



VLF Cable Testing Guide



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About This Guide

VLF testing applies an AC voltage at a very low frequency, usually 0.1 Hz, to an MV or HV cable to prove its insulation, joints and terminations. The low frequency cuts the charging current a cable needs, so a portable set can test a long circuit. This guide covers withstand levels and durations, tan delta, the sheath test, safe set-up and how to read the result.

What a VLF Test Is

An AC test on a shielded cable at 0.01 Hz to 1 Hz, most commonly 0.1 Hz (IEEE 400.2-2024 cl 5). A withstand proves the cable holds a set voltage for a set time; tan delta measures its dielectric loss.

When It Is Used

After installation and before energisation, as a maintenance test on aged cable, and after a fault repair before the circuit returns to service.

Why It Matters

Installation damage and poor joint workmanship rarely show on an insulation resistance test. A VLF withstand drives a gross defect to failure during a planned outage, when fault current and collateral damage are limited (IEEE 400.2-2024 cl 5).

Guide at a Glance

Measures

Withstand (pass or fail); tan delta, tip up and stability in units of 10^{-3} .

Frequency

0.1 Hz sine or cosine-rectangular; the VLF range is 0.01 Hz to 1 Hz.

Test Level

IEEE 400.2-2024 Table 3 or the asset owner's level, e.g. 16 kV rms sine for 11 kV acceptance.

Duration

60 min new, 30 min aged, at 0.1 Hz. Below 0.1 Hz, consider a longer hold (IEEE 400.2-2024 cl 5.1.1).

Judged Against

No breakdown; tan delta against IEEE 400.2 Tables 4 to 6, the other phases and the trend.

Need the test done, or the instrument to do it? Megavar tests HV cables across Australia and hires the cable test sets in this guide.



Why Test Cables at Very Low Frequency?

VLF Testing in Four Numbers

0.1 Hz

Most common VLF test frequency
(IEEE 400.2-2024 cl 5)

60 min

Withstand on a new cable circuit
(IEEE 400.2-2024 cl 5.1.1)

500 times

Less charging current at 0.1 Hz than at 50 Hz
($I = 2\pi fCV$)

16 kV rms

Sine acceptance level for an 11 kV cable
(IEEE 400.2-2024 Table 3)

Why AC, and Why So Slow

AC Stress Like Service

An AC withstand stresses the insulation the way service voltage does. The typical level for any source is 1.5 U₀ to 3.0 U₀ (IEEE 400-2023 cl 6.2.2).

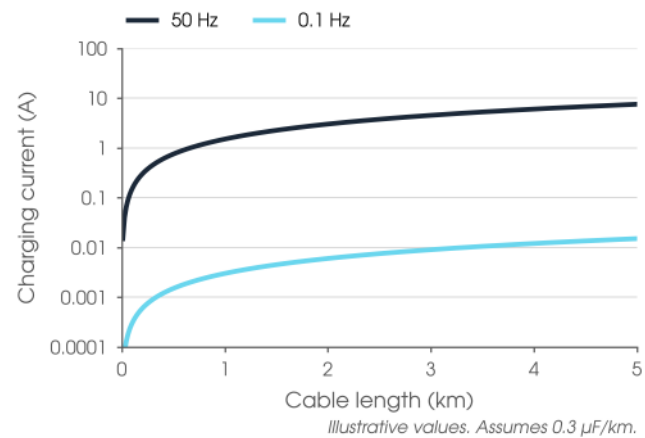
Portable Power

A cable is a capacitor, and charging current is $I = 2\pi fCV$. At 0.1 Hz it is 500 times lower than at 50 Hz, so a portable set can test a circuit that would need a trailer-mounted resonant system at power frequency.

A Controlled Failure

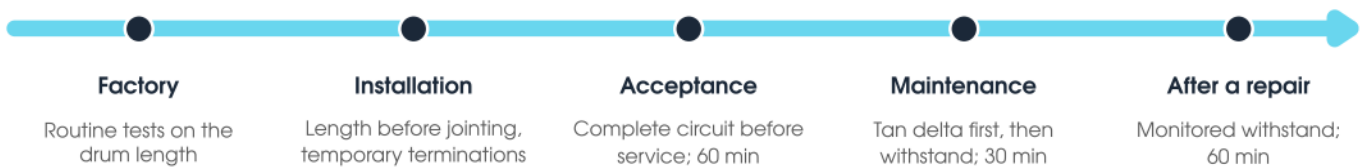
At the prescribed levels, a failure means the cable was already highly compromised. Failing on test, the fault current and damage are limited, which may not be so in service (IEEE 400.2-2024 cl 5).

