Network Standard

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NW000-S0096 NS161 SPECIFICATION FOR TESTING OF UNDERGROUND CABLES

ISSUE

For issue to all Ausgrid and Accredited Service Providers' staff involved with commissioning and testing of underground cables, 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Where this standard is issued as a controlled document replacing an earlier edition, remove and destroy the superseded document.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 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 any procedure, process or any other thing 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 or an alternative material or equipment to that currently approved the designer must obtain authorisation from the Network Standard owner before incorporating a variation to a Network Standard in a design.

External designers including those 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

Scope and Risks Addressed

This specification for testing pilot, low voltage and high voltage distribution and sub-transmission cable installations applies to cable installations which are:

- ☐ new
- ☐ repaired, or
- ☐ modified.

Where to for more information?

Section 2

Responsibilities

All test results shall be documented by Ausgrid's testing group or the Accredited Service Provider. The following information shall be recorded as a minimum:

- ☐ Testing organisation name
- ☐ Test date and location
- ☐ Accurate description of cable or equipment tested
- ☐ Cable 'passed' or 'failed' tests
- ☐ Details of test completed and result expressed as a value at a reference temperature (where applicable)
- ☐ Test equipment numbers and calibration dates.

Where to for more information?

Section 6

Tools and Forms

n/a

Types of Installations

This specification applies to the following types of cable installations :

- ☐ Pilot cable
- ☐ LV cable
- ☐ HV (5 AND 11 KV) cable
- ☐ Subtransmission cable.

Where to for more information?

Section 7, 9, 10, 11, 12

Tools and Forms

n/a

Test Requirements

Where there are post construction requirements that need to be considered they should be summarised here.

- ☐ Conductor resistance test
- ☐ Continuity check
- ☐ Core identification check (for pilot cables)
- ☐ Cross bonding/current injection Test
- ☐ Cross talk check (for pilot cable)
- ☐ Dielectric dissipation factor (DDF) and partial discharge (PD) measurement
- ☐ High voltage (HV) test
- ☐ Insulation resistance (IR) test
- ☐ Oil sample tests (for oil-filled cable)
- ☐ Phase identification
- ☐ Phase rotation check
- ☐ Remote energisation
- ☐ Sequence impedance measurements
- ☐ Serving test
- ☐ Sheath or screen resistance test
- ☐ Sheath voltage limiters (SVL)

Where to for more information?

Section 8, 9, 10, 11, 12

Tools and Forms

Annexure **B** Cable Insulation Resistance (IR) Test Report

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1.0 PURPOSE

This document is Ausgrid's specification for testing pilot, low voltage and high voltage distribution and sub-transmission cable installations. The purpose of performing cable tests is to prove the circuit is safe to energise or commission.

2.0 SCOPE

This specification applies to cable installations which are new, repaired or modified.

3.0 REFERENCES

3.1 General

All work covered in this document must 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

- Electrical Safety Rules
- ES 4 Accredited Service Provider Authorisation
- NS129 11kV Joints and Terminations - Paper Insulated Lead Covered Cables
- NS130 Specification for Laying of Underground Cables Up to and including 11kV
- NS156 Working Near or Around Underground Cables
- NS168 Specification for the Design & Construction of 33kV, 66kV & 132kV Underground Cables
- NS177 11kV Joints (including Transition Joints) and Terminations - Polymeric Insulated Cables
- NS181 Approval of Materials and Equipment and Network Standard Variations

3.3 Other standards and documents

- AS/NZS 1026 - Electric cables - Impregnated paper insulated – For working voltages up to and including 19/33 (36)kV.
- AS/NZS 1429.1 - Electric cables - Polymeric insulated - For working voltages 1.9/3.3 (3.6)kV up to and including 19/33 (36)kV.
- AS/NZS 1429.2 - Electric cables - Polymeric insulated - For working voltages 19/33 (36)kV up to and including 87/150 (170)kV.
- AS/NZS 1931.2 – High-voltage test techniques - Measuring systems.
- AS/NZS 60840 Power cables with extruded insulation and their accessories for rated voltages above 30kV (Um = 36kV) up to 150kV (Um = 170kV) Test methods and requirements
- ENA D(b)31 Guide for the Maintenance of High Voltage Paper/Oil Insulated Cables and Accessories, Energy Networks Association formerly the Electricity Supply Association of Australia.
- ENA Doc 001-2019 National Electricity Network Safety Code
- IEC 60141 – 1 Tests on Oil Filled and Gas-Pressure Cable and their Accessories
- IEC 60502 – 2 Power cables with extruded insulation and their accessories for rated voltages from 1kV up to 30kV - Part 2: Cables for rated voltages from 6kV up to 30kV.
- IEC 60229 Tests on cable oversheaths which have a special protective function and are applied by extrusion.
- IEEE P400.2/D5 Guide for Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF).

3.4 Acts and regulations

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

4.0 DEFINITIONS

Refer to NS001 Glossary of Terms.

5.0 INTRODUCTION

The purpose of performing cable tests is to prove the circuit is safe to energise or commission. The tests specified in this Network Standard are minimum requirements. Additional testing may be required in some cases due to local conditions. Where additional tests are required, they will be specified by Ausgrid prior to commissioning.

Where tests are specified, they must be carried out in accordance with this Standard unless otherwise stated by Ausgrid.

This Network Standard should be read in conjunction with NS130 Specification for laying underground cables up to and including 11kV and NS156 Working Near or Around Underground Cables.

