



Earth Resistance Testing Guide



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About This Guide

Earth resistance testing measures how well an earth electrode or substation earth grid carries fault current into the ground. On a single electrode it is one resistance reading. On a substation grid it is a set of measurements: grid impedance, earth potential rise and the touch and step voltages a person could meet. This guide covers the methods, the set-up and how to judge a result.

What Earth Resistance Testing Is

A measurement of the resistance or impedance between an earthing system and remote earth. On substations it extends to the earth potential rise and the touch and step voltages that follow from it during a fault.

When It Is Used

Soil resistivity before design, continuity during construction, injection testing at commissioning, and repeat tests after extensions, nearby works or theft of earth conductors.

Why It Matters

An earth grid is buried and cannot be inspected by eye. A broken weld or a missing bond can sit unnoticed for years and only show itself when fault current, or a technician's hand, finds the gap. A test finds it first.

Guide at a Glance

Measures

Electrode resistance, grid impedance, earth potential rise, touch, step and transferred voltages.

Methods

Fall of potential, soil resistivity (Wenner), current injection, clamp-on, high-current continuity.

Test Current

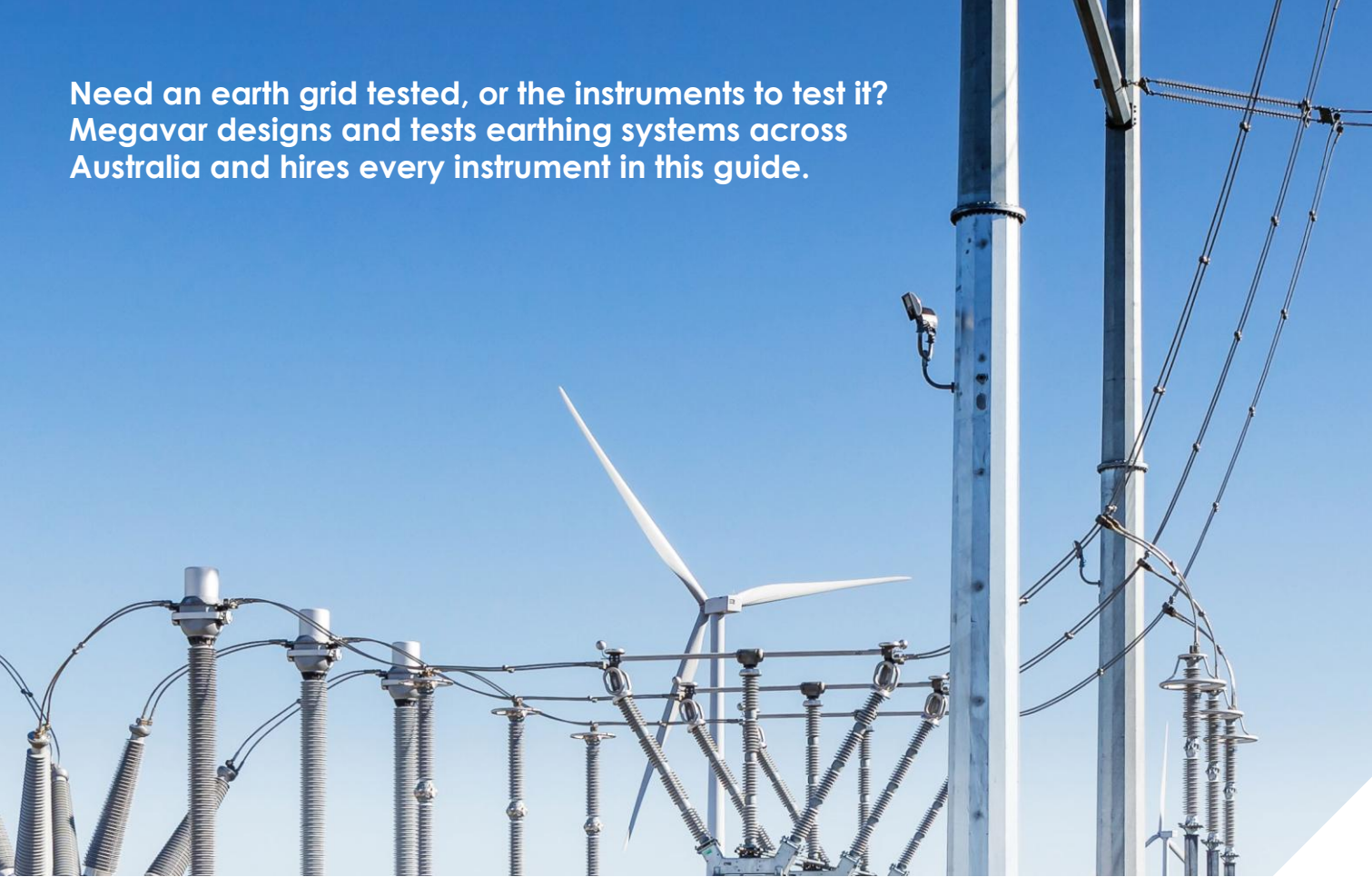
Milliamps for earth testers; 1 to 30 A off frequency for grid injection (EG-1); 50 A or more for continuity (OMICRON).