Charging Current and Frequency



Charging current at 16 kV rms against route length. At 0.1 Hz a 5 km circuit draws less current than 20 m of cable at 50 Hz.

When to Test



Where Is It Used?

Cables and Tests

Cable or situation	What the test finds	Usual test
New XLPE or EPR circuit, before service	Installation damage, poor joint and termination workmanship	VLF withstand at acceptance level, 60 min; sheath test
Cable length before jointing	Shipping, storage or pulling damage	Installation test with temporary terminations (IEEE 400-2023 cl 5.2.1)
Aged extruded cable in service	Water treeing, wet joints, general ageing	VLF tan delta first, then a withstand at maintenance level, 30 min
Circuit after a fault repair	Workmanship of the repair	Monitored withstand, 60 min (IEEE 400.2-2024 cl 5.1.1)
Mixed XLPE and paper circuit	Wet splices, dry or degraded paper sections	VLF sine with tan delta stability and tip up (Table 6); asset owner rules
Cable above 30 kV to IEC 60840	Accessory installation defects	AC 20 Hz to 300 Hz (IEC 60840:2020 cl 16.3); other tests by agreement
Outer sheath	Cuts, holes and termite damage that let water reach the screen	Sheath test, metallic screen to earth

Choosing the Test Level

IEEE 400.2-2024 Table 3

Levels by cable rating and test type. For 11 kV: installation 14, acceptance 16, maintenance 13 kV rms sine. For 33 kV: 37, 42 and 31 kV rms.

AS/NZS 1429.1:2006

Sets no VLF level. Appendix F2 suggests 24 h at operating voltage, or a higher AC voltage below power frequency as agreed between purchaser and installer.

Asset Owner Levels

Western Power: 3 VN for 60 min at 0.01 to 1.0 Hz, which is 14 kV rms on 11 kV and 41 kV rms on 33 kV (Distribution Commissioning Manual, 2024).

Our Recommendation

Use the asset owner's specification where there is one. Otherwise test to IEEE 400.2-2024 Table 3, and name the source of the level in the test plan.

Acceptance or Maintenance Level

Maintenance Is Lower

About 75% of the acceptance level (IEEE 400.2-2024 Table 3 Note 3). Western Power reduces to 80% for existing cable and 60% for cable over 30 years old.

Rated or Operating Voltage

Where a cable runs below its rating, maintenance tests use the operating voltage class (Table 3 Note 1). Agree the level with the circuit owner (cl 5.1.2).

Not Higher for Shorter

Raising the voltage above 3 U0 to shorten the test does not replicate a lower voltage, longer test (cl 5.1.1).

Good to Know

Sine and cosine-rectangular levels differ. Cosine-rectangular values are the sine rms values times $\sqrt{2}$ (Table 3 Note 6).

How Does It Work?

How a VLF Test Works

Two Waveforms

A sine set gives a smooth 0.1 Hz sine. A cosine-rectangular set holds DC plateaus and reverses polarity every 5 s, through transitions equal to 30 Hz to 300 Hz (IEEE 400.2-2024 cl 3.1, 5.2).

Tan Delta

The ratio of loss current to capacitive current, $\tan \delta = IR / IC$ (IEEE 400-2023 cl 6.3.1). A perfect cable is a pure capacitor; water trees, moisture and degraded accessories add loss. It needs a sine source.

Monitored Withstand

Tan delta, and often partial discharge, recorded through the withstand, so the result shows how the cable behaved, not only that it survived (cl 3.1). Partial discharge has its own guide in this series.

Connection Rules

One Phase at a Time

HV lead to the conductor under test. Its metallic screen and the other phases stay earthed.

Far Ends Open and Guarded

Remote ends cleared, cordoned off and marked (IEEE 400.2-2024 cl 4.1).

Connected Plant Off

Surge arresters, VTs and motors disconnected from the cable where possible (cl 4.1).

