

Tests for transmission / sub-transmission underground cables

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1. Purpose

To set the minimum standard for tests required to be performed on transmission, sub-transmission and the first section of high voltage distribution cables.

2. Scope

This instruction outlines the broad commissioning, re-commissioning and testing requirements for the following cable systems:

- transmission and sub-transmission underground cables;
- first section of high voltage distribution cable (11/22kV) exiting a zone substation;
- all transformer cables located in both transmission and zone substations;
- all 11/22kV cables located inside the transmission and zone substations; and,
- pilot cables;

This standard does not cover the testing requirements for 11kV and 22kV distribution cables, other than the first section of high voltage distribution cables. Refer to Substation Design Instruction SDI 120 – Testing and commissioning for distribution systems for these requirements.

3. References

External Regulations	
Work Health and Safety Act 2011 (NSW)	
ENA National Electricity Network Safety Code (Doc 01-2008)	
Endeavour Energy Network Management Plan December 2013 Review	

External Standards		
Standard No.	Year	Title
AS/NZS 1026	2004	Electric cables - Impregnated paper insulated – For working voltages up to and including 19/33 (36) kV
AS/NZS 1125	2001	Conductors in insulated electric cables and flexible cords
AS/NZS 1429.1	2006	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	2009	Electric cables - Polymeric insulated - For working voltages above 19/33 (36) kV up to and including 87/150 (170) kV (Reconfirmed 2020)
AS/NZS 60840	2020	Power cables with extruded insulation and their accessories for rated voltages above 30kV up to 150kV – Test method and requirements
ESAA D(b)31	1989	ESAA Guide for the Maintenance of High Voltage Paper/Oil Insulated Cables and Accessories.

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IEC 60229	2007	Tests on cable oversheaths which have a special protective function and are applied by extrusion
IEEE P400.2/D5	2024	Guide for Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF)

Company Policies and Procedures

Company Policy (Network) 9.9.1	Network Asset Maintenance
Company Procedure (Environment) GPE 0069	Polychlorinated Biphenyl Management
Division Form (Network) FNV 1111	Power cable test report form
Division Form (Network) FNV 1112	Pilot cable commissioning test report form

Company Standards

Environmental Management Standard EMS 0008	Environmental Incident Response and Management
Environmental Management Standard EMS 0017	Oil Management
Mains Maintenance Instruction MMI 0012	Overhead transmission line routine inspection
Substation Design Instruction SDI 120	Testing and commissioning for distribution systems
Substation Maintenance Instruction SMI 103	Testing of in-service insulating oil

4. Definitions and Abbreviations

Term	Definition
Commissioning	Testing required after any new installation, or augment of cables and accessories
Cross-bonded systems	A system that sectionalises the cable sheaths along the route into minor sections and cross connecting them to approximately neutralise the total induced voltage over the major section.
DDF	Dielectric dissipation factor
De- energised cable	A de-energised cable for 3 months or more
DGA	Dissolved gas analysis
First section of high voltage distribution cable	The section of 11kV or 22kV cable connected from a zone substation to the first termination. The first termination may be a padmount substation, switch, UGOH, or similar
HDPE	High-density polyethylene
HV	High voltage - A system with a nominal voltage range of greater than 1000V.
Insulation breakdown	Damage by the way of punctured insulation and resulting in permanent damage
IR	Insulation resistance

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IRT	Insulation resistance tester
Major section	The section between two solidly grounded segments of a cable in a cross-bonding system
Megger	Commonly used trade name for insulation resistance tester.
PD	Partial discharge
PE	Polyethylene
Pilot cable	Used for communications, signalling and protection purposes
PVC	Polyvinyl chloride
Rad	Radian – unit of angle measured in a $\tan\delta$ test
Re-commissioning	Re-testing required after any major works including the installation of a joint and/or re-termination.
Single end point bonded systems	A cable system in which the sheaths of each phase are solidly bonded together and to earth at one end. These systems require the installation of an earth continuity conductor.
Soaking test	Full rated voltage applied to the cable, supplied from the network and incorporating service voltage test with sensitised protection settings.
SVL	Sheath voltage limiter
$\tan\delta$	Dielectric loss angle
Transmission and sub-transmission	A system with a nominal phase-to-phase voltage range from equal to or greater than 33kV but less than or equal to 132kV
TDG	Total dissolved gases
VLF	Very Low Frequency (generally refers to 0.1Hz test frequency, but can also go down to 0.01Hz)
XLPE	Cross-linked polyethylene cable

5. ACTIONS

5.1 General Requirements

Where tests are to be performed on underground cables (as defined in section 2.0), either as a commissioning test, recommissioning after major works, or maintenance, they shall be carried out in accordance with:

- Endeavour Energy Workplace Instructions.
- Australian Standards; and,
- Manufacturer's instructions.

