

In terms of worker safety, step voltages are generally of little concern since it is expected that workers will always be wearing suitable footwear. However, working on hands and knees is a valid concern, although the vast majority of risk contacts are either hand-hand or foot to left hand, with foot-foot rarely resulting in a value of concern. Consideration must always be given for special circumstances where greater contact might reasonably occur.

As per AS/NZS 4853 standard contact scenarios, voltage hazards are of less concern for members of the public.

6.3.1 Pipeline Earthing

Earthing of a metallic above ground (and sometimes below ground) pipeline in strategic locations will minimise voltage hazards by keeping the soil at the earthed locations, closer to the voltage of the pipeline. It should be noted that addition of earthed points may cause the voltage magnitude to shift along the pipeline between earthed points. Therefore, in the absence of detailed desktop studies, this measure of hazard mitigation can be limited in effectiveness, and form only one of multiple layers of required protection. It may function well at each local point of earthing, but then voltage may rise in-between the earthed points, albeit generally to a lower value than otherwise.

In all such instances of earth point (or equipotential earthing) installations, careful consideration must be given to the use of DC decouplers, to ensure that the Engineering control measure doesn’t turn into an asset maintenance corrosion issue.

Each earthing electrode should be electrically tested prior to connection to the pipeline and demonstrated to have an acceptable resistance to remote earth criteria. If such resistance cannot be easily achieved, an additional electrode (ideally spaced at a distance of at least twice the first electrode’s depth away to avoid overlapping the electrical zones of influence), can be installed, and considered as a single electrode, to meet the design requirement and avoid overlapping the zones of electrical earth influence.

Earthing electrodes shall be a minimum ø13 mm copper bonded steel. Electrical continuity to the pipeline shall be not more than 10 mΩ from the top of the electrode to the pipeline metal, and comprise a PVC insulated 35 mm^2 stranded copper conductor, as a minimum. To obtain a low contact resistance with the pipeline, removal of any typical pipeline coating may be required.

When directly earthing without the use of DC decouplers, careful consideration of the materials such as copper or copper-bonded steel mentioned herein is required, with zinc being a better option for preventing corrosion.

Pipeline grading control wires, typically zinc, installed along the length of the pipeline, can be very useful in preventing accumulating induced voltage by way of constant current leakage. However, similarly, or even more so than IJs, it is prohibitively expensive unless installing at the time of the original pipeline installation, so is a rarely utilised control measure.

Section 6.3.4 details cathodic protection concerns when specifying pipeline earthing as a mitigation.

6.3.2 Appurtenance Earthing

Earthing of appurtenances can entail either an earth electrode (as discussed in Section 6.3.1) and/or a grading ring, depending on the locations and nature of expected contact. This has a dual purpose of earthing the pipeline to reduce overall maximum voltage of the pipeline, as well as reducing local touch voltage.

If there is a particular touch voltage concern, a grading ring may perform better than an electrode since it will maintain a wider area of soil to be of voltage as close as possible to the pipeline appurtenance.

Connections to the water pipeline can similarly be made as described in Section 6.3.1.

Section 6.3.4 details cathodic protection concerns when specifying pipeline earthing as a mitigation.

6.3.3 Equipotential Pads/Mats

A similar function to that of a grading ring around an appurtenance, the equipotential pad (also referred to as equipotential mat) minimises touch voltage rather than decreasing the voltage of the pipeline towards remote earth. It has less effect on the pipeline voltage than a buried grading ring or electrode. Workers may use temporary roll out mats, bonded to the pipeline, for field work, but, where mitigations are permanently required, permanent equipotential pads can be installed.

An equipotential pad could be a purpose made or off the shelf high voltage switching pad, installed on top or just below the surface. A disadvantage of this option is corrosion.

A more corrosion resistant option, albeit more expensive, is a concrete slab with steel reinforcement. For such an installation, the concrete must not be protected with a waterproof membrane, as it is intended that it remain exposed to ground moisture. The reinforcement mesh shall be tack-welded at every intersection, or as a minimum, be tack-welded from one corner to the opposite, and from the same corner, along both perpendicular edges of the mesh. This equipotential concrete and steel reinforced pad is not to be confused with a concrete high impedance surface treatment (Section 6.3.5), in which a waterproof membrane is required, in order to reduce the current flow through the human.