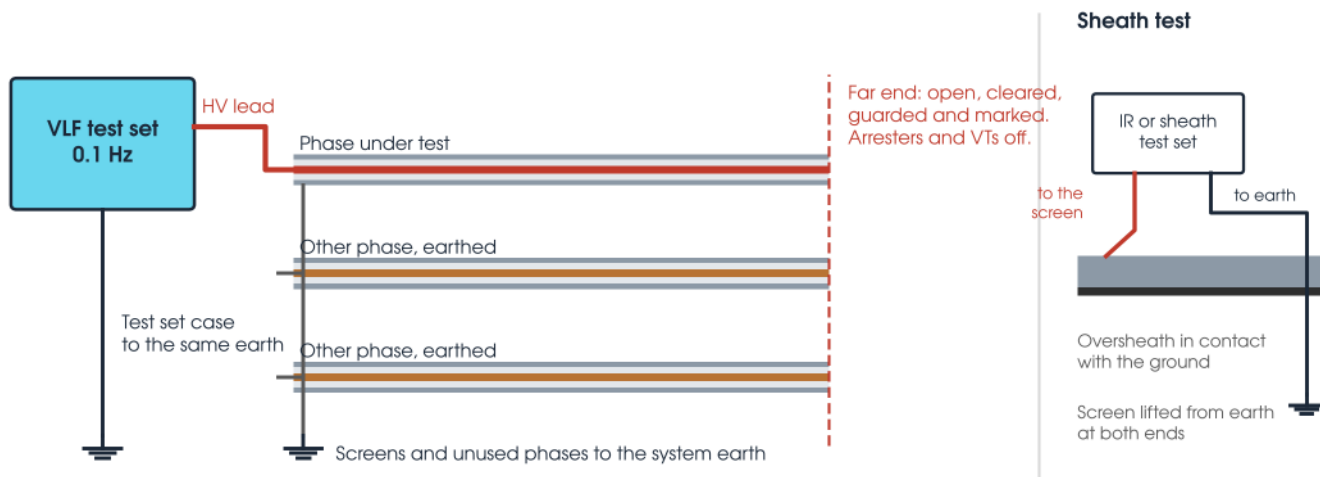
One System Earth

Test set case and all exposed metal bonded to a single system earth at the test site (cl 4.2).

Good to Know

Check the set's load rating against the cable capacitance before mobilising. Halving the frequency doubles the length a set can test, but 0.05 Hz results do not trend against 0.1 Hz results (HV Inc, 2021).

Connection Arrangement



VLF withstand on one phase. The sheath test uses the screen instead: lifted from earth at both ends and tested to earth.

How Do I Set Up Safely?

Permits, Isolation and Earthing

1 Access Permit

Covers the whole cable, both ends, and any temporary removal of earths. Permit earths are removed and replaced only by the person the asset owner authorises.

2 Isolated, Proved Dead, Earthed

Confirm it at both ends with the permit issuer before connecting anything.

3 Disconnect Connected Plant

Remove arresters, VTs and anything that would load the test, and record what was removed.

