Network Standard

Document No.
NS193

Title:
Ground movement, vibration and pressure limits near buried cables

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Technical Approver		Authorised By			
Name	Joseph Metti	Name		Dean Starkey	
Designation	Senior Engineer	Designation		Head of Asset Risk & Performance (Acting)	

Revision

No	Date	Description	Technical Approver	Authorised By
0	22/04/2022	A new standard for ground movement and vibration limits near buried cables.	Joseph Metti	Dean Starkey
1	21/08/2023	Revised and expanded vibration limits for buried cables in Table 3	Joseph Metti	Matthew Cupples
2	12/12/2023	Expanded and updated to include ground pressure limits	Joseph Metti	Darren Jenkins

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Scope

This standard sets the acceptable ground movement, ground vibration and ground pressure limits for Ausgrid's buried electrical cables to prevent damage to Ausgrid's assets due to major site works by other organisations.

This standard is intended to apply to major projects such as tunnels, deep excavations, major roadworks, piling works, rock breaking, large mobile crane loads etc. It does not apply to conventional trenching, road re-surfacing or minor works near Ausgrid's buried cables.

This standard does not deal with the requirements for major excavation works near or below Ausgrid's substation assets. For these projects, early contact shall be made with Ausgrid to establish the specific requirements for ground movement, ground vibration and ground pressure control near substation assets.

Reference Documents

All work covered in this document shall conform to all relevant Legislation, Standards, Codes of Practice and Network Standards.

Ausgrid Documents

NS001 Glossary of Terms

Electrical Safety Rules

Electricity Network Safety Management System Manual

Other Standards and Documents

AS 2187.2: Explosives – Storage and Use – Use of Explosives

AS/NZS 2566.1: Buried Flexible Pipelines – Part 1: Structural Design

Acts and Regulations

Electricity Supply (General) Regulation 2014 (NSW)

Electricity Supply (Safety and Network Management) Regulation 2014 (NSW)

Work Health and Safety Act 2011 (NSW)

Work Health and Safety Regulation 2017 (NSW)

Clause	Standard Requirements

1 General

1.1 The controls outlined in this standard shall be put in place to minimise the likelihood of damage to Ausgrid's buried electrical cable assets in the vicinity of major site works where significant ground movement, ground vibration or ground pressure may occur (e.g. tunnels, deep excavations, large mobile crane loadings).

1.2 This standard applies to any Ausgrid buried cable asset:

- where site works (e.g. tunnels, deep excavations) occur within 50 metres of the cable, or
- where predictive analysis indicates that ground movement due to site works will exceed 10mm at the cable location, or
- where predictive analysis indicates that ground vibrations will exceed 50% of the acceptable Peak Particle Velocity (PPV) limits in this standard at the cable location, or
- where predictive analysis indicates that ground pressures will exceed 50% of the acceptable limits in this standard at the cable location.

1.3 Organisations that perform site works near Ausgrid cable assets shall enter into an agreement with Ausgrid. This agreement shall cover the ground movement, vibration and pressure impacts associated with the site works and the necessary controls in accordance with the requirements of this standard.

2 Predictive Analysis of Ground Conditions

2.1 Organisations proposing to undertake site works near Ausgrid's underground cable network shall provide Ausgrid with one of the following technical submissions:

a) subject to Clause 2.2, a statement from a geotechnical engineer that the following conditions apply:

i) ground movement in any direction in the vicinity of cables will not exceed 10 mm,

ii) ground vibrations in the vicinity of cables will not exceed 50% of the acceptable PPV limits in this standard,

iii) ground pressures in the vicinity of cables will not exceed 100% of the acceptable limits in this standard, or

b) a technical assessment and report of the expected ground movements, ground vibrations or ground pressures. Information shall be produced by a geotechnical engineer and:

i) for ground movement, presented in the form of contour maps showing maximum predicted settlement and ground strains. For deep excavations, the horizontal movement shall also be determined,

ii) for ground vibration and pressure, shall include details about the model assumptions, the modelling method, modelling software and the predicted vibration or pressure levels for each Ausgrid asset.

2.2 For complex, high risk or critical cable asset locations, as determined by Ausgrid, all technical submissions shall comply with Item b) in Clause 2.1.