With the limitations of concrete moisture absorption from soil in mind, an ‘asphalt sandwich’, a layer of asphalt, with an equipotential grading mat on top, followed by a surface layer of asphalt, may be a more practical alternative.

A minimum 35 mm^2 Green/Yellow PVC insulated stranded copper conductor shall be used to bond to the pipeline.

Connections to the water pipeline can be made as similarly described in Section 6.3.1.

Section 6.3.4details cathodic protection concerns when specifying pipeline earthing as a mitigation.

6.3.4 Permanent Earthing and Cathodic Protection

Permanent earthing of pipelines and appurtenances may interfere with cathodic protection and require additional measures such as installation of DC blocking devices such as decouplers or PCR (polarisation cell replacement) devices between earthing and the pipeline. Such devices will prevent DC current flow (providing DC electrical isolation), whilst allowing the flow of AC current (for earthing), thus, providing the intended safety mitigation of the engineering control mechanism, and preventing corrosion and interference to the cathodic protection system. Refer to TS 0440 for further CP pipeline design direction.

6.3.5 Ground Impedance Layer Treatments

A ground impedance layer treatment provides a permanent or semi-permanent layer which mitigates voltage hazards by increasing the electrical resistance between people and the soil.

The most common ground impedance layer treatments are:

- Asphalt
- Crushed rock, and
- Dry concrete

Crushed rock is an approved SA Water mitigation, although upgrading to asphalt may be preferred where longevity is a concern. Asphalt is always the preferred ground impedance layer treatment, due to its superior safety performance, lifespan, and reliability, however, the Designer must always demonstrate the requirement for asphalt over crushed rock.

Dry concrete is not an approved SA Water mitigation.

Table 6-1 presents a summary of the pros and cons of ground impedance layer treatments.

Table 6-1 - Summary of Approved Ground Impedance Layer Treatments

Ground Impedance Layer Treatment	Pros	Cons
Crushed Rock	Easiest and cheapest to install. A good cost compromise if a long-life time is not required, or if only a marginal amount of increasing the allowable limit is required. Suited well for outdoors. Easy to inspect to see whether it is retained and free of fines.	Will spread out if a retention mechanism is not installed. Can fill with fines/dust/weeds which over time, can decay the electrical resistivity of the medium, and result in inadequate performance.
Asphalt	Highest level of ground impedance layer treatment safety. If installed correctly, is very durable, and suited well for outdoors.	Requires preparation of a road base underlay, to prevent cracking. Cracking reduces the electrical performance.

6.3.5.1 Crushed Rock

Crushed rock installed as blue gravel with rock diameter minimum 20 mm typically provides a 3,000 Ω.m resistivity. It is recommended to be installed to a 100 mm depth, to disperse heavy rainfall, help to prevent weed growth, and maintain a high resistance ground impedance layer.

The ground shall not be dug out to accommodate crushed rock at the same finished surface level without special drainage. Preference is for the rock to be mounded on top of a flat surface.

A consideration when installing the rock is to retain it within a concrete strip, or mechanical retention, which holds it in place but also gives regard to drainage.

Where crushed rock is proposed by the Designer, consideration of the requirement for maintenance should be allowed for.

6.3.5.2 Asphalt

Asphalt is a preferred ground impedance layer treatment because it provides higher allowable voltage limits than dry concrete or crushed rock and does not require as much planning to install.

However, for longevity of an asphalt installation, care must be given to provide a solid road base, particularly with regards to reactive soils with larger amounts of soil movement (expansion and contraction) throughout the varying seasonal cycles. An asphalt thickness of 100 mm shall be specified when calculating allowable limits, however, consultation with the Designer may deem that a documented thickness down to no less than 50 mm would be adequate.

- **Note:** Asphalt requirements presented in this section pertain to ground impedance only. Asphalt expected to carry traffic loads etc. should be appropriately designed for such applications.

6.4 Administrative Controls

Administrative controls may involve signage warning of the hazards, permanent work procedures, or toolbox meetings to discuss the site-specific maintenance, operation or construction activities.

