



SFRA Testing Guide



PARTNERS IN
POWER

About This Guide

SFRA testing (sweep frequency response analysis) measures how a transformer winding responds to a low-voltage signal swept from 20 Hz to 2 MHz, producing a trace that is a fingerprint of the core and winding geometry. This guide sets out the four measurement types, what each frequency band is sensitive to, the lead and earthing rules that make a trace repeatable, and how to compare two traces.

What an SFRA Test Is

A frequency response measurement on each winding: a signal is applied at one terminal and the amplitude ratio and phase at another are recorded across the sweep. Also called FRA or frequency response analysis. The result is compared, never read as a single number.

When It Is Used

At the factory to set the fingerprint, before and after transport, at commissioning, after a through fault, protection trip or gas alarm, and when an older or relocated unit is assessed.

Why It Matters

A winding that has buckled, telescoped or moved can pass ratio, resistance and insulation tests and still fail at the next through fault. SFRA is the most sensitive electrical test for that movement, and it finds it before energisation, without applying high voltage.

Guide at a Glance

Measures

Amplitude in dB ($20 \log V_{out}/V_{in}$) and phase, 20 Hz to 2 MHz, on a 50 ohm measuring impedance.

Method

Three coaxial leads: source and reference on one terminal, response on the other; shields earthed by the shortest braid.

Measurement Types

End-to-end open circuit (standard), end-to-end short circuit, capacitive and inductive inter-winding.

Compared With

The unit's own baseline first, then a twin or sister unit, then the other phases.

Judged By

Changed shape, a resonance gained or lost, or a resonance moved. No standard gives a numerical pass limit.

**Need an SFRA test done, or the instrument to do it?
Megavar tests power transformers across Australia and
hires every SFRA set in this guide.**



Why Measure the Frequency Response?

SFRA Testing in Four Numbers

20 Hz to 2 MHz

Sweep range: at or below 20 Hz to at least 2 MHz recommended (AS/NZS IEC 60076.18, 4.5)

200

Minimum measurement points per decade above 100 Hz (AS/NZS IEC 60076.18, 4.5)

30 m

Maximum lead length for a passive lead system, 50 ohm (AS/NZS IEC 60076.18, 5.2)

±0.2 dB

Short-circuit low-frequency agreement; outside it, investigate (IEEE C57.149, Table 5)

Why Geometry Shows in Frequency

A Winding Is an RLC Network

Every turn has inductance, every gap between turns, discs, windings and tank has capacitance. Together they resonate at frequencies fixed by the geometry. Move the geometry and the resonances move.

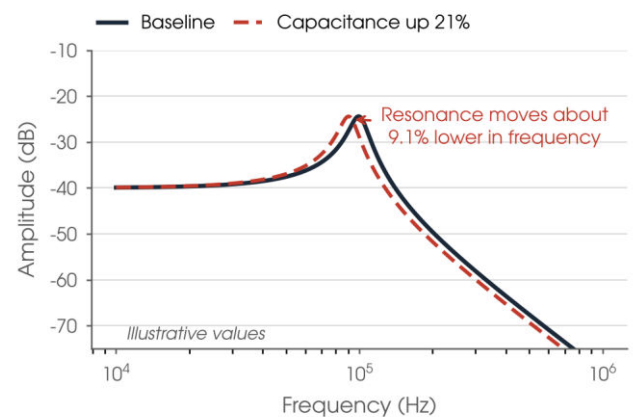
What Moves It

Short-circuit forces from a through fault, shocks in transport, a seismic event or a tap changer fault can buckle, tilt or telescope a winding or shift the core (AS/NZS IEC 60076.18, Clause 3).

Why Other Tests Miss It

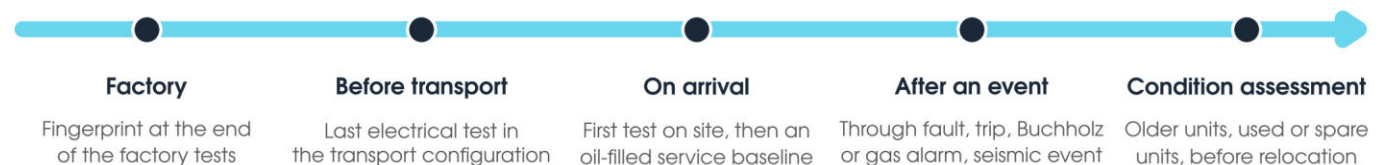
A buckled winding does not typically change ratio or insulation resistance and is hard to see in capacitance (as summarised by OMICRON). SFRA sees the movement directly, without high voltage.