2.3 The technical statement / report from the geotechnical engineer shall provide details of the methodology that was used to arrive at the conclusions presented.

2.4 Following the submission of the predicted ground conditions, Ausgrid shall undertake an initial assessment to determine which assets are affected, what the resulting risks are, and what the subsequent control requirements will be.

3 Ground Movement

3.1 Predicted Ground Movements

Organisations proposing to undertake site works near Ausgrid's underground cable network shall provide Ausgrid with a technical submission in accordance with Section 2.

3.2 Location of Ground Movement Monitoring Stations

3.2.1 Where ground movement monitoring is required, one or more monitoring stations shall be installed at the most vulnerable cable / cable joint locations as determined by Ausgrid. The proposed ground movement measuring equipment, installation method, measuring technique and monitoring records shall be submitted to Ausgrid for review and approval.

3.2.2 Each ground movement monitoring station shall be effectively coupled to and in good contact with the ground.

3.2.3 All ground movement monitoring stations shall be installed as permanent installations at locations that are unlikely to require future repositioning. The aim is to ensure continuity of the baseline data that is collected for the location.

3.3 Acceptable Cable and Conduit Strains

3.3.1 Ground movement is measured in terms of strains and maximum tilts which are indicative of the longitudinal tensile strain in a buried cable. The strain due to the radius of curvature shall be added to the longitudinal strain.

3.3.2 The acceptable cable strain values in Table 1 are based on limiting cable pulling loads which have a factor of safety included for this short-term loading situation. Ground movement occurs over a longer term and requires a more conservative approach to provide for other factors such as thermal change.

3.3.3 The acceptable conduit strain values in Table 1 are based on the typical material properties of UPVC conduits.

Table 1 – Acceptable Cable and Conduit Strains

Material	Limiting Load	Stress	Elastic Modulus	Strain at limiting load
Stranded aluminium	5 kg/mm^2	50 MPa	22 GPa	0. 23%
Stranded copper	7 kg/mm^2	69 MPa	37 GPa	0.19%
Lead sheath	-	5.5MPa[1] (at yield)	-	0.3%[2] (at yield)
UPVC	-	28 MPa[3] (at yield)	3 to 3.3 GPa	1.0% (at yield)

[1] Value is age dependent due to creep.
[2] Value is for low cycle loading.
[3] Long term creep rupture.

3.3.4 Based on the strain values at limiting load shown in Table 1, the risk of damage due to cable strain shall be taken as follows:

- Low risk - cable strain of 0.1% - based on stranded aluminium or copper pulling limits with an additional factor of safety.
- Moderate risk - cable strain of 0.2% - based on accepted stranded aluminium or copper pulling limits.
- High risk - cable strain of 0.3% - based on stranded aluminium or copper pulling limits with a reduced factor of safety, and on low cycle strain limits for lead sheaths.

3.3.5 Refer to Clause 3.5 for the ground movement limits for cables, and to Section 7 for the required response due to increasing cable strain and risk of damage.

3.3.6 Bending stress and strain on the cable shall be ignored because of the flexibility provided by the stranded wire structure.

3.4 Impacts of Cable Installation Method

3.4.1 For direct buried and solid laid cables, which have little capability to redistribute strains, the acceptable cable strains as indicated in Clause 3.3.4 shall be used directly without any additional strain capacity due to the installation method.

3.4.2 For cables in conduits, an additional strain of 0.1% is allowed above the acceptable cable strains indicated in Clause 3.3.4. This provision accounts for the additional strain capacity that is available for cables within conduits due to movement of the cable relative to the conduit. This mechanism will have the effect of averaging out higher localised strains in the cable.

3.4.3 For ductlines encased in TSB or concrete, the curvature due to ground movement puts the ductline into bending. The bending tensile strains of conduits and cables on the tension side of the ductline shall be added to the ground tensile strain.

3.4.4 The total longitudinal strain on the conduits and cables in an encased ductline shall be determined using an appropriate methodology that considers the depth of the lever arm of the ductline and the radius of curvature of the settlement.