Typical Result

Large substation grids typically below 0.5 Ω (Megger). Safety is set by voltage, not resistance.

Judged Against

The earthing design, ENA EG-0 safety criteria and the network owner's requirements.



Need an earth grid tested, or the instruments to test it? Megavar designs and tests earthing systems across Australia and hires every instrument in this guide.

Why Measure Earth Resistance?

Earth Testing in Four Numbers

61.8%

Potential probe position as a share of the distance to the current probe (Megger)

5 to 10 times

Current return distance as a multiple of the grid's largest dimension (IEEE 81-2025 cl 8.3.4)

1 m

Reach used for touch and step voltage measurement (OMICRON)

< 0.5 Ω

Typical resistance of a large substation earth grid (Megger)

Why It Matters

Safety Is Set by Voltage

During an earth fault the grid rises above remote earth. What harms people is the share of that rise across a hand and the feet, so a substation grid is judged on touch and step voltages, not on its resistance alone.

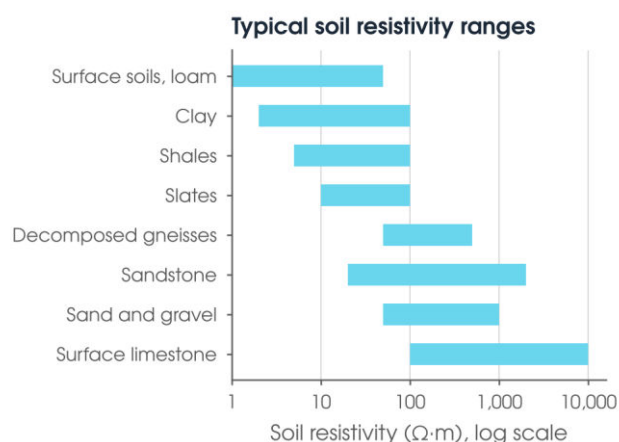
Grids Deteriorate Unseen

A 2025 Doble conference paper (Alabama Power) describes a defective below-grade exothermic weld that left a substation neutral floating since construction. An arc occurred when an unbolted transformer lead was set on the tank cover, and 145 A was then found flowing in the temporary earths.

Grids Are Bigger Than They Look

Fences, building earths and metallic pipes bonded to a grid form one system, and a deteriorated neighbour changes the result (OMICRON, 2026).

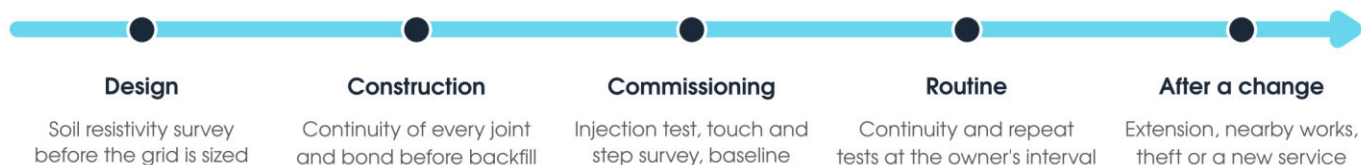
Soil Sets the Starting Point



Source: Megger, *Getting Down to Earth*, 2020, Table II

Soil resistivity spans four orders of magnitude, and moisture and dissolved salts move it further (Megger, 2020).