5.1.1 Reporting requirements

A copy of the test results shall be stored on the network drive, in 'G:\TIS\testserv'. All test reports shall be made available to the relevant testing manager within two (2) weeks of completion.

FNV1111 as per GNV1094.7 shall be used to record all test results.

5.2 Commissioning and Re Commissioning testing schedule

Table 1 details the required commissioning tests based on cable type:

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Table 1: Commissioning and re commissioning testing schedule

Test type	Clause	Commissioning		Re commissioning		
		XLPE 33/66/132kV	11/22kV First Section from zone substation	Gas or Fluid Filled	Paper	XLPE
Main insulation resistance test	5.4.1	✓	✓	✓	✓	✓
Cable serving insulation resistance	5.4.2	✓	✓	✓	✓	✓
Cable serving DC withstand test	5.4.3	✓	✓	✓	✓	✓
HV withstand test – AC	5.4.4	✓ ⁵	✓	✓	✓	✓
HV withstand test – VLF	5.4.4	✓	✓	✓	✓	✓
High voltage DC withstand test	5.4.5			✓ ²	✓ ²	
24hr soak test	5.4.6	✓ ¹	✓ ¹	✓ ¹	✓ ¹	✓ ¹
Partial discharge test	5.4.7	✓	✓	✓ ³		✓ ⁴
Zero and positive sequence test	5.4.8	✓				
Sheath cross-bonding and SVL test	5.4.9	✓		✓	✓	✓
Continuity and phasing test	5.4.10	✓	✓	✓	✓	✓
¹ If the DC, AC or VLF high voltage withstand test cannot be performed due to the limitation of the test equipment, a 24hr soak test shall be carried out instead, or in conjunction with a lower test voltage. ² For all hybrid insulation circuits involving XLPE jointed to paper, fluid-filled or gas-filled cables, a high voltage test (DC) shall not be applied to this circuit. Instead, a high Voltage (AC) test, a VLF test or a 24-hour soaking test shall be carried out. ³ Partial discharge test is only required if the gas or fluid filled cable circuit is connected to an XLPE cable. ⁴ Partial discharge test is not required if the XLPE circuits contains fluid impregnated paper. ⁵ For commissioning tests on 132 kV, transmission feeders, HV AC tests shall be performed (in lieu of a VLF test)						

5.3 Re-energising of out-of-service cables

For both gas-filled and fluid-filled cable feeders, if the cable circuit is to be de-energised, the pressure values shall be maintained for the period of the outage.

If a cable circuit is de-energised for a period of time and needs to be reconnected to the network, the following tests shall be carried out in order to determine the condition of the cable circuit before connection:

Table 2 Testing requirements for out of service cables

Cable type	De-energised period	Test requirement			
		Insulation resistance test	VLF/ AC test	24-hour soaking test	DC test
Impregnated paper cable, fluid and gas filled cable (without XLPE cable section)	≤ 3 months	✓		✓ ²	✓ ¹
	>3months	✓			✓
XLPE or a cable circuit with a section of XLPE cable connected	≤ 3 months	✓	✓ ¹	✓ ²	
	>3 months	✓	✓	✓ ³	
¹ Test only required if insulation resistance test result is not acceptable ² If the results from the insulation resistance test are acceptable, then a 24-hour soak test shall be performed. If the insulation resistance results are not acceptable, a 24-hour soak test shall not be performed and further investigation is required. ³ If no HV test can be performed, or required test voltages cannot be achieved, a 24-hour soak shall be performed.					

5.4 Tests for cables

5.4.1 Main insulation IR tests

When carrying out an insulation resistance test on the main insulation of a cable, the tests shall be carried out on each phase conductor individually. When a test is carried out on a given phase conductor, the other phase conductors and their related metal sheaths and/or armour shall be earthed.