6.0 RESPONSIBILITIES

Ausgrid or Accredited Service Providers are responsible for ensuring that the tests specified in this Network Standard are carried out in accordance with Ausgrid's requirements. An Access Permit for Test and Ancillary Work shall be arranged with the requirements specified in Ausgrid's Electrical Safety Rules prior to commencement of the tests. Within Ausgrid most of these tests will be carried out by Ausgrid's testing group, however some tests may be carried out by other competent staff such as jointers & technicians.

Ausgrid reserves the right to witness any HV tests required by this Network Standard carried out by specialised Accredited Service Providers.

All test equipment and instrumentation used for testing shall have been calibrated by a NATA Accredited Organisation and have a current test sticker affixed. The Accredited Service Provider is responsible for ensuring that test equipment and instrumentation used is traceable.

All test results shall be documented by Ausgrid or the Accredited Service Provider.

The following information shall be recorded as a minimum:

(a) testing organisation name

(b) test date and location

(c) accurate description of cable or equipment tested

(d) cable 'passed' or 'failed' tests

(e) details of test completed and result expressed as a value at a reference temperature (where applicable)

(f) test equipment numbers and calibration dates.

Within one week of the tests, the Accredited Service Provider shall provide Ausgrid's Representative (generally, the manager responsible for the asset) with a test report covering items (a) to (f) inclusive; except that calibration dates on item (f) may be excluded where the Accredited Service Provider demonstrates to the satisfaction of Ausgrid that these details are readily available from the Accredited Service Provider's records system.

7.0 TYPES OF INSTALLATIONS

7.1 New installations

A new installation is where a new section of cable has been installed between substations, or points of isolation.

7.2 Repaired installations - maintenance or repairs after failure or damage

A repaired installation is where a cable has been maintained or repaired after failure or damage resulting from, for example, an electrical fault, fluid leaks or serving damage. The repaired cable may have had a section of cable pieced in.

7.3 Modified installations - system modifications

A modified installation applies to any cable which has been attached to existing cables by jointing. Testing a modified installation will subject existing cables to these tests.

For example, a new section of LV cable from a distribution centre to a link box would be a new installation, while an extension to an existing distributor (by jointing on a new piece of cable) would be a modified installation.

8.0 GENERAL TEST REQUIREMENTS

8.1 General

Sections 9 to 12 state the specific tests to be performed on each particular cable installation. Test requirements are included for commissioning, after repairs and after modifications. Unless otherwise stated, each test is required on the complete Cable Installation. Where testing is required before jointing each section of cable, this is stated in the test requirement.

Tests should be performed in the sequence stated in Sections 9 to 12.

Unless otherwise specified, test procedures shall generally be in accordance with the relevant Australian Standards (Refer Clause 3.3).

8.2 Conductor resistance test

Determine the effectiveness of the conductor joints and terminations by measuring the dc loop resistance. The results of these tests can be compared with the manufacturer's conductor resistance usually expressed in ohms/km in the cable specification.

8.3 Continuity check

A continuity check is used to confirm the connection between ends of the cable.

This is usually only performed when a core or phase identification check or a loop resistance measurement is not required. This check is usually only required for fault location.

8.4 Core identification check (for pilot cables)

This test is performed by connecting one end of the core to a known conductor (e.g. screen).

The core is positively identified when the loop circuit is completed. The process is repeated until all of the cores are positively identified. Each core shall be marked as it is identified to ensure correct jointing/terminating.

8.5 Cross bonding/current injection test

Cross-bonding tests on the cable sheaths are performed to verify the integrity of the cross-bonding system. Usually only carried out on 132kV single core fully insulated circuits, this test ensures circulating sheath currents generated by induced voltages at full load will not adversely affect the cable rating.

This test involves injection of a 3 phase current into the cores of the cable, and measuring voltages and currents induced into the sheaths at each cross-bonding point along the complete cross bonding section. An injection current of greater than 50 A should be used. Sheath currents and voltages are to be measured at each cross-bonding point, earth point and termination. The cross-bonding connections shall be rearranged to prove incorrect connection, and checked again after correct restoration.

The procedure shall be repeated for each complete cross-bonding section of the cable run.

Current and voltage measurements are scaled up to the rated load current. Voltage values at isolated (not solidly earthed) cross-bonding points shall be less than the rated load current scaled voltages of the installation design.

Scaled voltage and current values for each cross-bonding point shall be reported to the branch responsible for cable ratings.

8.6 Cross talk check (for pilot cable)

This test determines if a measurable voltage is induced on the cores of any pilot pair from current flowing in the cores of another pilot pair.

Each pair of cores shall be shorted at one end. At the open circuit end, inject with variac and isolating transformer with unearthed secondary into each pilot pair, a voltage of 200V or a current of 3A.

Note: Because the multimeter is expected to give a zero reading, the instrument shall be checked for correct operation before use.

At the open circuit end, measure the induced voltage in the other pairs. The induced voltage should be unreadable on the multimeter.

8.7 Dielectric dissipation factor (DDF) and partial discharge (PD) measurement

This test is generally only applicable to 5kV / 6.6kV belted cables proposed to be operated at 11kV.

Sections of the cable installation shall be tested excluding joints. The test shall be applied between each conductor in turn and the other conductors connected to the sheath.

DDF shall be measured at 2kV, 3kV, 4kV, 5kV, 6.5kV, 7kV, 8.5kV, 10kV and 12kV ac voltage at 50Hz. The values of DDF determined by the test from 2kV to 7kV should be constant, and should not exceed 0.02.