A Resonance Moves With Capacitance



One resonance in an RLC network. Raise the capacitance by 21% and the resonance falls about 9.1% in frequency ($f = 1 / 2\pi\sqrt{LC}$).

When to Test



Where Is It Used?

Standard Measurements by Unit

Unit	What a changed trace points to	Standard measurements (AS/NZS IEC 60076.18, 4.4)
Two-winding three-phase transformer	Radial or axial winding deformation, bulk movement, shorted turns, core shift, loose connections	End-to-end open on each phase of each winding: 6 without taps, 9 with an OLTC
Auto-transformer	As above; series, common and tertiary windings separately	6 without taps, 9 with an OLTC, plus 3 if a tertiary is brought out to three terminals
Shunt reactor	Winding movement, core and clamping damage	Treated as a star winding: 3 without taps, 6 with taps
Phase shifting transformer	Movement in either core and coil assembly	18 measurements across neutral and extreme taps
Transport check (Annex C.1)	Core, winding and clamping damage in transit	End-to-end open with all other terminals floating, in the transport configuration before and after
After a short-circuit test (Annex C.2)	Subtle winding dimension changes not visible by inspection	Baseline at the test station, measurement after; short-circuit sweeps recommended as well

Choosing the Measurements

AS/NZS IEC 60076.18:2025

The standard measurement is end-to-end open circuit on each phase of each winding, phases and windings separated as far as possible and every other terminal floating (4.4.2.1). Inter-winding and short-circuit sweeps are additional, where specified.

IEEE C57.149-2024

Table 2 tests 1 to 9, the open circuit sweeps on HV and LV plus the HV short-circuit sweeps with the LV shorted, are the recommended minimum for a two-winding transformer. Tests 10 to 15 are the inter-winding sweeps.

Our Recommendation

We run the open circuit sweeps on every winding and the short-circuit sweeps on the HV as the standard set, and repeat any inter-winding sweep that exists in the baseline. The asset owner's specification overrides both.

Tap Position and Configuration

OLTC

Measure the tapped winding on the tap with the most effective turns in circuit and again with the tap winding out of circuit (60076.18, 4.4.2.2). IEEE C57.149 (5.8) uses extreme raise. Approach a neutral or change-over position from the raise side and record the previous tap.

DETC

Leave a service-aged unit on its as-found position and record it; moving a DETC for a test is not recommended (60076.18, 4.4.2.2; C57.149, 5.8).

Good to Know

Split a delta winding with six accessible terminals for the standard sweeps; keep a tertiary or stabilising delta closed. Record every neutral and tertiary state (60076.18, 4.4.4).

How Does It Work?

The Measurement

Principle

A low-voltage sinusoid is applied to one terminal with respect to the tank. The voltage at that terminal is the reference (V_{in}); the voltage at a second terminal, measured across $50\ \Omega$, is the response (V_{out}). Amplitude is $20 \log_{10}(V_{out} / V_{in})$ in dB; phase is the angle between them (60076.18, 4.1).

The Four Measurement Types

End-to-end open: source and reference at one end of a winding, response at the other, everything else floating. End-to-end short circuit: the same, with another winding of the same phase shorted. Capacitive inter-winding: source on one winding, response on another, other ends floating. Inductive inter-winding: as capacitive, but the far ends of both windings earthed (60076.18, 2.6 to 2.9).

What Each Band Sees

Up to about 2 kHz the core magnetising inductance dominates; 2 to 20 kHz the coupling between windings; 20 kHz to 1 MHz the winding structure; above 1 MHz (2 MHz at 72.5 kV and below) the leads and earthing. The limits move with the size of the transformer (60076.18, Annex B.3).