When to Test



Items Tested

Item	What the test shows	Method
Substation earth grid	Grid impedance, earth potential rise, touch and step voltages	Current injection with a remote return
Grid joints, risers and bonds	Broken, corroded or undersized connections	High-current continuity, 50 A or more (OMICRON)
Single electrodes and small grids	Resistance to remote earth	Fall of potential (3-point)
Electrodes on multiple earthed systems	Loop resistance of each electrode in service	Clamp-on (stakeless)
Site soil before design	Resistivity profile with depth for the soil model	Wenner or Schlumberger four-pin
Services leaving the site	Transferred potential on telecoms, pipelines and fences	Measured during the injection test

Choosing the Method

Electrode or Small Grid

Fall of potential. Accurate for driven rods and small groups of rods when the current probe can be placed far enough away (Megger, 2020).

Large Substation Grid

Current injection against a remote return. Fall of potential would need leads several kilometres long to find a flat region.

Multiple Earthed System

Clamp-on. Quick, with no probes and no disconnection, but it reads the loop through every parallel return path (Megger, 2020).

Before Design

Wenner or Schlumberger on at least two traverses (IEEE 81-2025 cl 7.4.3): inner spacing about 1 m, outer beyond the grid radius or diagonal (EG-1 cl 14.5.4.4).

Test Current and Frequency

Off the Power Frequency

Injecting near but not at 50 Hz and measuring with a frequency-selective meter rejects network noise; results are interpolated to mains frequency (OMICRON, 2026).

How Much Current

Earth testers use milliamps (AEMC 6471, up to 250 mA). Off-frequency grid injection needs 1 to 30 A (EG-1 cl 14.6.2.2): about 25 A from the Red Phase set, 100 A at 50 V from the CPC 100 with CP CU1.

Continuity Needs High Current

50 A and above reveals small resistance changes between grid parts that low-current testers miss (OMICRON, 2026).

Good to Know

Record the injected current and the test frequency with every reading, so the next test can repeat them.

How Does It Work?

Fall of Potential

Three Connections

The tester drives current from the electrode under test (E) to a current probe (C) and measures the voltage to a potential probe (P) between them. Voltage divided by current is the earth resistance.

The Flat Region

As P moves from E towards C, the reading rises, levels off, then rises again near C. The level part is the true resistance (Megger, 2020).

The 61.8% Rule

P at 61.8% of the E to C distance lands on the flat region for a simple electrode in uniform soil (Megger, 2020). EG-1 cl 14.6.3.5 limits the rule to small localised systems.

Electrode Rules

Current Probe Far Enough

For a 30 m by 30 m grid (43 m diagonal), Megger's guide table puts P about 111 m and C about 180 m from the electrode. Large systems need more.

Isolate a Single Electrode

Disconnect it, or the whole connected system is measured, but only under the approved isolation with temporary earthing in place. Zero current alone does not make it safe (IEEE 81-2025 cl 5.3).