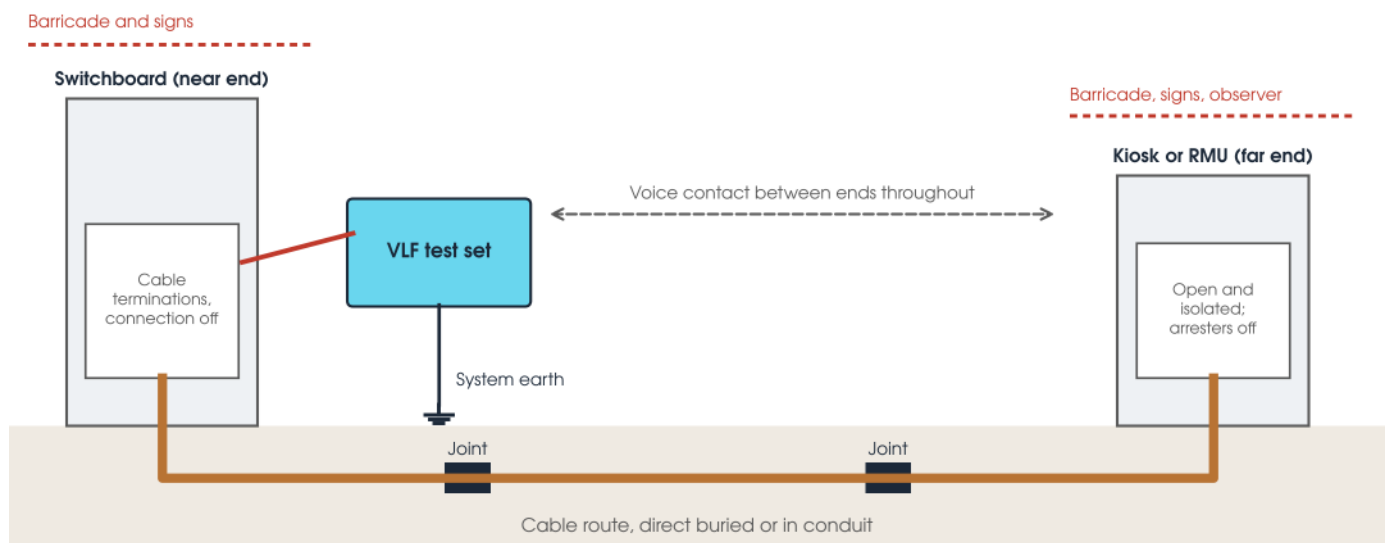
4 Guard Both Ends

Barricade and sign the far end and keep voice contact with it throughout (IEEE 400-2023 cl 4).

Who Should Test

Competent, authorised testing personnel under the asset owner's safety rules. At Megavar, assessed testers; less experienced staff work under direct supervision.

Set-Up on a Cable Circuit



Test from one end with the far end isolated, guarded and in voice contact. Disconnect arresters and VTs at both ends.

Important

This guide describes general practice for competent HV testing personnel. It is not a work procedure. Work under the asset owner's safety rules, the access permit and a site-specific safe work method statement. Manufacturer and asset owner criteria take precedence over the general guidance here.

Hazards Specific to Cable Testing

Stored Charge

A cable holds charge after the test and can recharge by dielectric absorption. Reduce the voltage slowly to zero, discharge, monitor the discharge, then earth (IEEE 400.2-2024 cl 4.1).

Isolation Points

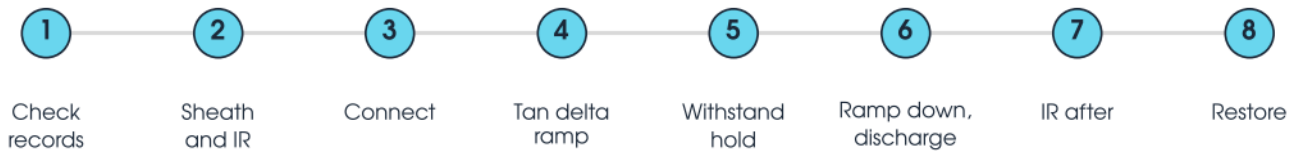
An open switch or air gap must hold the VLF voltage with the other side at line voltage. Check the device with its manufacturer (cl 4.1).

Failure on Test

Degraded insulation can break down before the test is stopped. Have crews ready to repair a joint, termination or section (cl 5.1.2).

How Do I Make the Measurement?

Eight Steps



Steps 1 to 4

1 Check Records

Cable type, rating, length, capacitance, joints and route. TDR can confirm length and accessory positions (IEEE 400.2-2024 cl 5.1.2).

2 Sheath and IR

Sheath test, then insulation resistance core to screen. A gross fault will not survive the VLF test.

3 Connect

As on page 5, with terminations clean and in good repair (cl 5.4.2).

4 Tan Delta Ramp

On aged cable, measure at 0.5, 1.0 and 1.5 U₀, at least six readings per step, 10 s apart at 0.1 Hz and longer apart below it (cl 5.4.2). Stop if TD rises sharply from 0.5 to 1.0 U₀.

Steps 5 to 8

5 Withstand Hold

Raise to the test level and hold: 60 min new, 30 min aged, at 0.1 Hz (consider longer below it). On a breakdown, record the voltage and time on test (cl 5.3, Annex D).

6 Ramp Down and Discharge

Slowly to zero, discharge and earth (cl 4.1).

7 IR After

Repeat insulation resistance. Western Power requires it after every VLF test (2024).

8 Restore

Reconnect removed plant and restore earths per the permit.

Good to Know

Keep the ramp the same from test to test, and record the cable temperature. Both affect the result (cl 5.4, Annex D).

Common Mistakes

Arresters or VTs Left Connected

They load or clamp the test voltage, or are damaged by it.

Wrong U₀

Acceptance tests use the component rating; maintenance tests use the system voltage (cl 3.1).

Dirty Terminations

Surface leakage raises tan delta and can track.