Lead and Earthing Rules

Three Matched Leads

Separate source, reference and response leads: coaxial, $50\ \Omega$, equal length, each with attenuation under 0.3 dB at 2 MHz, and no longer than 30 m for a passive lead system (60076.18, 5.2).

Shortest Braid, Method 1

The lead screen is earthed to the flange at the base of the bushing by the shortest possible braid, pulled tight along the bushing. Method 1 is the reference method and is used for baselines unless agreed otherwise (60076.18, Annex A.3).

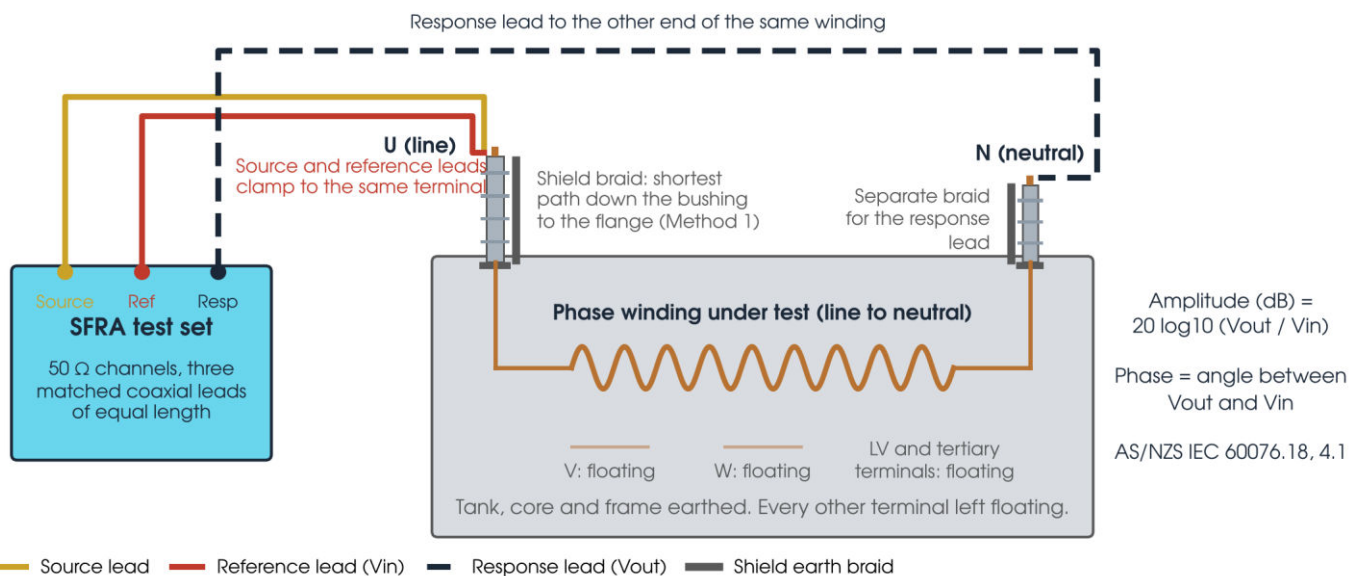
Clean Metal

Clean the terminal and the flange to bare metal. A bad contact gives a noisy low-frequency region and a lower amplitude trend (60076.18, B.4.9).

Good to Know

Use a flat braid, not a wire: the braid's lower inductance and larger surface suppress noise and give repeatable results above 500 kHz (as summarised by OMICRON).

Connection Arrangement: End-to-End Open Circuit



End-to-end open circuit on one phase of a star winding. Source and reference clamp to the line terminal; the response lead goes to the neutral; each lead screen is earthed by its own braid to the bushing flange.

How Do I Set Up Safely?

Permits, Isolation and Earthing

1 Access Permit

Confirm it covers the test, including disconnecting every bushing and lifting the terminal earths for the measurement, by the person the asset owner authorises.

2 Isolated, Proved Dead, Earthed

Confirm it at the plant with the permit issuer before connecting anything. Completely isolated from any HV source, tank earthed (IEEE C57.149, 5.2).

3 Disconnect Every Terminal

Line, neutral and tertiary connections off every bushing; tank earth, auxiliaries and CT service connections stay. Unconnected bushing CTs: secondaries shorted and earthed (60076.18, 4.2).