The inception and extinction voltages and the respective magnitudes of partial discharge shall be measured. The magnitudes of partial discharge shall also be recorded at 6.3kV and 7.6kV.

PD measurements can also be made on 33kV to 132kV cables using a power system frequency (30-300Hz). Measurements are to be made at the high voltage test values, recording inception and extinction voltages and magnitudes where applicable.

8.8 High voltage (HV) test

The high voltage test involves applying one of the test options below between each phase conductor to earth and between phases (where applicable) for a specified period of time

- dc voltage,
- Very Low Frequency (VLF) voltage,
- ac voltage (generated via a resonant test set),
- 50Hz ac voltage, or
- power system voltage “soak”.

The remaining phases not under test shall be earthed.

The tests involving dc voltage, VLF voltage or ac voltage via an external test supply must be carried out by a suitably accredited testing organisation.

The insulation resistance shall be measured prior to HV testing.

In performing the high voltage test, the voltage must be slowly increased to the levels indicated in Sections 9 to 12 of this Network Standard, and maintained at these levels for the relevant time periods.

The cable is deemed to have passed the test if there is no disruptive discharge or puncturing of the insulation. The test current shall be essentially constant throughout the test.

High Voltage dc tests shall only be applied to HV XLPE insulated cables and/or accessories for the purpose of fault location.

For XLPE and EPR cables, it is accepted that for the present, unipolar pulsed test voltages shall be required for fault location.

For XLPE and EPR cables that require confirmation of the cable’s integrity prior to energisation, a pulsed dc test can be applied if the cable cannot be remotely energised or high voltage testing is not available on site. This test involves measuring the insulation resistance of the cable before and after the application of the high voltage dc pulses. The cable is to receive two high voltage dc pulses per phase, with the cable earthed for 1 minute in between each pulsing application and before and after each IR measurement. The cable is deemed to have passed the test if there is no disruptive discharge or puncturing of the insulation.

Pulsing voltages for 11kV and 33kV are $8kV_{dc}$ and $24kV_{dc}$ respectively.

If new cable is being installed into existing switchgear, the test voltage values for existing cable in the relevant tables in Sections 9 though to Section 12 of this document may be used.

Cables with known poor condition issues and suggested reduced test voltages are listed in Annexure A.

8.9 Insulation resistance (IR) test

The Insulation Resistance (IR) test measures the dc resistance of the insulation of the cable installation using an Insulation Resistance Tester (IRT). It involves measuring both the phase-to-phase and phase-to-earth insulation resistances of power cables, and core to earth, core to core and metallic screen to earth on pilot cables.
Because of cable capacitance, the IRT shall be applied until a stable reading is obtained. The readings shall be recorded on the cable IR test report (sample in Annexure B).

Tables in the relevant cable sections give IR limits for new and existing cable circuits. New cable circuits must achieve the minimum IR figures given. Existing cable circuits must meet the “Existing” IR figures to be returned to service with no extra notification. Existing cable circuits meeting only the “Advisory” IR limits may be returned to service, however Mains Engineering shall be notified. If the “Advisory IR limits cannot be met, the cable must not be returned to service unless authorised by System Control in consultation with Mains Engineering.

8.10 Phase identification

Phase identification must be checked by the use either of the phasing resistors or a continuity check of each individual core wherever possible after all jointing work has been completed. Alternatively, the current injection phasing method may be used.

Refer also to ESR clause 4.3.2.

Phase identification checks must be carried out to ensure cables have been correctly connected as indicated on existing system diagrams or System Alteration Order.

Phase identification may relate to either conductors or sheaths.

8.11 Phase rotation check

For low voltage services and direct distributors where the load has a multi-phase supply, a phase rotation check shall also be performed before disconnection if possible, and after reconnection of the load.

8.12 Remote energisation

8.12.1 Remote energisation precautions

Staff responsible for completing the jointing work must take precautions before signing off access permits (where issued) and energisation, to ensure that remote energisation poses no risk to staff or the public.

An example of an acceptable safety system is to implement the following safety precautions before the cable is remotely energised:

- All new and existing cable exposed for the work and all joints are backfilled or covered with at least two layers of sandbags prior to energising.
- Excavations in the immediate proximity of substations are backfilled.
- All other excavations are safely barricaded and protected, with temporary fencing and road plates/boarding if needed, and arrangements are in place for regular checking to ensure that they remain safely barricaded and protected.
- It shall be confirmed that no staff are present in substations or tunnels along the cable route.

8.12.2 Cable installation

The cable installation is remotely energised at system voltage without load current for five minutes. The cable installation shall only be energised by remote control or by the operation of a switch remote from the actual locations on the circuit where work was performed.

Reconnection and System Alteration Orders (SAOs) must provide details of where work has been carried out. This enables operating staff to determine the most appropriate energisation point.

Remote energisation is performed once the installation is completed. The phasing of the installation is checked as part of the return to service or system alteration checks by an operator

The cable installation is deemed to have passed the test if the installation does not trip system protection and does not show other signs of malfunction.

8.12.3 When remote energisation shall not replace the high voltage test

Remote Energisation shall not replace the High Voltage Test for a HV cable installation if any of the following conditions are met:

- the circuits cannot be energised by remote control or by the operation of a switch remote from the actual locations on the circuit where work was performed (See Note 1.).
- cable installation difficulties were experienced;
- the type and/or condition of cable installation is in doubt;
- where Ausgrid's representative considers it necessary (See Note 2.).