5.4.1.1 Insulation resistance test

General requirements

In order to confirm that the condition of the insulation is suitable for a high voltage withstand test, an IR test shall be carried out before a high voltage withstand test (AC, VLF or DC) is applied to the main insulation or to the serving of the cable. A second IR test shall be performed after the withstand test.

For XLPE cables, when carrying out an IR test on the main insulation alone (no high voltage test required), the cable circuit shall be switched off for more than four (4) hours before conducting the test. The soil temperature within the cable trench shall be recorded immediately before starting the test.

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5.4.1.2 Insulation resistance test limits

Table 3: Insulation resistance requirements

System	Test Voltage	Duration	Requirement
Paper	5kV (dc)	1 min ¹	Results shall be compared to previous results.
XLPE			Acceptable IR results : - 200 MOhm for new cables, and - 100 MOhm for existing cables
¹ The insulation resistance shall be measured after 1 minute or after the value reaches steady-state.			

5.4.2 Cable serving IR test

5.4.2.1 Cable serving insulation resistance test requirements

Table 4: Cable serving insulation resistance requirements

System	Test Voltage (dc)	Duration	Requirement
≥33kV ¹	2.5kV	1 min ²	Acceptable IR results : - 200 MOhm for new cables, and - 100 MOhm for existing cables
≤22kV	1kV		Acceptable IR results : - 200 MOhm for new cables, and - 10 MOhm for existing cables
1 Due to the special cable construction and/or cable sheath bonding, this test may not be practical on some of the gas-filled cables. 2 The insulation resistance shall be measured after 1 minute or after the value reaches steady-state. 3 If the IR values before cutting/joining is less than the stipulated values, the IR measured after jointing shall not be reduced by more than 10%.			

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5.4.3 Cable serving DC withstand test

Table 5: Cable serving withstand requirements

System	Test Voltage (dc)	Duration	Requirement
≥33kV	≤5 years old: 10kV 5-20 years: 5kV >20years: 2.5kV	1min	No breakdown
≤22kV	5kV		

5.4.4 AC/VLF withstand test and 24hr soak test

5.4.4.1 Withstand test- AC / VLF

When carrying out a high voltage withstand test, the tests shall be carried out on each phase conductor individually. When a test is carried out on a given phase conductor, the other phase conductors and their related metal sheaths and/or armour shall be earthed.

After each high voltage withstand test, the cable circuit and test equipment shall be discharged to earth.

If abnormal results are obtained from the tests but an overall condition assessment concludes that the cable circuit can be put back into service under close condition monitoring, the normal scheduled frequency of tests should be suitably increased. If three (3) tests within six (6) months show that there are no further deteriorations in the test results for the affected circuit, the test period for the affected cable circuit shall revert back to the normal test cycle.

The test voltage for an installed cable shall be decreased to 80% of the new cable test value after a period of 5 years.

5.4.4.2 AC withstand test limits

Table 6: AC withstand test requirements

Rated voltage U (kV)	Test voltage for AC withstand test (kV)		Duration	Requirement
	Age < 5 years	Age ≥ 5 years (1.5 U0)		
11 ¹	12	9.5	15 min	No Breakdown
22 ¹	24	19		
33 ¹	36	28.5		
66 ²	72	57	60mins	
132 ²	132	106		
¹ figures and test times from IEC 60502-2, can be reduce to 5 mins when performed with PD measurements				
² figures and test times from IEC 60840				

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5.4.4.3 VLF withstand test limits

Table 7: VLF withstand test voltages

Rated voltage U (kV)	Test voltage for VLF withstand test (kV) ¹		Duration	Requirement
	Age < 5 years	Age ≥ 5 years		
11	23kV _{peak} ¹ (16kV _{rms})	18kV _{peak} (13kV _{rms})	15 min	No breakdown
22	40kV _{peak} ¹ (28kV _{rms})	31kV _{peak} (22kV _{rms})		
33	60kV _{peak} ¹ (42kV _{rms})	44kV _{peak} (31kV _{rms})		
66	113kV _{peak} * (80kV _{rms})	84kV _{peak} * (60kV _{rms})		
132	202kV _{peak} * (143kV _{rms})	170kV _{peak} * (120kV _{rms})		
¹ figures from IEE 400.2.				
* Limited by existing test set output				