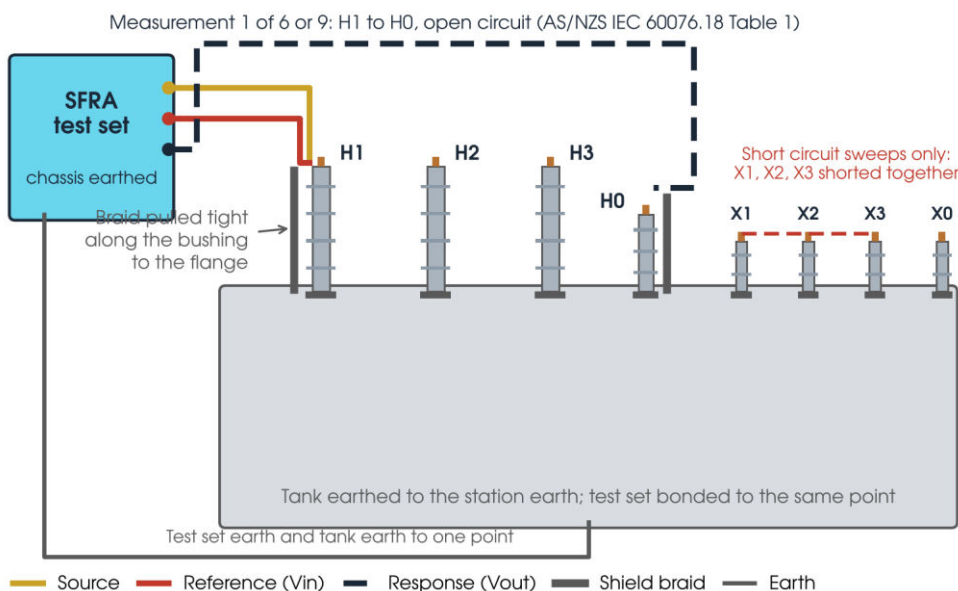
4 Earth the Test Set First

Bond the instrument chassis to the tank earth before any other lead, and remove it last (C57.149, 5.6).

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 Two-Winding Transformer



Measurement H1 to H0 on a YNd transformer. Bus, cables and arresters are off every bushing, the other terminals float, and the shorting link on X1, X2 and X3 goes on for the short-circuit sweeps only.

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 SFRA

Terminals Must Float

Every other terminal is unearthed while the sweep runs. Keep terminal earths on until the moment of measurement and restore them straight after.

Induced Voltage

Disconnected bushings near live lines or busbars act as antennas (C57.149, 5.6). Treat every terminal as live until clamped, and record the surroundings (60076.18, 6.2).

Stored Energy From Earlier Tests

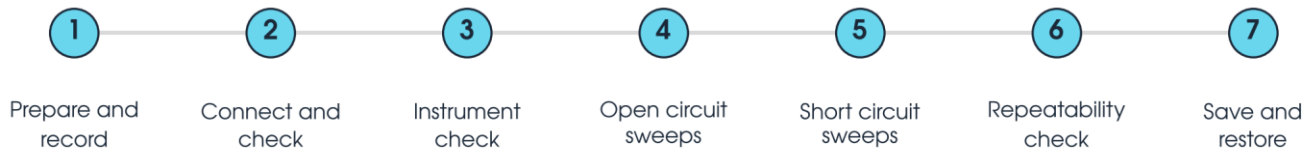
Windings hold charge after insulation tests and energy after DC winding resistance. Discharge and earth them before SFRA leads go on; better, run SFRA first.

Bushings and Height

Refit every bushing test tap cap before return to service. Terminals are usually reached from an elevating work platform under the site's working at height rules.

How Do I Make the Measurement?

Seven Steps



Steps 1 to 4

1 Prepare and Record

Nameplate, vector group, OLTC and DETC positions and the previous tap, oil level and top oil temperature, the state of every neutral and tertiary, and whether a DC test has just magnetised the core (60076.18, Clause 6).

2 Connect and Check

Clean the terminals and flanges. Clamp source and reference to the first terminal, the response to the other end, and each braid down its bushing. Check continuity of the main and earth connections at the instrument end of each lead (60076.18, 4.3.1).