Tan Delta on Cosine-Rectangular

That waveform does not support it (cl 5.2).

More Common Mistakes

Pushing On After a Sharp Tip Up

Risks starting electrical trees in a highly degraded cable (cl 5.4).

Shortening a Retest

Monitoring cannot cut the 60 min retest after a failure (cl 5.1.1).

Trending Different Frequencies

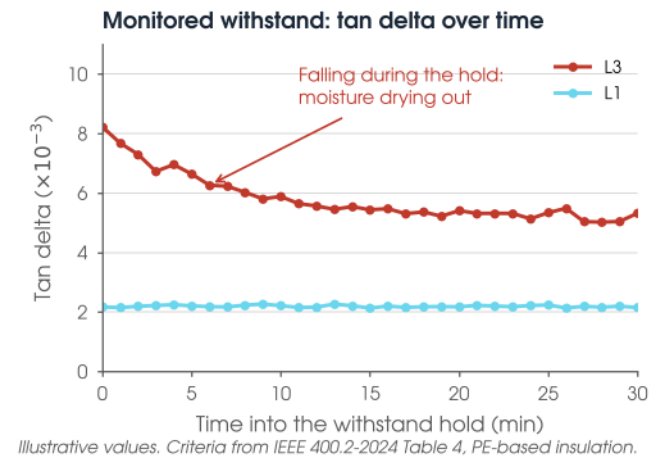
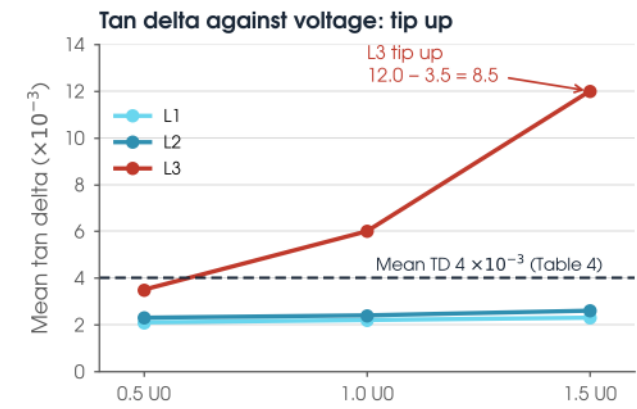
0.05 Hz and 0.1 Hz results are not comparable.

DC Hipot on Aged XLPE

See page 10.

How Do I Read the Result?

Tip Up, Stability and the Hold



L3 grades further study advised under IEEE 400.2-2024 Table 4. Its tan delta falls during the hold, a pattern BAUR (2014) attributes to moisture in a joint drying out.

Comparing the Result

Withstand

Pass if the cable holds the test voltage for the full hold without breakdown.

PE and XLPE (Table 4)

No action: SDev below 0.1, TU below 5 and mean TD below 4 (x10⁻³). Action required: SDev above 0.5, TU above 80 or TD above 50.

Filled and Paper (Tables 5, 6)

Separate criteria. On paper, a negative tip up can point to wet splices.

Scope of the Criteria

For aged cable, five or more years in service, from North American data; not for new cable (cl 5.4).

Phases and Trend

Compare phases of the same circuit, and each test with the last at the same frequency.

What a Bad Result Looks Like

Breakdown During the Hold

A weak point failed. Locate it, repair, and retest for 60 min (cl 5.1.1).

TD Rises With Voltage

Water treeing in extruded cable, or discharging paper (IEEE 400-2023 cl 6.3.1).

TD Falls Over Time or Voltage

May indicate moisture in accessories (IEEE 400-2023 cl 6.3.1).