5.4.5 DC voltage withstand test

When carrying out a high voltage DC withstand test on a cable circuit, the following conditions shall be observed and implemented:

- an insulation resistance test shall be performed before and after the DC withstand test;
- the cable circuit shall be switched off for more than four (4) hours (allows the cable to cool down) before conducting the test, and the soil temperature within the cable trench shall be recorded immediately before starting the test;
- the phase conductor shall be connected to the negative polarity of the DC test circuit;
- before conducting a high voltage DC withstand test on both gas-filled and fluid-filled cable systems, the oil and gas pressures shall be within the design pressure range. If the gas or oil pressure cannot be maintained for the duration of the test, a high voltage DC withstand test shall not be permitted;
- if oil flushing is carried out on a fluid-filled cable system, a high voltage DC test (if required) shall not be applied to the affected cable circuit within 24 hours after the completion of the oil flushing work;
- before carrying out a DC test and leakage current measurement, the background leakage current from the equipment and the connection leads used in the test shall be obtained;
- the test voltage shall be increased gradually, with the initial rate of rise no greater than 1kV/second. When the voltage reaches approximately 75% of the specified value, the rate of rise shall be increased to 2% each second until it reaches the final specified value;
- a leakage current measurement shall be performed and recorded when the test voltage reaches 25%, 50% and 75% of the final required value. The test voltage shall be maintained at each of these levels for one (1) minute or until the leakage current stabilises, before the leakage current is measured. For details on how to perform the current leakage test, refer to Annexure 2;
- when the test voltage reaches its full value (100% of the specified test voltage), leakage current shall also be recorded at 1, 3 and 5, or 1, 3, 5, 7, 9 and 10, minutes depending on the total withstand time required for the cable, as shown in Table 8;
- after each high voltage withstand test, the cable circuit and test equipment shall be discharged through a current limiting resistor. The discharge process through the current limiting resistor shall be repeated until there is no sparking evident. After this, the cable conductor is to be given a final discharge and connected to earth; and
- if the condition of the main insulation of the cable is suspect, in order to assess and decide whether the cable should be put back in service, another test, with either an increase in testing voltage or withstand time, or both, may be required to ascertain the condition of the cable.

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5.4.5.1 DC withstand test limits

Table 8: DC withstand test voltage, duration and pass/fail criteria based on age and cable type

Cable type	System Voltage (U) kV	>20 years		Requirement
		Test Voltage (kV)	Duration (min)	
Paper	11	13	5	No Breakdown And Leakage current unbalance coefficient between conductors: New cables: < 1.5 Existing cables: < 2
	22	25	5	
	33	38	5	
Fluid Filled	33	43	5	
	66	85	10	
	132	152	10	
Gas	33	38	5	
	66	76	10	

5.4.6 24hr soak test

Where an offline high voltage test cannot be performed or cannot be performed to the test voltage magnitudes required in sections 5.4 and 5.5, a soak test shall be performed prior to putting the cable under load.

A 24hr soak test is accomplished by energising the cable from the local HV network, at system voltage (essentially U_0). The first five (5) or ten (10) minutes of the 24-hour soak test would normally include a service voltage test where protection systems are configured with reduced settings and the HV network is configured to minimise risk.

Where technically possible during the service voltage test and the 24 hour soak test, on-line partial discharge monitoring devices shall be used on the cable circuit.

The test shall be deemed as having passed if there is no breakdown of the cable system insulation.

5.4.7 Partial discharge (PD) test

Tests shall be carried out on each phase/conductor in turn, or in pairs when using the balanced test circuit. Additional tests should be carried out when excessive PD levels are measured on a conductor pair, to establish the PD level on each conductor.

Where it is not possible to carry out a PD test using a separate source supply, a standard 24-hour soak test, together with an on-line PD (OLPD) test, may be carried out.

The amount of background partial discharge shall be noted whilst performing the PD test.

Partial discharge is to be recorded at U_0 and $1.5U_0$. Where partial discharge is measured, the inception and extinction voltage levels are to be recorded, together with the inception and extinction partial discharge magnitude. Any significant change to the amount of partial discharge shall be reported to the Network Maintenance Manager.