3 Instrument Check

Run the zero check or the manufacturer's performance check when performance is in doubt: channels joined, 0 dB $\pm$ 0.3 dB across the range; response open, below -90 dB (60076.18, 4.3.4).

4 Open Circuit Sweeps

Each phase of each winding, line to neutral or in the head-to-tail order of Table 1 or Table 2, at or below 20 Hz up to 2 MHz with at least 200 points per decade (60076.18, 4.4 and 4.5).

Common Mistakes

Long or Coiled Earth Lead

A loop or a wire instead of a tight braid changes the trace above about 500 kHz, and worse connections push the effect lower (C57.149, 5.5 and 5.6).

Braid Touching the Terminal

Shorts the measurement to earth at the clamp and distorts the high frequencies (as summarised by OMICRON). Use an insulated cover on the braid.

SFRA After Winding Resistance

Residual magnetism moves the core resonance to the right and the low-frequency region no longer matches the baseline.

Steps 5 to 7

5 Short Circuit Sweeps

HV end to end with X1, X2 and X3 shorted together, not earthed and not including the neutral (C57.149, Table 2 note a). Braided copper shorting leads are sufficient.

6 Repeatability Check

Take the leads and braids off, reconnect and repeat the first measurement. It shows the frequency range that can be relied on under the day's conditions (60076.18, 4.3.3).

7 Save and Restore

Save every sweep as XML with the Clause 6 record and photographs of the connections. Restore the terminal earths, then remove the test set earth last. Demagnetise if a DC test follows.

Good to Know

Run SFRA before winding resistance, or demagnetise the core first: a DC test shifts the core resonance and spoils the comparison (IEEE C57.152, 7.2.7; 60076.18, B.4.6).

More Common Mistakes

Bus or Arresters Still Connected

Adds capacitance and inductance the baseline did not have. If a bus must stay, test the same way every time and record it (C57.149, 5.3).

Tertiary or Neutral in a Different State

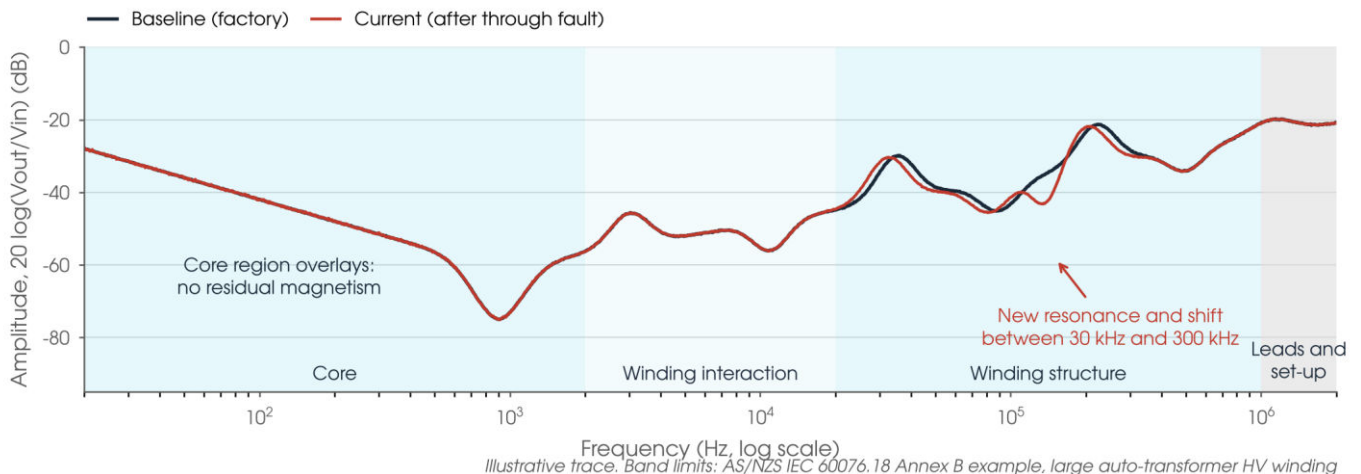
An open, closed, floating or earthed tertiary, or joined neutrals, changes the interaction region. Match the baseline and record it (60076.18, B.4.1 and B.4.2).