Note 1. It may be possible to place an additional distribution centre in LV parallel so that energisation may be undertaken at a distribution centre that is remote from the work site.

Note 2. Ausgrid may request HV testing where the cable being energised has been out of service or stored for long periods.

8.13 Sequence impedance measurements

These tests are carried out for protection settings, earth potential rise and fault analyses. The tests are circuit dependent.

Measurements shall be performed on all new feeders for voltages of 33kV and above (unless requested otherwise). The cable measurements shall include DC resistance, positive, negative and zero sequence impedances, and shall be expressed at a reference temperature of 20°C.

The measured values shall be compared with the calculated theoretical values, or those provided by the cable manufacturer.

8.14 Serving Test

8.14.1 Sub-transmission cables

For sub-transmission cables, a high voltage DC test between the metallic sheath or screen wires to earth is performed to test the integrity of the outer sheath. An IR test is performed prior to and after the high voltage test to assess the insulation integrity of the cable. The high voltage test voltages and acceptable IR limits are stated in Section 12.

8.14.2 High voltage cables

For 11kV XLPE or EPR cables, only an IR test between the metallic sheath or screen wires to earth is performed to test the integrity of the outer sheath for direct-buried cables.

The IR test voltage and acceptable limits are stated in Section 11.

8.15 Sheath or screen resistance test

Measure the dc resistance of the metallic sheath or screen wires and connections and compare with the manufacturer's sheath resistance usually expressed in ohms/km in the cable specification.

8.16 Sheath voltage limiters (SVL)

There are various types of Sheath voltage limiters (SVL) available (previously referred to as Cable Covering Protection Units – CCPUs). These units with non-linear voltage/current characteristics are connected to the metallic cable sheaths to limit the transient voltage rises to avoid puncturing the cable servings under fault conditions.

The units are tested to ensure their compliance with their original characteristics. The test shall be carried out in accordance with the manufacturer's recommendations.

9.0 PILOT CABLE INSTALLATIONS

9.1 Requirements

This section describes electrical tests for protection pilot cables. These include both distribution pilots (including translay and balanced voltage (BV) pilots) and sub-transmission pilot cables (including UPC and UCC pilots).

9.2 Required tests

Table 1 lists the tests that shall be performed on all new, repaired and modified distribution pilot cable installations. These include BV and translay pilots.

Table 1- Required tests distribution pilot cables

Test	New Cable	After Repair	After modification
Continuity	√	√	√
Core Identification	√	√	√
IR Test	√	√	√

Table 2 lists the tests that shall be performed on all new, repaired and modified sub-transmission pilot cable installations. These include UPC and UCC pilots.

Table 2 - Required test sub-transmission pilot cables

Test	New Cable	After Repair	After modification
Continuity	√	√	√
Core Identification	√	√	√
IR Test	√	√	√
HV Test	√	√*	√
Conductor Resistance	√	√*	√
Screen Resistance Check	√	√*	√
Cross Talk Check	√*	√*	√*

* where required

9.3 Continuity and core identification

9.3.1 Requirements

Prior to and after jointing, continuity and core identification shall be performed on all cores.

9.3.2 IR Tests

Prior to and after jointing, Insulation Resistance tests are to be performed on all pilot cables. IR shall be measured core to core, core to earth and screen to earth (for cables with a metallic screen).

Table 3 provides acceptable IR results for different types of pilot cable.

Table 3 - Acceptable IR test results

Cable type	IRT Voltage (Vdc)	New cable	Existing	Advisory
Translay or BV	500	100MΩ	0.25MΩ	0.1MΩ
Intertrip pilot	500	100MΩ	0.25MΩ	0.1MΩ
UPC/UCC and other high insulation pilots	1000	100MΩ	1MΩ	0.6MΩ

9.4 Sub-transmission general tests

9.4.1 Requirements

Conductor resistance, screen resistance and cross-talk checks shall be performed on completed sub-transmission pilot installations.

9.4.2 High voltage tests

For sub-transmission pilots, the high voltage tests in Table 4 shall be performed.

Table 4 - Required HV tests for Sub-transmission pilots

UPC/UCC Pilot Cable test	Test Duration	New Cable Test Voltage	Existing Cable (more than 1 year old) Test Voltage
core-to-core	1 min	10kVdc	1.0kVdc
cores-to-screen	1 min	15kVdc	2.5kVdc
screen-to-earth	1 min	15kVdc	2.5kVdc

10.0 LV CABLE INSTALLATIONS

10.1 Requirements

This section describes electrical tests for Low Voltage (LV) cables. These include LV distributors, street light cable installations and customer service cables.

10.2 Required tests

Table 5 lists the tests that shall be performed on all new, repaired and modified LV distributor, service and street light cable installations.

Table 5 - Required LV tests

Test	New Cable	After repair or modification
IR Test	√	√
Phase Identification	√	√
Phase Rotation	√*	√*

* where required

10.3 IR tests

IR tests shall be performed phase to phase and phase to earth.

Table 6 provides acceptable IR results for low voltage cables.

Table 6 - Acceptable IR test results for LV cables

IRT voltage (Vdc)	New cable	Existing	Advisory
500	200MΩ	20MΩ	0.1MΩ

10.4 General tests

Phase rotation checks shall be carried out after energisation but before providing load capability to a customer.