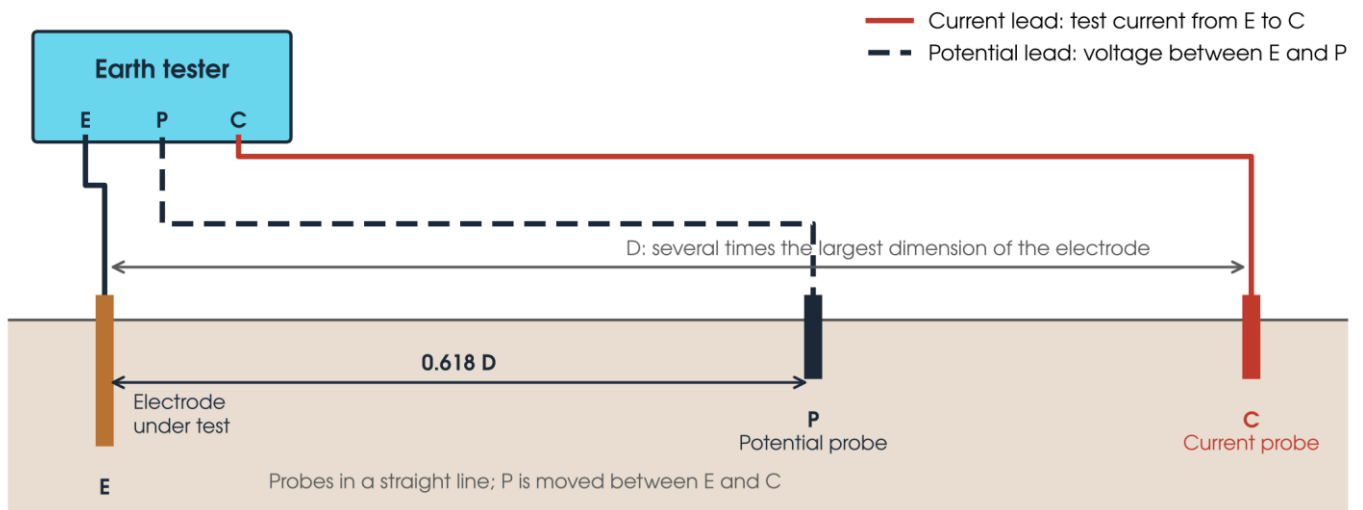
Wenner for Soil

Four equally spaced probes; resistivity $\rho = 2\pi aR$, valid when probe depth is under 5% of the spacing a (AS/NZS 3835.2:2006 cl 6.16).

Good to Know

Plot the full curve rather than one reading at 61.8%. A flat region is what proves the result.

Fall-of-Potential Electrode Layout



Three-point fall-of-potential test. The current lead runs to C; the potential lead runs to P, placed at 0.618 of the distance from E to C.

How Do I Set Up Safely?

Permits and Precautions

1 Permit and Owner Approval

Grid injection is done on live substations, under the network owner's safety rules and access permit.

2 Treat Test Leads as Live

If a network earth fault occurs during the test, the grid rises and every lead bonded to it carries that voltage to its far end.

3 Barricade the Remote Ends

Current return electrodes and reference probes can be at hazardous voltage during injection. Guard them and the lead route.

4 Keep Test EPR Under 60 V

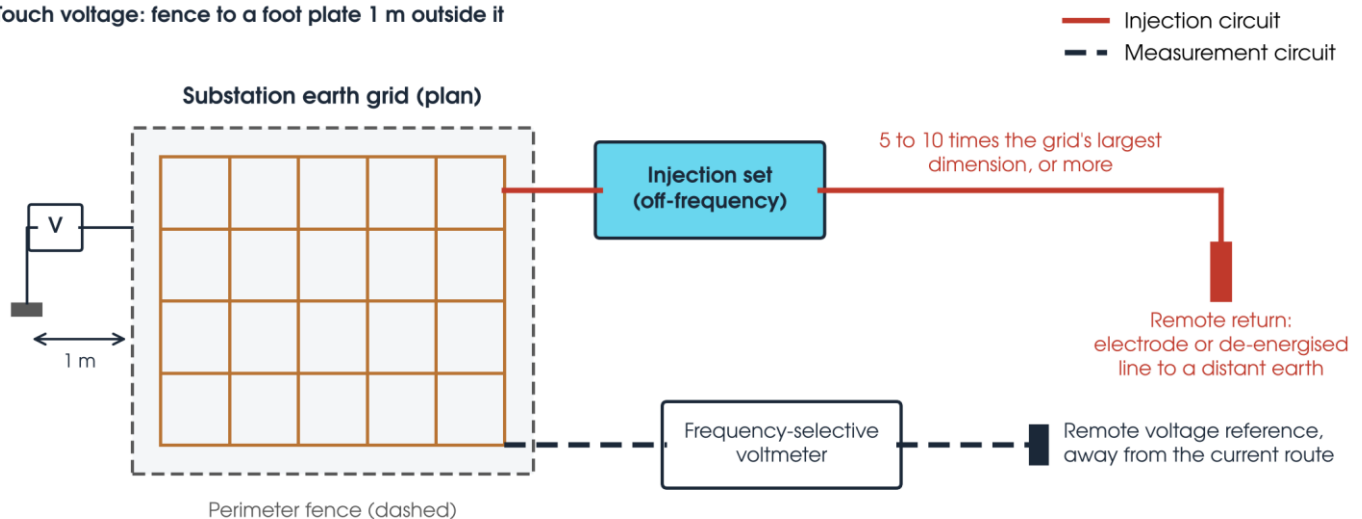
Use the least current that gives good readings; measured EPR must never exceed 60 V (AS/NZS 3835.2:2006 cl 6.13). Stop for lightning.