Tests for transmission / sub-transmission underground cables

5.4.7.1 PD test limits

Table 9: Partial discharge requirements

System	Test Voltage	Requirement
Gas/paper/fluid filled/ hybrid	150% of U_0	record values for reference
XLPE	150% of U_0	$PD \leq 10\text{pC}$

5.4.7.2 Cables Connected to Switchgear

In some cases cables are connected to switchgear and cannot be disconnected (eg 33kV Tamco switchgear). It is important to note that switchgear may have different partial discharge (PD) measurement thresholds compared to cables.

As a result, there may be PD resulting from the switchgear when the cable is tested connected to the switchgear. In these cases, it may be possible to identify discharge activity coming from the switchgear via TEV methods.

5.4.8 Zero and positive sequence impedance test

Zero and positive sequence impedance tests shall be carried out with all metal sheaths and/or armour earthed in the designed configuration. SVLs shall not be short-circuited during the tests. Zero sequence tests may be required to be carried out by injecting current from both ends where cables are used as inter-connectors or part of ring feeds.

Zero and positive sequence impedance shall be obtained for the whole feeder.

Zero and positive sequence impedance is not required for transformer cables.

5.4.9 Sheath cross-bonding and SVL test

Cross-bonding tests on the cable are performed to verify the integrity of the cross-bonding system to ensure circulating sheath current at full load will not adversely affect the cable rating. These tests are only carried out on 33kV-132kV single core fully insulated circuits.

This test involves injection of a balanced 3 phase current into the cores of the cable, and measuring voltages and currents induced into the sheaths at each sheath 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 to be scaled up to the rated load current. Voltage values at isolated (not solidly earthed) cross-bonding points shall be less than the design value of 160V.

If any scaled voltages are above 160V, the full cable test results shall be reported to the design branch for rating re-assessment.

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5.4.9.1 General information

SVL tests

DC reference current shall be applied to the unit and voltage drop (DC reference voltage) shall be measured. The DC reference voltage obtained from the test shall be compared with the manufacturer's recommended values.

When the test cannot be performed in situations, an IR test at 5kV shall be performed.

For Single Point Bonded cables where one end is an UGOH pole, SVLs are not required to be removed from the circuit and will get a HV test during the Sheath Voltage test.

Link box tests and inspection

A contact resistance test across all link contacts in each link box shall be carried out after installation as well as after the removal and/or replacement of the links. This test shall be carried out upon completion of final testing prior energisation (prior to closing the link box lid for the final time).

At the time of the test, an inspection of the general condition of the link box (such as the water tightness) shall be conducted.

5.4.9.2 Sheath bonding test limits

The cross-bonding system test is the same for all systems and comprise the tests listed in Table 10:

Table 10: Sheath bonding tests and requirements

System	Test	Test Voltage	Duration	Requirement
1	Cable serving DC withstand Test	See table 6	1min	No breakdown
2	SVL test	dc reference current or 5kV IR test to be applied	-	dc reference voltage in line with manufacturer recommendations or no breakdown at 5kV
3	Link contact resistance	-	-	$\leq 20\mu\Omega$

5.4.9.3 Tests/inspection required under special situations

Apart from the tests as listed above, the integrity of the serving, the bonding leads and the functionality of the SVL shall be checked/tested at the earliest convenient opportunity if the following conditions occur:

- if a fault occurs in a major section of a cross-bonding system, check/test shall be carried out for the affected major section; and
- if a fault occurs on the direct earthing terminals connecting two major sections in a cross-bonding system, the same check/test shall be applied to both major sections.

If the sheath cross-bonded system carries a heavy through fault current, the check/test shall be carried out for the whole cross-bonding system.

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5.4.10 Continuity and Phasing

Continuity and phasing of the cores of the cable under test, between known ends of the cable, shall be confirmed during testing. This shall be performed during commissioning, after augmentation and after fault repairs.

This is usually performed by positively identifying phases using an IRT and removing phases from earth. Other methods, eg current injection, may be suitable for identifying phase connection at both ends.