Extra Winding Earths

Earths added under local rules on windings not under test give a unique trace that cannot be compared with one taken without them (C57.149, 5.5).

How Do I Read the Result?

Baseline and Current Trace on One Winding



The core and interaction regions overlay. In the winding structure region a resonance has appeared and two have moved. Repeatable in the same configuration, this may indicate mechanical change.

Comparing the Result

Which Reference

The unit's own baseline in the same configuration first; then a twin (same drawings), then a sister unit, then the other phases. Sister units can carry design changes that look like damage (60076.18, Annex B.2).

Three Criteria

A change in the overall shape, a change in the number of resonances and anti-resonances, or a shift in the resonant frequencies (60076.18, B.2). The most significant indicator is a resonance gained or lost, then a shift of an existing one (IEEE C57.149, 7.2).

Short Circuit Low Frequency

The three phases of the short-circuit sweep should agree within ± 0.2 dB in the inductive roll-off; outside that, investigate for radial deformation (C57.149, Table 5).

Useful Range

For winding geometry, typically about 2 kHz to 1 MHz (2 MHz at 72.5 kV and below); assess the core region below it separately. Above it, leads and earthing dominate (60076.18, B.3).

What a Bad Result Looks Like

New or Lost Resonance, 20 kHz to 1 MHz

Winding deformation. Radial buckling of an inner LV winding shows most clearly here (C57.149, Table 5).

New Peaks or Valleys, 5 to 100 kHz

Bulk movement of a winding relative to the others; axial telescoping also shows most clearly here (C57.149, Tables 6 and 7).

Open Circuit Trace Looks Like Short Circuit

The core reluctance has gone from the measurement: shorted turns, or a core defect if the core resonance shape has changed (C57.149, Tables 8 and 9).

Core Resonance Moved Right, Nothing Else

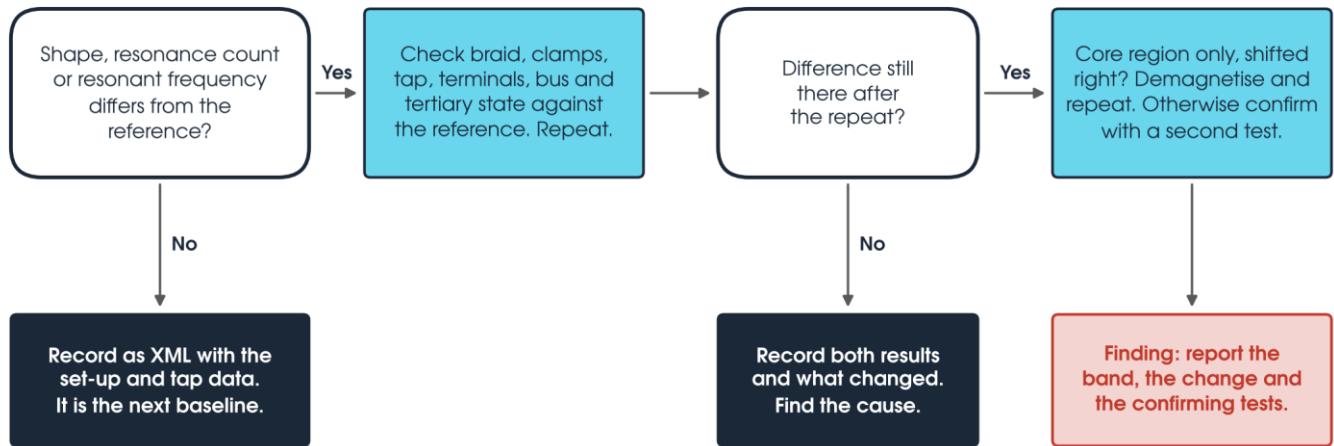
Residual magnetism from a DC test or switching, not a fault. Demagnetise and repeat (C57.149, 7.5.6).

Noisy Low Frequencies, Trace Lower Overall

A bad contact or loose connection (60076.18, B.4.9). Differences only above 500 kHz are usually the leads and braids.

Is My Result OK?