Who Should Test

Competent, authorised testing personnel. At Megavar, assessed testers, with less experienced staff under direct supervision.

Substation Current Injection Layout

Touch voltage: fence to a foot plate 1 m outside it



Off-frequency current flows between the grid and a remote return. Voltages are read against a separate remote reference.

Important

This guide describes general practice for competent HV testing personnel. It is not a work procedure. Work under the network owner's safety rules, the access permit and a site-specific safe work method statement. The earthing design, ENA EG-0 criteria and the network owner's requirements take precedence over the general guidance here.

Hazards Particular to Earth Testing

Transferred Potential

Leads and probes bring the grid potential outside the site, to places the earthing design never covered.

Induced Voltage

Long leads run parallel to energised lines pick up induced voltage. Route them away from lines where possible and keep the potential lead away from the current lead.

Disconnecting an Electrode

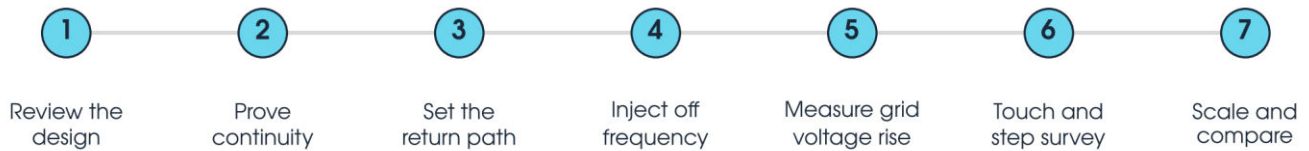
Measure the current and induced voltage before disconnecting, and do it only under the approved safety arrangement. A conductor carrying current can spark when opened (IEEE 81-2025 cl 5.3).

Public Land

Leads that cross roads, paddocks or footpaths need permission, protection and signage.

How Do I Make the Measurement?

Seven Steps for a Substation Grid



Steps 1 to 4

1 Review the Design

Obtain the soil model, design fault current, clearing time, current split assumptions and the permissible touch and step voltages.

2 Prove Continuity

Four-wire, at high current, on every bond the design requires. Over $1.0\ \Omega$ is clearly not bonded (IEEE 81-2025 cl 10.5.6). Confirm segregated fences are still separate (EG-1 cl 14.3).

3 Set the Return Path

A remote return 5 to 10 times the grid's largest dimension away (IEEE 81-2025 cl 8.3.4), or a de-energised line. Run the potential lead at 90° to it (EG-1 cl 14.6).

4 Inject Off Frequency

Inject a known current at the test frequency and confirm the meter is tuned to it.

Steps 5 to 7

5 Measure Grid Voltage Rise

Grid voltage against the remote reference, divided by the current entering the soil, is the grid impedance.

6 Touch and Step Survey

Prospective values, high impedance voltmeter, 1 m reach (EG-1 cl 4.4.2.1): fences, gates, entries, operating positions, boundary. The highest are often outside fences (OMICRON, 2026).

7 Scale and Compare

Scale every reading to the share of fault current that flows into the soil, then compare with the limits for the clearing time.

Good to Know

Repeat the survey after structural changes nearby: connected earthing systems deteriorate too (OMICRON, 2026).

Common Mistakes

Current Probe Too Close

The curve never flattens and the reading is too high or meaningless.

Potential and Current Leads Run Together

Coupling between the leads distorts the voltage reading.

Test-Level Reading Against a Fault-Level Limit

A reading of under a volt says nothing until it is scaled to fault current.

Current Split Not Measured

The earth potential rise is wrong even when the grid impedance is right.

More Common Mistakes

Clamp-On on the Wrong Earth

It needs parallel return paths; on an isolated electrode or a dominant substation grid the reading is meaningless.