5.4.11 Oil system tests

5.4.11.1 Pressure Tank oil tests

Table 11: pressure tank oil tests

Test	Requirement
Oil breakdown voltage.	> 50kV/2.5mm at oil temperature 20 ± 1 deg. C.
Tan δ of the oil.	< 0.005 rad at 100 ± 1 deg. C and field strength at 1kV/mm.

5.4.11.2 Oil and gas pressure alarm

Table12: Oil and gas pressure alarm

Test	Test Voltage	Requirement
Signalling system check.	-	Can send out the correct alarm signals.
Insulation check (conductor to earth) for the control cable	500 V	> 1M Ω .km at 20 deg. C

5.4.11.3 Cable oil tests

Table13: Cable oil tests

Test	Requirement
Oil breakdown voltage.	> 45kV/2.5mm at oil temperature 20 ± 1 deg. C.
Tan δ of the oil.	< 0.03 rad at 100 ± 1 deg.C and field strength at 1kV/mm.
DGA test.	Refer to Table in Annexure 1

If the DGA results reach or exceed the warning levels, a further study to find out the possible problem and/or ongoing condition monitoring of the affected cable is required.

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Fluid flushing

Consideration shall be given to flushing fluid from the cable where any of the following criteria are met:

- dielectric strength of the fluid is less than 45 kV/2.5mm at 20 deg. C;
- DDF is greater than 100 mrad and is continuing to trend upwards; and
- the total dissolved gases (TDG) are above 10,000 ppm.

If oil flushing is carried out on a fluid-filled cable system, a high voltage DC test (if required) shall not be applied to the affected cable circuit within 24 hours after the completion of the oil flushing work.

5.5 Tests for pilot cables

5.5.1 Commissioning tests for pilot cable

The following tests shall be carried out as part of the commissioning process and prior to re-commissioning after major works for pilot cables:

- loop resistance and continuity test;
- core identification test;
- test to confirm continuity and earthing integrity of screen;
- earthing arrangement compliance with design specification test;
- insulation resistance test; and
- high voltage DC withstand test.

5.5.2 Maintenance tests

Table14: Pilot cable insulation resistance requirements

Cable type	Test connections	DC insulation resistance test voltage (V)	Minimum acceptable insulation resistance (MΩ at 20 deg. C)	
			New cables	Existing cables
Pilot cable (with PE insulation)	Each core to all other cores and screen connected to earth	1000	100 MΩ	1 MΩ
	Screen to earth (sheath test)			
Pilot cable (with PVC insulation)	Each core to all other cores and screen connected to earth		40 MΩ	0.5 MΩ
	Screen to earth (sheath test)			

Table15: Pilot cable DC withstand test limits

Pilot cable test	Test duration (min)	New cable test Volt (kV DC)	Cable (more than 1 year old) test volt (kV DC)
Each core to all other cores and screen	1	10	1
All cores to screen	1	15	2.5
Screen to earth (sheath test)			

6. AUTHORITIES AND RESPONSIBILITIES

General Manager Future Grid and Asset Management has the authority and responsibility for approving this instruction.

Head of Asset Management and Digital has the authority and responsibility for making recommendations to the General Manager Future Grid and Asset Management in respect to this instruction.

Asset Engineering Manager has the authority and responsibility for:

- keeping the content of this instruction up to date; and
- interpreting power cable test results.
- analysing commissioning power cable test results and recommending actions where results do not meet criteria; and

Telecommunications Manager has the authority and responsibility for interpreting pilot cable test results to identify potential problems and taking appropriate action.

Regional Transmission Managers have the authority and responsibility for:

- confirming that Endeavour Energy employees and/or contractors engaged to perform the work have appropriate qualifications;
- meeting the requirements of this instruction;
- confirming the work performed is carried out in accordance with local and statutory requirements;
- identifying potential problems with cables when test reports are received;
- maintaining a high level of public safety;
- confirming employees are conversant with, and work in accordance with, the Electrical Safety Rules; and,
- confirming that cable tests, data recording, and issue of test reports are carried out only by authorised persons.

Endeavour Energy employees and contractors have the authority and responsibility for:

- meeting the requirements of this instruction;
- working in accordance with local and statutory requirements;
- maintaining a high level of public safety;
- working in accordance with Endeavour Energy's Electrical Safety Rules;
- recording maintenance and test data in Endeavour Energy's electronic databases; and
- confirming employees engaged to perform work have appropriate qualifications.