Where electrical hazards exist, signage shall be applied on, or near, appurtenances to:

- Warn of specific hazards;
- Warn of unnecessary contact;
- Use PPE;
- Advise that when standing within a particular area that an equipotential mat/pad is installed;
- Advise that ground impedance layer treatments should be visually observed to be in good condition; and
- Preclude conducting pipeline inspections or non-emergency operations during thunderstorms.

Administrative (and PPE) layers of protection should be applied as a last resort, and ideally not be relied on by themselves to provide safe outcomes.

6.5 PPE

For purposes of this Technical Standard, various forms of PPE footwear are assumed as part of the probabilistic risk determination used by AS/NZS4853.

It should be noted that a hand-hand voltage contact has generally a greater bodily severity than hand-foot, for the same voltage, and as such the type of contact is important to consider. For example, PPE footwear is irrelevant when considering a hand-hand contact.

Site specific risk assessments should always be undertaken to determine suitable layers of protection. Any site specific PPE that is required as part of a risk assessment must be clearly articulated in the site Operation and Maintenance Manual.

6.5.1 Footwear

AS/NZS 4853 provides references to various levels of footwear safety and references the ENA EG-0 document. Between AS/NZS 4853 and ENA EG-0, three levels of footwear are defined: Standard Footwear, PPE Footwear, and Gumboot Safety Footwear.

For the purposes of calculation and determination of levels of electrical safety, the use of 'standard footwear' should be assumed. Electrical footwear must never be used as a single layer of mitigation, and that an additional source(s) of protection should also be in place.

6.5.1.1 Standard Footwear

Standard Footwear considers a probabilistic distribution curve of footwear worn by the public, which includes all sorts of footwear in varying conditions. This level of footwear is often considered when performing desktop AS/NZS 4853 assessments, so that conservatively, PPE does not form a critical aspect of the hazard assessment.

6.5.1.2 PPE Footwear

PPE Footwear considers a probabilistic distribution curve of construction and industry personnel work boots, of which the sole is considered as rubber or elastomer, in varying conditions, and dry or wet conditions. Ultimately, this footwear, although not specifically designed to provide electrical protection for hand-foot or foot-foot contact scenarios, does provide a higher level of electrical safety.

The benefit of PPE Footwear may be bypassed if the shoes are muddy, a worker encounters hand-hand contact, or is in a kneeling position.

6.5.1.3 Gumboot Safety Footwear

Gumboot Safety Footwear is defined by AS/NZS 4853 and ENA EG-0 as footwear that provides a much greater level of electrical protection. This footwear, when used as a risk mitigation measure, must be cleaned, and inspected prior to use, and replaced if worn or damaged.

Some benefit of Gumboot Safety Footwear may be bypassed if the shoes are muddy, a worker encounters hand-hand contact, or is in a kneeling position.

6.5.2 High Voltage Insulating Mats

Differing to that of an equipotential pad/mat, high voltage (HV) insulating mats provide an option for easy temporary deployment of a layer of insulating protection. During rainfall or occasions of waterlogged ground, the function of the mat could be bypassed. Insulating mats should be maintained as free from debris, as when any rocks or construction materials are stepped on, they may damage the mat, and could reduce service life.

HV insulating mats could deteriorate over time and may require testing to prove functionality. The voltage rating of mats of 3 kV or greater, if proven via testing should be sufficient for most pipeline voltage hazards encountered, which >> 90% of pipeline voltage hazards would be < 3 kV.

A limitation of the HV insulating mat is that it doesn't provide protection for hand-hand voltage contacts, for example, contact between two sections of a pipeline being jointed, or cathodic protection cables in one hand and the cathodic protection box to the other hand.

HV insulating mats should always be used in conjunction with other layers of protection.

6.5.3 High Voltage Gloves

HV gloves provide a similar function to that of the HV mat, although provide protection for both hand-hand contacts as well as hand-feet contacts, although are difficult to perform tasks with and so are not a preferred option.

HV gloves deteriorate over time and may require testing to prove functionality.

HV gloves should be compliant to IEC 60903 (note that this IEC standard supersedes AS 2225).