One Reading at 61.8%

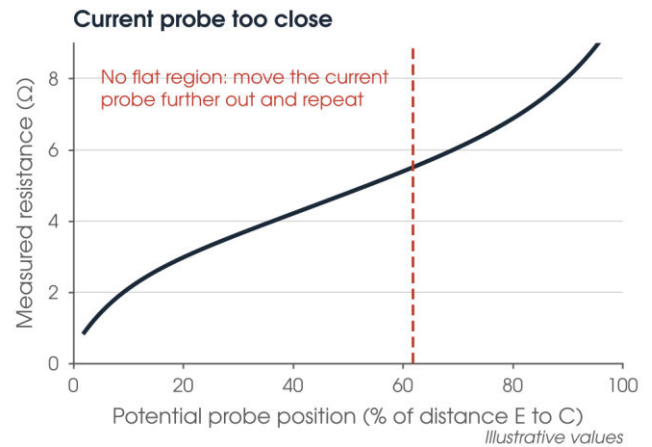
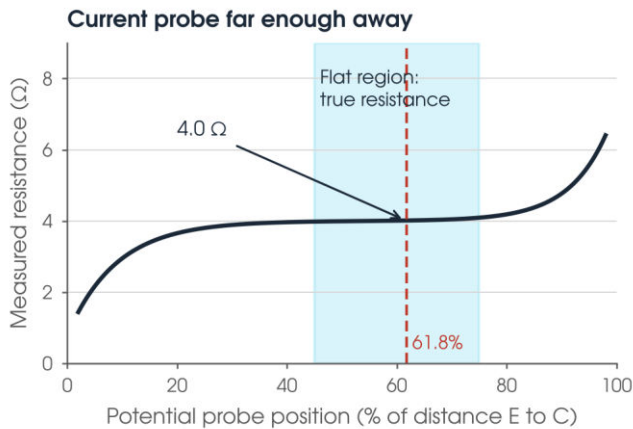
No curve, no proof that the reading sits on the flat region.

Continuity Tested at Low Current

Damaged joints can pass at milliamps and fail at fault current.

How Do I Read the Result?

Fall-of-Potential Curves



Left: the current probe is far enough away and the curve flattens around 61.8%. Right: the current probe is too close and there is no flat region, so no reading on that curve is valid.

Reading the Curve

Flat Region

The resistance where the curve levels off is the electrode's resistance to remote earth.

No Flat Region

The current probe is inside the electrode's area of influence. Move it further out and repeat.

Bumps and Steps

Buried pipes, cables or a local change in soil distort the curve near them (Megger, 2020). Try a different direction.

Season

Earth resistance changes with moisture and temperature (Megger, 2020), so compare tests taken in similar conditions.

What a Bad Result Looks Like

Grid Impedance Above Design

Check the current split and remote reference first, then the soil model the design used.

One Touch Point Far Above Its Neighbours

A missing or broken bond at that structure.

High Readings Outside the Fence

A fence not bonded to the grid, or not separately earthed as the design intended.

Unstable Readings

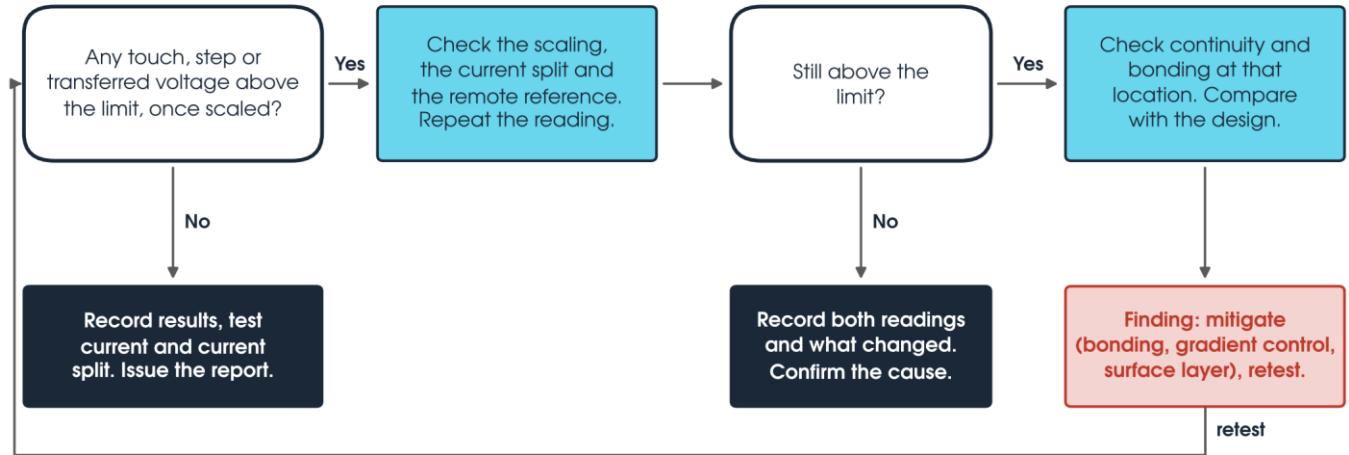
Noise at the test frequency, a loose lead, or a probe with poor soil contact.