Oil sampling technologist or contractors have the authority and responsibility for:

- obtaining oil samples in accordance with SMI 103;

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- handling, storing, disposing of and transporting oil in accordance with company procedures as listed under references. (including EMS 0008, EMS0017 and GPE 0069);
- testing oil samples within 10 days of being received at the laboratory in accordance with SMI 103 and the requirements of Annexure 1;
- updating Endeavour Energy's maintenance database to indicate that an oil sample was taken and tested; and
- identifying potential problems with equipment based on oil sample results.

Annexure 1 – Dissolved gas analysis results for fluid filled cables.

Table16: Warning levels for abnormal gases dissolved in the fluid-filled cable system

Abnormal gas components in cable oil system		Warning level (ppm)
Hydrogen	H ₂	500
Methane	CH ₄	200
Acetylene	C ₂ H ₂	Trace (2~10)
Ethylene	C ₂ H ₄	200
Carbon monoxide	CO	100
Ethane	C ₂ H ₆	200
Carbon dioxide	CO ₂	1,000
Total combustible gas		1,100
Total dissolved gas		10,000

For fluid filled cables, when dissolved gas analysis (DGA) is carried out, the warning levels for different dissolved gases in the oil system are as shown in Table 16. If the DGA results reach or exceed the warning levels, a further study to find out the possible problem and/or ongoing condition monitoring of the affected cable is required.

Non-routine sampling

Where gas levels are above the levels in Table 16, or the trends are increasing, further investigation is required.

The investigation should include verifying the gas readings and re-sampling the section of the cable over a much shorter time frame, in order to accurately establish trends and the rate of increase. The sampling frequency would typically be increased to once every three (3) months, but could be varied depending on the present level or trend of the gases. Where the DGA indicates partial discharge, PD measurement at the suspect joints should be considered.

Similarly, trends in the DDF of the fluid should be established before any decisions are made to replace the fluid.

Annexure 2 – Leakage current measurements.

A2.1 General information

Leakage current shall be measured during the DC high voltage test.

To obtain the true leakage current for the cable, the background leakage current shall be subtracted from the measured value.

After completion of the leakage current measurement, the leakage current unbalanced coefficient (the ratio between the maximum and minimum leakage currents obtained from different phase conductors) shall be calculated and recorded.

The leakage current unbalance coefficient between conductors shall not be larger than 1.5 and 2 for both new and existing cable circuits respectively.

Both the leakage current and unbalanced coefficient should be used only as a tool by which to assess the condition of the insulation. It should not be used alone to determine if a cable should be put back into service.

The leakage current measured, when test voltage reaches each of 25%, 50%, 75% and 100% of specified value, should remain constant at each of these stages. Any measured increase in leakage current over the duration of each test stage indicates possible defects in the insulation, requiring further investigation to determine the root cause of the problem.

Leakage currents obtained from the test shall be compared with the previous set of test results. Further investigations are required to find out the root cause if any of the following abnormal conditions are observed:

- if substantial differences are found on comparison with previous sets of test results; or
- during the test, large fluctuations in leakage current are observed; or
- when either the test voltage or the time is increased, a rapid rise of leakage current is detected.

Leakage current is sensitive to the temperature of the surrounding environment of the tested object. Therefore, the soil temperature within the cable trench shall be measured and recorded.

The following factors may affect the accuracy of leakage current measurement.

A2.2 Corona discharge

When the test voltage increases to a high level, field strength on the surface of the metal part of the cable termination and/or on the connection wires may reach very high levels and corona discharge may occur. If this phenomenon occurs, the following actions shall be carried out to minimise the effects:

- increase the effective diameter of the connection wires;
- if possible, increase the separation between the connection wires and the earthed objects nearby;
- provide effective shielding between cable terminations.

A2.3 Leakage current across the surface of the termination bushing

Leakage current may occur across the dirty surface of the cable termination. This is especially true if humidity is high during the test, as leakage current through the surface of the cable termination could be much greater than the actual leakage current of the cable itself.

To avoid this, the surface of the cable termination needs to be checked and/or cleaned, if required, before carrying out the test, and relative humidity shall be recorded.