In addition to these tests, all new service cable installations shall have tests performed in accordance with the requirements of ES 4 – Accredited Service Provider Authorisation.

11.0 HV (5 AND 11 KV) CABLE INSTALLATIONS

11.1 Requirements

This section describes electrical tests for High Voltage (HV) cables rated from 5kV to 11kV.

11.2 Required tests

Table 7 lists the tests that shall be performed on all new, repaired and modified HV feeder cable installations.

Table 7 - Tests required on HV feeder cables

Test	New Cable	After repair or modification
IR Test	√	√
Phase Identification	√	√
HV Test	√*	√*

* Where remote energisation cannot be performed (Clause 8.12.2)

11.3 IR tests

11.3.1 Requirements

IR tests shall be performed phase to phase, phase to earth and screen to earth (for direct laid cables). For newly laid, repaired and modified cable circuits, IR tests shall be performed (a) between laying and jointing each section of cable, and (b) once all jointing works are complete.

IR Tests ensure a new, repaired or modified cable is fit for duty and assists in fault location prior to jointing.

Table 8 provides acceptable IR results for HV cables.

Table 8 - Acceptable IR results

Cable Type	IRT voltage (Vdc)	New cable	Existing
XLPE or EPR	500-1000Vdc	200MΩ	100MΩ

Notes:

1. Values below 500kΩ can indicate sheath damage. Values between 1MΩ and 10MΩ may not indicate damage in a single location. Fault finding can therefore be very difficult.
2. In the case of existing cables i.e. those already laid where the cable has passed a HV test, but has an IR result of less than 100MΩ then the cable is deemed fit for service and shall be placed into service. The definition of existing cables includes such cables already laid with line joints completed but not yet placed into service.

11.3.2 IR test exceptions

The only situation (Note 1) where it is considered impractical to IR test the final cable circuit is where switchgear is of a design where the feeder tails cannot be 'laid back' (e.g. Hazemeyer RMI units) and the load on the substation with this switchgear cannot normally (Note 2) be transferred away to permit the substation to be interrupted for testing purposes. In this case, the feeder may be remotely energised without an IR test provided the Remote Energisation precautions (Refer Clause 8.12) and the following additional precaution are implemented:

- All new and (as far as possible) existing cables are IR tested prior to making the final commissioning joint.

Notes:

1. While this relaxation of requirements is allowed in this situation, the conditions imposed by Ausgrid's Electrical Safety Rules for proving mains and apparatus de-energised and phasing of the cables must still be complied with, and may still require placing more than one substation in low voltage parallel.

2. In this context 'normally' means that the substation can only be held in LV parallel or supported by mobile generator outside normal business hours.

3. Reference should also be made to important Electrical Safety Rules (ESR) requirements specified in ESR clauses 9.6.2, 9.10.1, 10.4.1 & 10.4.2 re: appropriate isolations, insulation mediums for when test voltages are applied and where earths cannot be removed for application of test voltages that would prevent IR tests taking place.

11.4 High voltage tests

Care must be taken to determine the various types of cables that are connected to the circuit being tested, to prevent DC test voltages being applied to XLPE and EPR cable types.

High Voltage DC Tests must only be applied to HV XLPE insulated cables and/or accessories for the purpose of fault location.

For XLPE and EPR cables, the application of unipolar pulsed test voltages is current accepted practice for fault location.

Prior to jointing a cable that has been out of service for more than one year or is suspected of damage or water ingress, a HV test should be performed.

Where a HV cable installation consists of long runs of cable, or where the condition of the cable is in doubt, the project manager should speak with testing personnel before jointing. It may be possible to ascertain the condition of the cable by HV testing or fault location, before jointing.

Table 9 shows the test voltage type, test voltage level and test period for testing of 5kV cable circuits.

Table 9 Test requirements for 5kV cable circuits

Cable Test	Test Voltage		Application	Test Period
		In-service cable		
dc test	PILC	7.5kVdc	All phases to earth	15 mins
	PILC	10.5kVdc	Between phases	15 mins
VLF ac test	PILC/XLPE	7.5kV peak (5.5kVrms)	Each phase in turn with others earthed	15 mins
50Hz ac test	PILC/XLPE	5.5kVrms	Each phase in turn with others earthed	5 mins

Table 10 shows the test voltage type, test voltage level and test period for testing of 11kV PILC cable circuits.

Table 10 - Test requirements for 11kV PILC cable circuits

Cable Test	Test Voltage		Application	Test Period
	New cable	In-service cable		
dc test	25kVdc	17.5kVdc	All phases to earth	15 mins
	34kVdc	30kVdc	Between phases	15 mins
VLF ac test	25kV peak (17.5kVrms)	17.5kV peak (12.5kVrms)	Each phase in turn with others earthed	15 mins
50Hz ac test	15kVrms	12kVrms	Each phase in turn with others earthed	5 mins

Table 11 shows the test voltage type, test voltage level and test period for testing of XLPE and EPR cable circuits.

Table 11 - Test requirements for XLPE and EPR cable circuits

Cable Test	Test Voltage		Application	Test Period
	New cable	In-service cable		
VLF ac test	25kV peak (17.5kVrms)	17.5kV peak (12.5kVrms)	Each phase in turn with others earthed	15 mins
50Hz ac test	15kV rms	12kV rms	Each phase in turn with others earthed	5 mins

11.5 Voltage uprating of cable installations

Cables that are proposed to have their operating voltage up-rated usually from 5/6.6kV to 11kV shall be assessed during the project planning phase by PD, DDF & HV testing to ensure that the cables are capable of withstanding the new service voltage. For large projects it may be possible to test only a limited number of cables, eg a selected sample based on age / failure history / load sensitivity - advice should be sought from Mains Engineering.