Continuity Out of Family

A corroded, loose or broken joint between that point and the grid.

Is My Result OK?

Decision Path



Scaling to Fault Level

Readings at test level are scaled linearly to the share of the design earth fault current that flows into the soil:

$$V_{\text{fault}} = V_{\text{measured}} \times I_{\text{grid,fault}} / I_{\text{grid,test}}$$

Both currents are the soil-return share after the current split. Where the clearing time is under 0.5 s the fault current is first increased by the decrement factor for the system X/R (EG-1 Table 8.3). Use total injected current only where none of it leaves by sheaths or earth wires (EG-1 cl 14.6.3.3).

Worked Example

With 10 A injected and all of it returning through the soil, the grid rises 2.0 V and a fence touch point reads 0.80 V. If 4,000 A enters the soil, the grid impedance is 0.2 Ω, the earth potential rise is 800 V and the prospective touch voltage is 320 V. The 320 V is compared with the limit.

Good to Know

Never compare a test-level reading with a fault-level limit.

What to Report

For Each Location

Measured and scaled voltage, the limit, its EG-0 case (TSI or ZSI inside the fence) and the clearing time.

For the Grid

Grid impedance, EPR, the measured current split against the design, and scaled transferred potentials.

Prospective, Not Loaded

Limits are prospective (AS 2067 cl 8.8). A loaded check uses about 1000 Ω for the body (IEEE 80-2013 cl 7.1) and weighted 8 cm radius discs, wet ground (EG-1 cl 14.6.3.4.1).

Traceability

Injected current, test frequency, return and reference locations, instrument serial numbers and calibration dates.

What About Large Substation Earth Grids?

Why Fall of Potential Runs Out

The Distance Problem

EG-1 cl 14.6.3.5 asks for a current lead at least 5 times the largest grid diagonal; Megger's ideal is 10 times, about 900 m for a 90 m grid.

The Slope Method

Readings at 20%, 40% and 60% of the current probe distance are fitted to a model, so no flat region is needed (Megger, 2020).

Resolution

Large grids typically measure below 0.5 Ω (Megger, 2020). Many low power meters are unsuitable below 5 Ω (EG-1 cl 14.6.3.5); use injection on large HV sites (AS/NZS 3835.2 cl 6.8.3).

Why the Current Split Matters

Current Injection and the Split

Power Line Injection

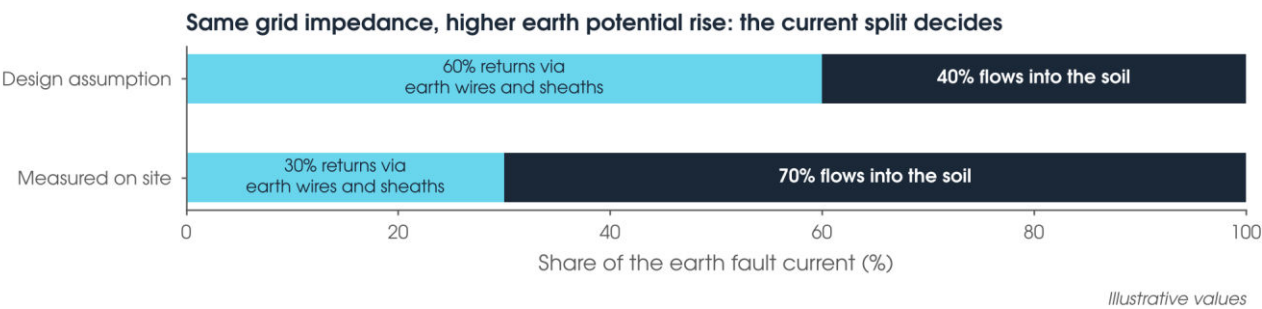
A disconnected line returns the test current through a remote earth, reflecting real fault current distribution (OMICRON, 2026).