Decision Path



What the Decibel Scale Means

The amplitude axis is a ratio, not a voltage (AS/NZS IEC 60076.18, clause 4.1):

$$\text{Amplitude (dB)} = 20 \times \log_{10} (V_{\text{out}} / V_{\text{in}})$$

So -20 dB means the response is one tenth of the reference, -40 dB one hundredth, and -60 dB one thousandth. A difference of 6 dB between two traces is a factor of two in the ratio; 3 dB is a factor of 1.41.

Worked Example

A baseline reads -46.0 dB at 85 kHz and the current trace reads -43.0 dB at the same frequency. The response has risen by a factor of $10^{(3/20)} = 1.41$. USB FIST 3-31 reports changes under 3 dB as normal; treat 3 dB or more as a change to explain, and a resonance that has moved as more significant than one that has changed height.

What to Report

Every Sweep

Reference and response terminals, terminals shorted and earthed, OLTC tap and previous tap, DETC position, peak test voltage, oil temperature and whether the unit was oil filled (60076.18, 6.1).

The Set-Up

Connection method, braid and lead lengths, core magnetisation state, bus or busbar connected, surroundings such as live lines nearby, and photographs of the connections (60076.18, 6.2).

The Comparison

Which reference was used (baseline, twin, sister or phase), the band in which the traces differ and the criterion met.

Traceability

Instrument make, model and serial number, calibration date and measuring impedance, with the data as XML so it can be read without the instrument software in 20 years (C57.149, 6.2.1).

How Do I Compare Two Traces?

Three Ways to Compare

Overlay

Both traces on one plot, dB against log frequency: the most common method (C57.149, 7.3.1).

Difference Plot

Subtract one amplitude trace from the other; any region away from zero needs explaining (C57.149, 7.3.2).

Correlation Coefficient

The Pearson coefficient of the two amplitude traces, from -1 to 1 with 1 identical, for the whole sweep or band by band (C57.149, 7.3.3).

Interpreting the Numbers

No Pass Value

Neither standard sets a threshold for the coefficient; 60076.18 keeps interpretation informative (Annex B). Repeat the sweep before calling a fault (B.4.11).

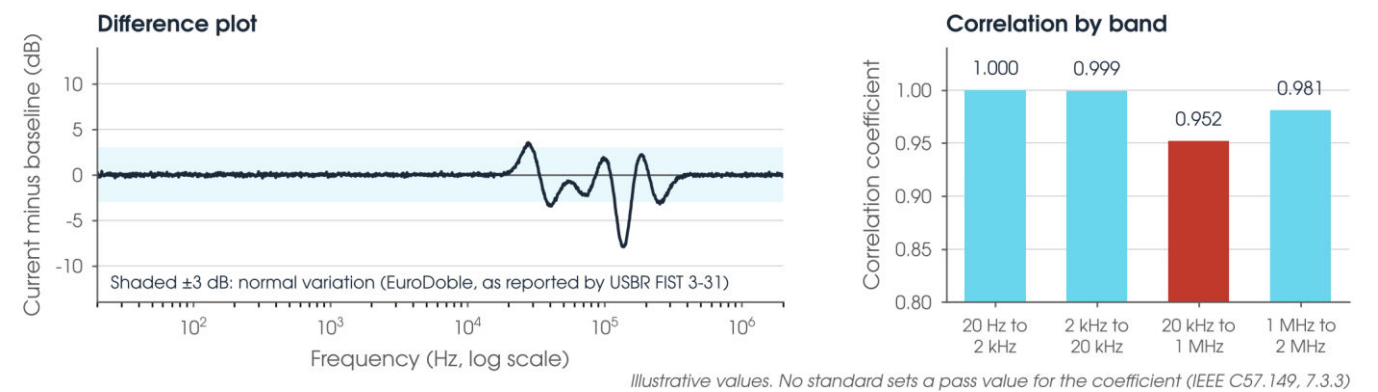
Confirm With a Second Test

A short-circuit low-frequency change is checked with leakage reactance, and the flat response below 30 Hz with DC winding resistance (C57.149, 7.4).

Good to Know

Good agreement above 1 MHz between traces that differ lower down makes a lead or earthing error unlikely, but does not rule out a configuration difference (60076.18, B.4).