High, Unstable Readings

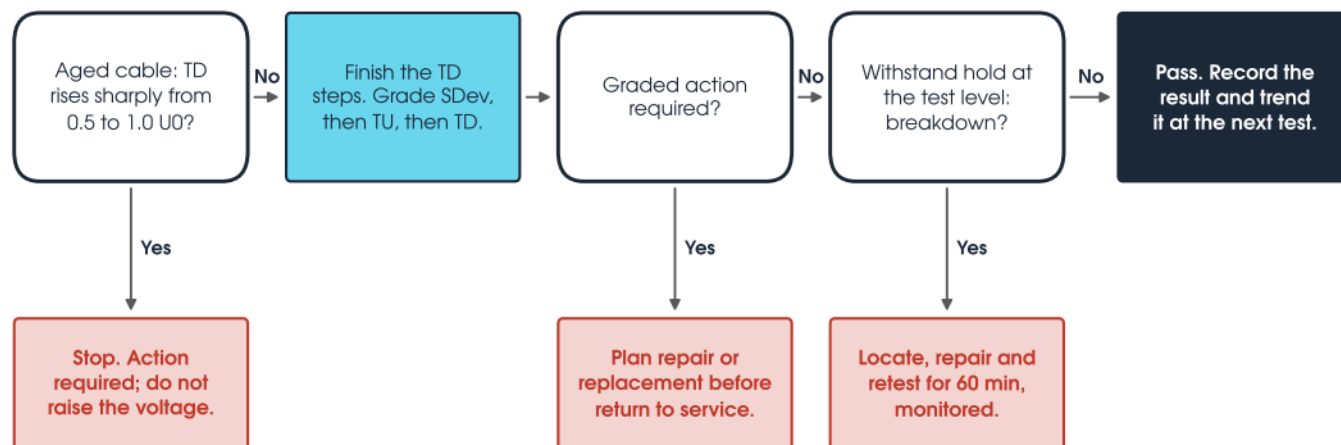
Poor stability is the most sensitive sign of ageing (IEEE 400.2-2024 cl 6).

One Phase Unlike the Others

Localised loss in that phase, often a joint or termination.

Is My Result OK?

Decision Path



Working Out the Tan Delta Features

IEEE 400.2-2024 cl 5.4.2 defines the three features. Mean TD is the average at one voltage, SDev their standard deviation, and:

$$TU = \text{mean TD at } 1.5 U_0 - \text{mean TD at } 0.5 U_0$$

Worked Example

L3 reads 3.5, 6.0 and 12.0×10^{-3} at 0.5, 1.0 and 1.5 U_0 , with SDev 0.08 at U_0 . $TU = 12.0 - 3.5 = 8.5$ (5 to 80: further study). Mean TD at $U_0 = 6.0$ (4 to 50: further study). The worst feature sets the grade: further study advised.

What to Report

The Test

Method, waveform, frequency, voltage peak and rms, duration (IEEE 400-2023 cl 5.6).

The Result

Pass or fail; on a failure, the failure voltage, time on test and the component that failed.

Tan Delta

Mean TD, SDev and TU per phase, the grade, and the cable temperature.

Traceability

Cable, length, accessories, the criteria used, instrument serial number and calibration date.

Why Is DC No Longer Used on XLPE?

What DC Does to XLPE

Space Charge

HVDC builds space charge in aged extruded insulation, which can cause failure when AC is reapplied (IEEE 400-2023 cl 6.2.2).

The Standards

IEEE 400-2023 rates HVDC withstand on aged extruded distribution cable 'Do not use' (Table C.1). AS/NZS 1429.1:2006 Appendix F1: DC testing of the primary insulation is not recommended.

Asset Owners

Western Power: HV XLPE cable must not be tested with DC hipot equipment (2024). SA Power Networks limits XLPE testing to 5,000 V DC (TS105, 2021).

Where DC Still Has a Place

Paper Cable

Western Power still specifies a DC hipot on paper-insulated belted cable (2024).