3.5 Ground Movement Limits

3.5.1 The ground movement limits contained in the Table 2 utilise the acceptable strains and other factors outlined in Sections 3.3 and 3.4. These limits shall apply in the vicinity of the cables unless alternative ground movement limits have been approved in writing by Ausgrid (refer to Section 6).

3.5.2 The impact of ground movement on buried cables need not be considered if it is predicted to be less than 10 mm displacement. Ground movement shall be taken as a vector sum of vertical and horizontal movements.

3.5.3 An abrupt localised step change (or shear) in ground levels, of any magnitude, is not tolerable by buried cables or conduits (including empty conduits) and will not be acceptable to Ausgrid.

Table 2 – Ground Movement Limits for Cables (excluding oil-filled cable joints)

Risk of damage to cables	Direct Buried Cables	Cables in Conduits	
	Maximum Tensile Ground Strain[1]	Maximum Tensile Ground Strain	Minimum Radius of Curvature of Ground Movement[2]
Low	<0.1%	<0.2%	500m
Moderate	0.1% to 0.2%	0.2% to 0.3%	350m
High	0.2% to 0.3%	0.3% to 0.4%	250m
Unacceptable	>0.3%	>0.4%	<250m

[1] Ground tensile strain is geometrically connected to the change in slope. Direct buried cables govern strain limit.

[2] Cable stress due to curvature of ductline limits strains. The lever arm for a concrete encased ductline with 4 rows of conduits is 870mm (Movement Limits for Buried Cables – D21/311209, Annexure C).

3.6 Pre-existing Cable Condition

The ground movement limits in Table 2 are based on cables in good condition and with minimal residual stresses due to previous movement or damage. Ausgrid may impose lower limits for cables that are known to be in poor condition, or where previous ground movement has occurred.

3.7 Oil-Filled and Gas-Filled Cable Joints

3.7.1 Oil-filled and gas-filled cable joints are vulnerable to leaks due to movement. Due to the likely network impact, environmental impact and repair costs, ground movement shall be kept within the "low risk" category in Table 2.

3.7.2 The longitudinal ground movement near oil-filled and gas-filled cable joints shall not exceed 10mm.

3.7.3 Where oil-filled or gas-filled cable joints are present in the impacted area, a longitudinal profile of the feeder shall be obtained so that the impact of the predicted ground strains on the joints can be fully assessed.

4 Ground Vibrations

4.1 Predicted Ground Vibrations

Organisations proposing to undertake site works near Ausgrid's underground cable network shall provide Ausgrid with a technical submission in accordance with Section 2.

4.2 Notification of Major Ground Vibration Events

4.2.1 Organisations that perform site works shall provide written notification to Ausgrid of all significant vibration producing events (blasting, demolition, excavation) that may have an impact upon Ausgrid's assets. This notification shall be submitted to Ausgrid at least two (2) weeks prior to each significant vibration producing event.

4.2.2 The required notification period shall be increased to at least four (4) weeks where the ground vibrations will exceed 80% of the acceptable PPV limits for Ausgrid's assets.

4.3 Location of Vibration Monitoring Stations

4.3.1 Where vibration monitoring is required, one or more PPV loggers shall be installed at the most vulnerable cable / cable joint locations as determined by Ausgrid. The PPV measuring equipment, installation method, measuring technique and monitoring records shall comply with the requirements of AS 2187.2.

4.3.2 Each ground vibration transducer shall be effectively coupled and in good contact with the ground, in accordance with AS 2187.2.

4.3.3 All ground vibration transducers shall be installed as permanent installations at locations that are unlikely to require future repositioning. The aim is to ensure a continuity of the baseline data that is collected for the location.

4.4 Vibration Monitoring Equipment

4.4.1 The PPV measuring equipment shall be fully calibrated and shall have a minimum sampling rate of 4000 Hz. The frequency range of the measuring equipment shall be at least 2 Hz to 250 Hz (-3 dB roll off), with a tolerance of 10% over this frequency range. The measuring equipment transducers shall be triaxial, and the axes shall be aligned with the buried cable direction at the location.

4.4.2 The selection of appropriate PPV measuring equipment (geophone or accelerometer) for a site shall be based on the critical vibration frequencies that need to be assessed, the expected signal content of the ground vibration spectra over various distances, and the corresponding capabilities of the measuring equipment to accurately capture the data.