12.0 SUB-TRANSMISSION CABLE INSTALLATIONS

12.1 Requirements

This section describes electrical tests for sub-transmission cable installations. Non-electrical tests for Fluid Filled cables are described in Section 13.

The testing requirements for sub-transmission cable installations vary according to operating voltage and cable type.

12.2 Required tests

Table 12 provides the tests that are required prior to each sub-transmission cable being energised.

Table 12 - Required pre-energisation tests for sub-transmission cables

Test	Commissioning	After repair	After modification
IR Test (conductor)	√	√	√
Conductor Resistance Test	√	√	√
Phase Identification (conductor)	√	√*	√
Sheath Resistance Test	√	√*	√
Phase Identification (sheath)	√**	√**	√**
Cross-bonding Test	√**		√**
SVL Test	√**	√**	√**
Sequence Impedance Measurements	√		√*
Serving Test	√	√	√
High Voltage Test (conductor)	√	√	√

* As appropriate for the particular repair or modification.
** Single core cables.

Note: Additional commissioning tests of the earthing/ECC system shall be carried out as per NS260 Clause 6.6.

12.3 IR tests

For repaired and modified cable circuits, IR tests shall be performed prior to jointing each section of cable, to ensure the existing cable is acceptable. It is advisable to IR test each section of new cable after laying and prior to jointing, to expedite the fault location process if required.

Table 13 provides acceptable IR results for different types of sub-transmission cable conductor insulation.

Table 13 - Acceptable IR results for sub-transmission cable conductor insulation

Cable type	IRT voltage (Vdc)	New cable	Existing
Sub-transmission	500-1000	200MΩ	100MΩ

12.4 Serving tests

Table 14 shows the test voltage level, and test period for serving tests on sub-transmission cables.

Table 14 - Requirements for serving tests on sub-transmission cables

Cable Type	New Installations		Existing Installations	
	33kV & 66kV	132kV	33kV & 66kV	132kV
PILC	Not Applicable	Not Applicable	Not Applicable	Not Applicable
XLPE	10kV /1min	15kV/1min	2.5kV/1 min	2.5kV/1 min
GAS PRESSURE	Not Applicable	15kV/1min	2.5kV/1 min	2.5kV/1 min
OIL FILLED	Not Applicable	15kV/1min	Not Applicable	2.5kV/1 min

Table 15 provides acceptable IR results for different types of sub-transmission cable serving insulation.

Table 15 - Acceptable IR results for sub-transmission cable serving insulation

IRT voltage (Vdc)	New cable	Existing
500-1000	200MΩ	100MΩ

Note: Where serving test results are beneath the IR limits defined in Table 15, they are to be compared to previous testing results. Further assessment or testing may be required depending on known issues with the cable or its life-cycle stage;

- if the IR value has decreased by 25% or more compared to the previous test result,
- particularly if the IR value is less than 100kΩ for oil-filled cable.

12.5 High voltage tests

For new cables, these tests shall be performed after laying and bedding. For existing and modified cables, the tests shall be performed after backfilling of joints, prior to surface restoration works. Electrical tests shall be performed after cable damage where it is suspected that electrical failure has been involved, or there is a possibility of future failure at the damage area.

Tables 16, 17 & 18 show the test voltages and test times for 33kV, 66kV and 132kV sub-transmission cables.

For feeders that comprise a mix of new & existing cables and/or different cable types, the test voltage shall be the **minimum** value of the test voltages for each individual cable section. The test type shall be chosen in descending order of those listed in Tables 16, 17 & 18, subject to test equipment limitations. If test equipment limitations prevent the full dc, VLF ac or resonant test voltage being applied then the power system "soak" test shall be carried out instead.

Approval may be sought from Mains Engineering to reduce these testing requirements on a case by case basis for cables with known problem, if needed to extend their service life.

12.6 General tests

An additional check for Gas Pressure cables after jointing but prior to installing the coffin, is to pressurise the joint sleeves and check there are no leaks. Prior to restoring the cable to service, check gas alarms and reset with all cylinders being at their operating pressures. Where Gas Pressure cable has experienced crush damage to the cable sheath or serving, a serving test shall be performed.

An additional check for cross-bonded cable installations where an existing joint was disturbed and the connections removed during repairs, is to perform a phasing check from the box through to the next cross-bonding box.

SVL checks must be performed after repair where the cable has carried fault current.

Table 16 - Requirements for tests on new & existing 33kV cables

Test Type	PILC	GP	XLPE
dc test	*New*: 75kV dc for 15 mins. *Existing*: 45kV dc for 15 mins.	*New:* 75kV dc for 15 mins. *Existing:* 45kV dc for 15 mins.	XLPE cable shall not be dc tested.
VLF ac test	*New:* 75kV$_p$ (53kV$_{rms}$) for 15 mins. *Existing:* 45kV$_p$ (31.8kV$_{rms}$) for 15 mins.	*New:* 75kV$_p$ (53kV$_{rms}$) for 15 mins. *Existing:* 45kV$_p$ (31.8kV$_{rms}$) for 15 mins.	*New:* 75kV$_p$ (53kV$_{rms}$) for 15 mins. *Existing:* 60kV$_p$ (42.4kV$_{rms}$) for 15 mins.
ac resonant test	*New*: 33kV$_{rms}$ for 15 mins *Existing:* 26kV$_{rms}$ for 15 mins.	*New:* 33kV$_{rms}$ for 15 mins *Existing*: 26kV$_{rms}$ for 15 mins.	*New:* 33kV$_{rms}$ for 15 mins. Existing: 26kV$_{rms}$ for 15 mins.
system voltage	*New & existing:* Power system voltage "soak" for 24 hrs.	*New & existing:* Power system voltage "soak" for 24 hrs.	*New & existing:* Power system voltage "soak" for 24 hours.