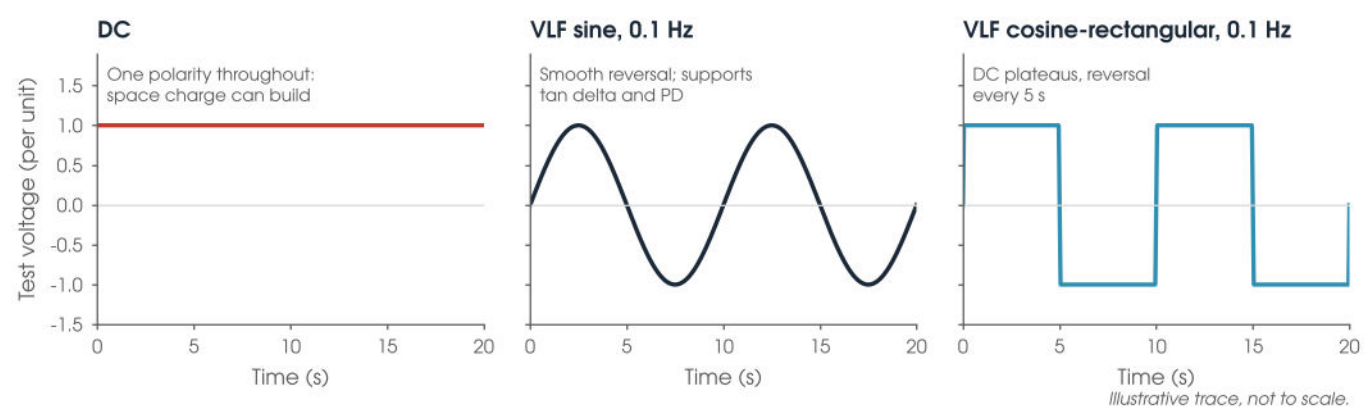
The Sheath Test

DC from screen to earth proves the oversheath (IEC 60840:2020 cl 16.2). AS/NZS 1429.1 Appendix F4 suggests a 1,000 V minimum insulation tester.

Good to Know

A 5,000 V insulation resistance test is not an HV DC test (TS105 cl 8.3). If a specification calls for a DC hipot on XLPE, raise it with the asset owner first.

DC and the Two VLF Waveforms



Recommended Solutions		
Instrument	Rating	Best used for
HVA 60kV VLF Cable Test Set	60 kV peak, 0.1 Hz sine	Withstand on cables rated to 36 kV, including 33 kV acceptance; DC and sheath test modes
HVA 28kV VLF Test Set with Integrated Tan Delta	28 kV, 0.1 Hz sine	Tan delta and withstand on 11 kV cable; tan delta to 1.5 U0 on 22 kV
SUTE 300 kV HV Resonant Test Set	300 kV, 25 to 300 Hz	AC withstand on HV cable to IEC 60840 cl 16.3
Phenix 500 kV HV Resonant Test Set	500 kV, 45 to 300 Hz	AC withstand on long and transmission class cable circuits
Phenix BK130 130 kV Hipot Test Set	130 kV AC	Power frequency withstand on short cables, terminations and switchgear
Megger MIT1020 10kV Insulation Resistance Tester	10 kV DC	Insulation resistance before and after the withstand

Every instrument is available calibrated, with leads, from Megavar's offices: [cable testing equipment hire](#).

Frequently Asked Questions

Common Questions

What is a high voltage test on cable and how is it performed?

A voltage above operating level, applied between conductor and earthed screen for a set time on an isolated cable. On XLPE it is a VLF or resonant AC test; the cable passes if it holds.

What are the differences between VLF and Megger testing for cables?

A Megger (insulation resistance) test applies up to a few kV DC and reads resistance. A VLF test applies AC above operating voltage and proves the cable holds it.

Is 33kv HV or mv?

Both terms are used. AS/NZS 1429.1 covers polymeric cables up to 19/33 (36) kV, the range usually called MV. AS 2067:2016 cl 1.4.34 defines high voltage as exceeding 1,000 V a.c., so 33 kV is HV.

What is a good tan delta value?

For aged PE or XLPE at 0.1 Hz, mean TD at U0 below 4×10^{-3} with tip up below 5 and SDev below 0.1 (IEEE 400.2-2024 Table 4).

Standards and References

IEEE Std 400.2-2024, field testing of shielded power cable systems using VLF.

IEEE Std 400-2023, field testing and evaluation of shielded power cable insulation.

AS/NZS 1429.1:2006 (R2017), polymeric insulated cables to 19/33 (36) kV, Appendix F.

IEC 60840:2020, extruded cables 30 kV to 150 kV, Clause 16. Western Power, Distribution Commissioning Manual, 2024.

SA Power Networks, TS105 Testing Standard for Distribution up to 33 kV, 2021.

BAUR, VLF Sine 0.1 Hz Testing and Diagnostics, 2014.

HV Inc, VLF Testing vs Tan Delta vs Partial Discharge, 2021.

More Questions

What does a tan delta test measure?

The dielectric loss of the whole cable: the ratio of loss current to capacitive current. It grades overall condition but cannot locate a single defect.

How long is a VLF test?

60 min on a new circuit or a repair; 30 min on aged cable (IEEE 400.2-2024 cl 5.1.1).

What is the IEC standard for cable insulation resistance testing?

AS/NZS 1429.1:2006 has no insulation resistance test for the cable insulation, and IEC 60840:2020 uses an AC test after installation. Asset owners set IR criteria, e.g. SA Power Networks TS105.

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