4.4.3 On-site PPV monitoring shall be downloaded at regular intervals for analysis. Additional downloads may be required following notified vibration events of particular interest due to proximity, magnitude etc. or to assess the effectiveness of on-site vibration mitigation measures. Where site facilities allow, this information shall be remotely accessible via an internet connection.

4.5 Ground Vibration PPV Limits

4.5.1 For buried cable assets that are affected by ground vibrations, the PPV limits as indicated in Table 3 shall apply in the vicinity of the cables, unless alternative PPV limits have been approved in writing by Ausgrid (refer to Section 6).

4.5.2 The PPV limits indicated in Table 3 are based on the typical cables, configurations and support systems found within Ausgrid network, and apply to short term vibrations due to major site works.

Table 3 – Ground Vibration PPV Limits for Cables

Specific PPV[1] Limits (mm/s)		
Asset	**Alarm Limit (mm/s)**	**Stop Work Limit (mm/s)**
All cables (excluding the assets listed below)	80	100
Cables in conduits encased in TSB or concrete	50	60
Cable joints (excluding oil-filled and gas-filled transmission cables)	40	50
Oil-filled and gas-filled transmission cable joints	20	25

[1] PPV - Peak Particle Velocity.

4.6 Pre-existing Cable Condition

The ground vibration PPV limits in Table 3 are based on cables in good condition and with minimal residual stresses due to previous movement or damage. Ausgrid may impose lower limits for cables and joints that are known to be in poor condition.

5 Ground Pressure

5.1 Predicted Ground Pressures

Organisations proposing to undertake site works near Ausgrid's underground cable network shall provide Ausgrid with a technical submission in accordance with Section 2.

5.2 Location of Ground Pressure Monitoring Stations

Ground pressure monitoring is not required for Ausgrid's buried cable assets, except where advised otherwise in writing by Ausgrid for specific projects.

5.3 Ground Pressure Limits

5.3.1 For buried cable assets that are affected by ground pressures, the limits as indicated in Table 4 shall apply in the vicinity of the cables, unless alternative limits have been approved in writing by Ausgrid (refer to Section 6).

5.3.2 The limits indicated in Table 4 are based on the typical cables, configurations and bedding systems found within Ausgrid network, and apply to short term imposed ground pressures due to major site works.

Table 4 – Imposed Ground Pressure Limits for Cable Assets

Asset		Acceptable Limit (kPa)	
		At Asset Level	**Ground Surface**
Buried Cables	Polymeric cables up to and including 11kV	200	200[1]
	Taihan 33kV-132kV cables	120	120[1]
	PILC[3] 11kV cables	100	100[1]
	Oil-filled and gas-filled 33kV-132kV cables	100	100[1]

	All other cable types	100	100[1]
Cable Joints	Non-oil / gas filled cable joints	50	50[1]
	Oil and gas filled cable joints	25	25[1]
Conduits and TSB	Conduits in compacted bedding > 0.4m depth	-	120
	Conduits in compacted bedding < 0.4m depth	-	40
	TSB and concrete bedding / backfill	200[2]	200[1,2]

1 The ground surface limit can be increased using the method from AS/NZS 2566.1 and the asset level limit in this Table, where the depth of the asset is known. Calculations justifying the proposed limit shall be submitted to Ausgrid for review.

2 A higher limit for TSB and concrete will require a site-specific assessment of ground conditions and is subject to approval in writing by Ausgrid.

3 PILC – Paper Insulated Lead Covered.

5.4 Pre-existing Cable Condition

The ground pressure limits in Table 4 are based on cables in good condition and with minimal residual stresses due to previous movement or damage. Ausgrid may impose lower limits for cables and joints that are known to be in poor condition.

6 Alternative Ground Movement, Vibration and Pressure Limits

6.1 Ausgrid may consider alternative ground movement. ground vibration and ground pressure limits where it can be demonstrated that the buried cables and conduits can safely tolerate greater displacements, vibration and pressure levels.

6.2 It shall be the responsibility of the organisation proposing to undertake site works to demonstrate that any alternative ground movement, vibration or pressure limits are appropriate.