Table 17 - Requirements for tests on new & existing 66kV cables

Test Type	OF	XLPE
dc test	*New:* 135kV dc for 15 mins. *Existing:* 120kV dc for 15 mins.	XLPE cable shall not be dc tested.
ac resonant test	*New:* 72kV$_{rms}$ for 1 hr. *Existing*: 58kV$_{rms}$ for 1 hr.	*New:* 72kV$_{rms}$ for 1 hr. *Existing*: 58kV$_{rms}$ for 1 hr.
VLF ac test	*New& existing:* 90kV$_p$ (63.6kV$_{rms}$) for 15 mins – this is limited to the maximum rating of Ausgrid's test equipment so a system voltage test shall also be carried out.	*New& existing:* 90kV$_p$ (63.6kV$_{rms}$) for 15 mins – this is limited to the maximum rating of Ausgrid's test equipment so a system voltage test shall also be carried out.
system voltage	*New & existing:* Power system voltage "soak" for 24 hrs.	*New & existing:* Power system voltage "soak" for 24 hrs.

Table 18 - Requirements for tests on new & existing 132kV cables

Test Type	OF	OF with submarine section	XLPE
dc test	*New & Existing*: 264kVdc for 15 mins.	*New:* 264kVdc for 15 mins. *Existing:* 150kVdc for 15 mins.	XLPE cable shall not be dc tested.
ac resonant test	*New:* 132kV$_{rms}$ for 1 hr. *Existing:* 106kV$_{rms}$ for 1 hr.	*New:* 132kV$_{rms}$ for 1 hr. *Existing:* 106kV$_{rms}$ for 1 hr.	*New*: 132kV$_{rms}$ for 1 hr. *Existing:* 106kV$_{rms}$ for 1 hr.
VLF ac test	*New & Existing*: 90kV$_p$ (63.6kV$_{rms}$) for 15 mins – this is limited to the maximum rating of Ausgrid's test equipment so a system voltage test shall also be carried out.	*New & Existing*: 90kV$_p$ (63.6kV$_{rms}$) for 15 mins – this is limited to the maximum rating of Ausgrid's test equipment so a system voltage test shall also be carried out.	*New & Existing*: 90kV$_p$ (63.6kV$_{rms}$) for 15 mins – this is limited to the maximum rating of Ausgrid's test equipment so a system voltage test shall also be carried out.
System voltage	*New & Existing*: Power system voltage "soak" for 24 hrs.	*New & Existing*: Power system voltage "soak" for 24 hrs.	*New & Existing*: Power system voltage "soak" for 24 hrs.

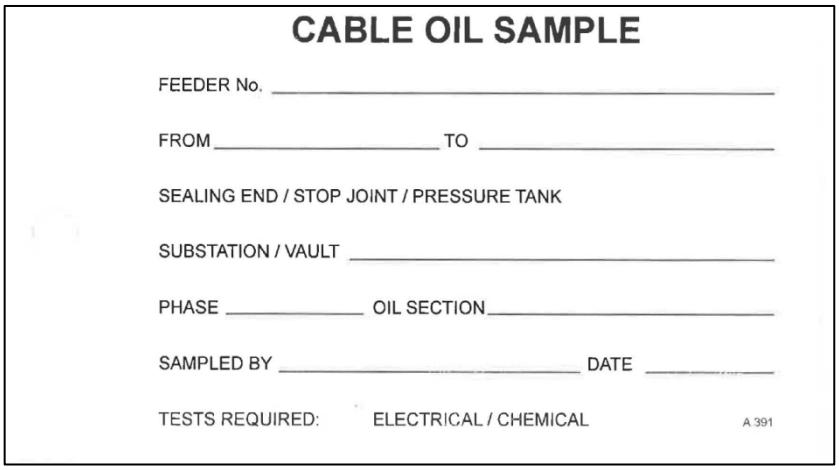
13.0 OIL SAMPLE TESTING REQUIREMENTS

13.1 General

Oil samples shall be taken from all 132kV oil-filled cables and accessories during scheduled maintenance and submitted to Ausgrid's testing laboratory for analysis. The purpose of the tests is to provide Ausgrid with data that can be used to determine degradation of a cable and other metrics for identifying possible failure modes, reliability and life cycle factors.

13.2 Sampling Requirements

Oil samples are to be collected in an approved container and labelled using the following tie-on tag, which is supplied by Ausgrid's testing laboratory. Personnel collecting oil samples must ensure details recorded on the label are complete and correct before submitting for testing.



CABLE OIL SAMPLE

FEEDER No. _____

FROM _____ TO _____

SEALING END / STOP JOINT / PRESSURE TANK

SUBSTATION / VAULT _____

PHASE _____ OIL SECTION _____

SAMPLED BY _____ DATE _____

TESTS REQUIRED: ELECTRICAL / CHEMICAL A 391

13.3 Test Requirements

Oil samples shall be tested to determine the level of each component specified by Table 19.