HV gloves should always be used in conjunction with other layers of protection.

LV gloves, or even regular PPE (unrated) leather gloves also provide a (lesser) layer of protection.

7 Testing and Verification

All records of risk treatment and testing are to be kept for the lifetime of the pipeline.

7.1 For Voltage Hazards

If mitigations for voltage hazards are likely to be significantly greater than the cost of testing, then the requirement for testing should be discussed with SA Water. If there is certainty in all parameters used in the modelling, then testing may not provide any benefit. A sensitivity analysis of modelling parameters, such as the pipeline coating condition, might also be an option prior to the expense of testing, to validate that there are hazards requiring resolution.

If the cost of installing mitigation is cheaper than testing, then it should be questioned on a case-by-case basis whether the mitigations should just be installed without the need for testing.

7.1.1 Testing for LFI Borne Hazards

For any situations where testing has been deemed as necessary due to LFI borne hazards, two testing options are to be considered for existing or newly installed assets.

7.1.1.1 Out of service powerline current injection test

Ideally, the powerline of concern would be placed out of service, and an off frequency current injection unit would be used to inject over the line, allowing for scaled touch voltage measurements to be made on the pipeline. This is rarely practicable due to reliability requirements of the power networks, and can be prohibitively expensive. Such testing may need to be planned many months or years in advance.

7.1.1.2 Correlation of powerline load data

A practical and cost-effective option for validating a LFI system or model of the LFI system, is to perform voltage logging at points of a pipeline for 24 h, with 1 minute interval recordings. Then, secure powerline load data for the same period, with 1 minute interval recordings (or as to match). Comparison of several points in the pipeline will reveal a correlation or a difference, and consideration of what parameters used in the modelling need to be adjusted can be made; this might include but not be limited to; adjustments to the soil model (or subsequent additional soil testing), pipeline coating resistivity and thickness/condition, or the average current leakage per kilometre of above-ground (or below-ground) pipelines. When the adjusted model is completed, the modelling of actual powerline LFI can be reassessed accordingly.

7.1.1.3 Hybrid current injection test and model test simulation

Another option which would not require interfacing with other utilities, nor incur disproportionate expense, is a scaled down current injection of temporary cable alongside the pipeline can be used in the area of concern. Touch voltages can be measured. Noting the exact separation distance of the current injection (for simulating LFI), then the temporary test circuit can also be modelled; results of each are then compared. Differences may inevitably occur, and similarly to the above, the model can be resolved accordingly.

7.1.2 Testing for EPR-transferred Hazards

For any situations where testing has been deemed as necessary due to EPR transfer hazards, or in lieu of a study (which would be reasonable where a powerline passes a Level 1 AS/NZS 4853 safety assessment for LFI, but not for EPR), then an EPR test may be a practical way to assess a hazard. The fall-of-potential method could be used to determine EPR contours from a pole as well as the local earth resistance; although methods to consider any interconnected earth wires must be employed.

7.2 For Corrosion Control

When the modelling of the normal load conditions has identified that induced voltages to a pipeline are greater than the AS/NZS 4853 4 VAC or 10 VAC limits, and/or the induced voltage is of concern to SA Water's corrosion control systems, testing of actual induced voltages may be requested.

A voltage data logger can be used for 24 hours or several days, to capture the average voltage during real-world power system conditions.

8 Standard Drawings

This section is a placeholder for future versions of this document to incorporate, when available, standardised drawings available for use by a Designer to specify mitigations, such as, but not limited to:

- Pipeline Earth Electrodes
- Appurtenance Earth Electrodes
- Appurtenance Earth Rings
- Appurtenance Equipotential Pads/Mats
- Asphalt Ground Impedance Layer
- Crushed Rock Ground Impedance Layer

9 Other Project Requirements

At project commissioning and completion, the Constructor shall follow the guidelines outlined in Section 7 of AS/NZS 4853, and provide SA Water with a documented Electrical Hazard Integrity Management Plan (EHIMP) and provide as-built documentation detailing (as a minimum):

- A list of mitigations that were put in place;
- Photos of mitigations;
- Layouts outlining the location of the mitigations; and
- Ongoing operational and maintenance recommendations.