7 Response to Predicted Ground Movement, Vibration and Pressure

7.1 General

For all ground movement, ground vibration and ground pressure categories in Table 2, Table 3 and Table 4, any site locations where:

- buried cables are in poor condition,
- previous ground movement has occurred, or
- oil-filled / gas-filled cable joints are present,

shall be required to have a detailed assessment for reduced ground movement, ground vibration or ground pressure limits. Refer to Clauses 3.6, 3.7, 4.6 and 5.4.

7.2 Ground Movement

7.2.1 Where the predicted ground movements are less than 10 mm or are categorised as being ‘low risk’ in accordance with Table 2, no further requirements shall apply for buried cable assets, subject to Clause 7.1.

7.2.2 Where ground movement is categorised as ‘moderate risk’ in accordance with Table 2, a monitoring and reporting plan shall be provided to Ausgrid in accordance with Section 8.

7.2.3 Where ground movement is categorised as ‘high risk’ in accordance with Table 2, in addition to the requirements for the ‘moderate risk’ category, a technical report shall be prepared to justify the predicted ground movement, present alternative site works proposals and provide mitigation measures to protect the buried cables and conduits.

7.2.4 Where ground movement is categorised as ‘unacceptably high risk’ in accordance with Table 2, in addition to the requirements for the ‘high risk’ category, cable relocation shall be considered, or a

Deed of Indemnity shall be agreed to cover the consequential costs of potential cable failures and repairs.

7.3 Ground Vibrations

7.3.1 Where the predicted ground vibrations in the vicinity of cables do not exceed 50% of the acceptable PPV limits in Table 3, no further requirements shall apply for buried cable assets, subject to Clause 7.1.

7.3.2 Where the predicted ground vibrations will exceed 50% of the acceptable PPV limits in Table 3, a monitoring and reporting plan shall be provided to Ausgrid in accordance with Section 8.

7.4 Ground Pressures

7.4.1 Where the predicted imposed ground pressures in the vicinity of cables do not exceed the acceptable limits in Table 4, no further requirements shall apply for buried cable assets, subject to Clause 7.1.

7.4.2 Where alternative ground pressure limits have been approved in writing by Ausgrid (refer to Section 6), additional reporting requirements may apply for the buried cable assets.

8 Monitoring and Reporting

8.1 For all predicted ground movements that are categorised as “moderate risk” or greater, and for all predicted ground vibrations that will exceed 50% of the acceptable PPV limits, a monitoring and reporting plan shall be prepared by the organisation proposing to undertake the site works.

8.2 A monitoring and reporting plan is not required for predicted ground pressures, except where advised otherwise in writing by Ausgrid for specific projects.

8.3 The monitoring plan shall include details of the locations of ground movement and/or vibration monitoring stations, a program of reports to be provided and technical information about the proposed monitoring equipment to be used.

8.4 On-site ground monitoring and data acquisition shall be suitable for the purposes of measuring and controlling the actual ground movements and/or vibrations experienced on the site.

8.5 Where specific limits have been set and monitoring is used for controlling ground movement and/or vibrations, suitable ‘Alert’ and ‘Stop Work’ levels shall be determined, and a notification system established.

8.6 Notifications shall be automatically produced when a ground movement and/or vibration limit is exceeded, and all parties advised accordingly. Movement and vibration alerts shall contain the following details as a minimum:

- Date time stamp of the event,
- Event type as an “Alert” notification or “Stop Work” level,
- Project site location,
- Sensor location description,
- Ground movement in mm,
- Peak Particle Velocity in mm/s,
- Frequency range of vibration causing the alert.

8.7 For ground vibrations, the installed PPV measuring equipment shall capture the full waveform causing the alert, allowing this information to be downloaded by the monitoring service.

8.8 The following monitoring reports for ground movement and vibration measurements shall be prepared and submitted to Ausgrid:

- The first full day of monitoring,
- Each exceedance event,
- Weekly reports if no exceedance events are recorded.

8.9 The reporting frequency can be reduced to monthly where there are no exceedance events recorded over the preceding two months.

8.10 For ground movements, suitable criteria for determining the end of the monitoring period shall be established for review by Ausgrid. The required monitoring period may extend beyond the completion of site works to adequately capture any long-term ground movement impacts.