Table 19 – Oil Test Requirements

Test	Component	Alert level
DGA	Hydrogen (H_2)	> 150 µl/l
	Oxygen (O_2)	> 100 µl/l
	Nitrogen (N_2)	> 100 µl/l
	Methane (CH_4)	> 30 µl/l
	Carbon Monoxide (CO)	> 100 µl/l
	Carbon Dioxide (CO_2)	> 100 µl/l
	Ethylene (C_2H_4)	> 20 µl/l
	Ethane (C_2H_6)	> 25 µl/l
	Acetylene (C_2H_2)	> 2 µl/l
	Propane (C_3H_8)	n/a
Moisture	H_2O	> 10 ppm
Dielectric	Dissipation Factor @ 90 Deg. C Resistivity @ 90 Deg. C Breakdown Voltage	> 0.02 < 60 Gohm < 65 kV
PCB	Polychlorinated bi-phenyls	> 2 ppm

Test results that exceed the Alert level shall be noted on the test report, and advice should be sought from Mains Engineering on any actions that may be needed.

13.4 Reports & Recording

Ausgrid's testing laboratory shall issue a written report for each oil sample tested. The report must at a minimum provide:

- Unique Report Number
- Customer details
- Sample details: Feeder Route | Feeder No.| Phase | Substation Vault | Oil Section | Sampling Point |Sample Date | Received Date.
- Test results for each component with the following column headings:- Test | Component | Results | Units | Test Method (reference Standard)
- Comments as applicable, including notes that alert levels have been infringed.
- Contact details and signature of Testing Officer

Ausgrid's Testing Laboratory shall maintain a record of test results in electronic spreadsheet or database form that is accessible by all relevant Ausgrid staff.

14.0 RECORDKEEPING

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

Table 20 – 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	Work Folder for Network Standards (HPRM ref. 2014/21250/257)	Unlimited
Working documents (emails, memos, impact assessment reports, etc.)	Record management system Work Folder for Network Standards (HPRM ref. 2014/21250/257)	Unlimited

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

15.0 AUTHORITIES AND RESPONSIBILITIES

For this network standard the authorities and responsibilities of Ausgrid employees and managers in relation to content, management and document control of this network standard can be obtained from the Company Procedure (Network) – Production / Review of Engineering Technical Documents within document repository. The responsibilities of persons for the design or construction work detailed in this network standard are identified throughout this standard in the context of the requirements to which they apply.

16.0 DOCUMENT CONTROL

Content Coordinator : Manager - Transmission and Distribution Mains Engineering

Distribution Coordinator : Manager Network Standards & Electrical Safety

Annexure A – Testing of selected 132kV cable circuits

The normally accepted test voltages applied in Section 11 should be reduced where special circumstances warrant it; for example, in the case where submarine cables are involved, or where an installation contains elements (such as specific joints) which are known to be prone to failure.

Table A1 lists existing 132kV cable installations that have special conditions, and suggests maximum test voltages to be applied should the occasion arise. Included in the schedule are ex-ECNSW, ex-SCC and ex-SE feeders.

Table A1 - Reduced test voltages for selected 132kV cable installations

Feeder	Destination	Cable Make	Suggested Test Voltage (kVdc)	Reasons for reduced test voltage
929	Lane Cove - Dalley St	Sumitomo	150	Submarine cable
928/3	Lane Cove - Dalley St	Sumitomo	150	Submarine cable
92L/1	Dalley St - Surry Hills	Pirelli	150	Suspect joints
92L/3	Lane Cove - Dalley St	Pirelli	150	Submarine cable
92M	Lane Cove-Surry Hills Tee Lane Cove - Dalley St	Pirelli	150	Submarine cable

Annexure B - Sample IR test report

To: Supervisor _____

CABLE INSULATION RESISTANCE (IR) TEST REPORT

Time:_____ Date: _____

Location/Project: _____

Procedure:

Phase-to-Phase and Phase-to-Earth IR readings are to be taken before and after jointing works.

Equipment:

500V Megger with minimum range 200MΩ

Instrument No.:_____ Calibration Date:_____

Minimum IR Values for Power Cables (from NS 161 Clause 9.4.2):

Cable Type	New Cable	Existing Cable(1)	Advisory(2)
Low Voltage	200MΩ	20MΩ	0.1MΩ
High Voltage	200MΩ	100MΩ	5MΩ

"Existing Cable" are cables that have been in service or are older than 1 yr. If "Existing Cable" values are not achieved but "Advisory" are, the cable may be returned to service but the results must be reported to your Supervisor.

If "Advisory" values are not achieved, the matter must be referred to your Supervisor who will make a decision with the System Operator as to whether the cable shall be returned to service. Alternatively, Network Test may be contacted to arrange a cable test.

Results:

Cable Type/Description: _____

Before	A-B		A-N		A-E		PASS / FAIL
	A-C		B-N		B-E		
	B-C		C-N		C-E		
After	A-B		A-N		A-E		PASS / FAIL
	A-C		B-N		B-E		
	B-C		C-N		C-E		

Comments:_____

Cable Type/Description: _____

Before	A-B		A-N		A-E		PASS / FAIL
	A-C		B-N		B-E		
	B-C		C-N		C-E		
After	A-B		A-N		A-E		PASS / FAIL
	A-C		B-N		B-E		
	B-C		C-N		C-E		

Comments:_____

Tested By:_____ Signature:_____