Difference Plot and Correlation by Band



Recommended Solutions

Instrument	Measurements	Best used for
OMICRON FRANEO 800	SFRA: open, short circuit, capacitive and inductive inter-winding	Baselines and diagnostics to IEC 60076-18 Method 1, with overlay against the fingerprint
OMICRON FRAnalyzer	SFRA: end-to-end, end-to-neutral, cross-phase	Compact SFRA set for site and factory
OMICRON TESTRANO 600	Winding resistance, ratio, short-circuit impedance, demagnetisation	Confirming a finding; demagnetising before the sweep
OMICRON CPX 200	Ratio, winding resistance, excitation, demagnetisation	Compact companion set for the confirming tests
OMICRON CPC 100	Winding resistance, short-circuit impedance, excitation	Leakage reactance and winding resistance

Every instrument is available calibrated, with leads, from Hobart, Launceston, Adelaide and Newcastle: [transformer test equipment hire](#).

Frequently Asked Questions

Common Questions

What is a SFRA test?

A sweep frequency response analysis: a low-voltage signal swept from 20 Hz to 2 MHz through a transformer winding, recorded as amplitude in dB and phase against frequency, and compared with a reference trace to find winding or core movement.

How to read a SFRA graph?

Overlay the current trace on the reference. Look for a changed shape, a resonance gained or lost, or a resonance moved. Below about 2 kHz is the core, 2 to 20 kHz the winding interaction, 20 kHz to 1 MHz the winding structure, and above 1 MHz the leads.

What is sweep frequency?

The test signal is a sinusoid whose frequency is stepped through the range, at least 200 points per decade above 100 Hz, so the response is measured at every frequency rather than from one impulse.

What is SC and OC test?

The open circuit (OC) sweep is end to end on one winding with everything else floating and shows the core and the winding. The short circuit (SC) sweep repeats it with the other winding shorted, which removes the core and shows the winding alone.

Standards and References

AS/NZS IEC 60076.18:2025, Power transformers, Part 18: Measurement of frequency response (identical adoption of IEC 60076-18:2012).

IEEE Std C57.149-2024, Guide for the Application and Interpretation of Frequency Response Analysis for Oil-Immersed Transformers.

IEEE Std C57.152-2025, Guide for Diagnostic Field Testing of Liquid-Filled Power Transformers, Regulators, and Reactors, clause 7.2.7 and Annex F.

AS/NZS 60076.1:2014, Power transformers, Part 1: General, clause 11.1.4.

OMICRON, SFRA Testing on Power Transformers: Introduction, 2019; SFRA and Leakage Reactance for Mechanical Faults, 2018; Performing Reliable and Reproducible Frequency Response Measurements, 2018; Diagnostic Testing of Power Transformers, 2025.

Doble Engineering, Impact of SFRA Setup Issues on Transformer Frequency Response, NETA World, 2020; SFRA Ratio Test on Transformers, Transformers Magazine, 2021.

US Bureau of Reclamation, FIST 3-31, Transformer Diagnostics, 2003.

Safe Work Australia, model Code of Practice: Managing Electrical Risks in the Workplace.

More Questions

Can SFRA be done without a baseline?

Yes, with care. Compare with a twin or sister unit, or between the phases of the same unit; the centre phase of a three-limb core normally differs at low frequency. The result is less certain than a baseline comparison.

Why is SFRA done before winding resistance?

A DC winding resistance test leaves the core magnetised, which moves the core resonance. Run SFRA first, or demagnetise the core before it (IEEE C57.152, 7.2.7).

Does the test voltage matter?

Only in the core region of an open circuit sweep, where the magnetising inductance depends on the signal level (as summarised by OMICRON). Record the peak voltage and use the same one next time.

Does Megavar test as well as hire?

Yes. Megavar tests power transformers from 11 kV distribution class to 500 kV transmission class, with SFRA compared against the factory baseline. Call 1300 730 499.

Hire or Have It Tested

Have It Tested

Megavar's engineers carry out [transformer testing](#), [factory acceptance testing](#) and [substation commissioning](#) across Australia.

Next Step

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Hire: rentals@megavar.com.au

Testing: service@megavar.com.au



Speak to our team today

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