The Current Split

Overhead earth wires and cable sheaths carry part of the fault current away from the soil. The reduction factor is the share still returning through the soil (EG-1 s 8.12).

Good to Know

Measure the current in every sheath and earth wire during injection. The split changes the answer.



Design assumed 60% returns through earth wires and sheaths; the test finds 30%. More current enters the soil and the earth potential rise exceeds the design.

Recommended Solutions		
Instrument	Output or range	Best used for
AEMC 6471	Up to 250 mA	Fall of potential, soil resistivity (Wenner), selective and stakeless tests
Red Phase 1.5 kVA Injection Set	1.5 kVA, typically up to 25 A	Substation grid injection for impedance, touch, step and current split
Red Phase 4025E	Tuned to 55 to 60 Hz	Frequency-selective voltage and current readings with the Red Phase set
Mitton TVM1100	Tunes 45 to 65 Hz	Off-frequency voltage and current with phase angle, for grid impedance and current split
OMICRON CPC 100	Up to 800 A on its own; 100 A at 50 V with CP CU1 over a power line	Grid impedance by power line injection, and high-current continuity
Red Phase 4022C	Up to 100 A DC	Continuity of joints, risers and bonds

Every instrument is available calibrated, with leads, from Megavar's offices in Hobart, Launceston, Adelaide and Newcastle: [earth testing equipment hire](#).

Frequently Asked Questions

Common Questions

What is the 3 point test for earthing?

The fall-of-potential method: current from the electrode to a remote current probe, voltage measured to a potential probe between them. The reading on the flat part of the curve, at about 61.8% for uniform soil, is the earth resistance.

What is the proper procedure for testing an earthing system?

Review the design, prove continuity, inject off-frequency current against a remote return, measure grid voltage rise, survey touch and step voltages, check transferred potentials, and scale every reading to fault level before comparing with the limits.

How to calculate soil resistivity test?

Wenner method: $\rho = 2\pi aR$, with a the probe spacing and R the tester reading. Repeat at increasing spacings to profile resistivity with depth.

What is the normal reading for earthing?

There is no single value. Large substation grids typically measure below 0.5 Ω (Megger), but safety is proven by scaled touch and step voltages against the limits for the clearing time.

Standards and References

AS 2067:2016, Substations and high voltage installations exceeding 1 kV a.c.

ENA DOC 025-2022 (EG-0) v2, Power System Earthing Guide, Part 1: Management Principles.

ENA DOC 045-2022 (EG-1) v2.0, Substation Earthing Guide.

IEEE Std 80-2013, Guide for Safety in AC Substation Grounding.

IEEE Std 81-2025, Guide for Measuring Earth Resistivity, Ground Impedance and Earth Surface Potentials.

AS/NZS 60479.1, Effects of current on human beings and livestock.

AS/NZS 4853:2012, Electrical hazards on metallic pipelines; AS/NZS 3835.1:2006 and 3835.2:2006, Earth potential rise.

Megger, Getting Down to Earth: A Practical Guide to Earth Resistance Testing, 2020.

OMICRON, Diagnostic Testing of Grounding Systems, 2026.

L. Cost, Arc Flash Incident Due to Faulty Substation Ground Grid, Doble Client Conference, 2025.

More Questions

What are the prices of earth resistance tests?

Priced per site. The drivers are grid size, the number of touch and step points, the distance to a usable return path, outage availability, travel and the report required.

What are the methods of earthing?

For HV sites, a buried copper mesh with driven rods, combined with a neutral earthing method: solid, resistance, reactance, resonant or isolated. The neutral method sets the fault current the grid is tested against.

Which earth testing equipment does Megavar hire?

The AEMC 6471, the Red Phase 1.5 kVA injection set, 4025E meter and 4022C continuity tester, the Mitton TVM1100 tuned voltmeter and the OMICRON CPC 100.

Does Megavar do the earthing design as well as the test?

Yes. Megavar provides soil resistivity surveys, earth grid design, and step, touch and earth resistance testing as one service, to ENA EG-0 and IEEE 80.

Hire or Have It Tested

Have It Tested

Megavar's engineers provide [earthing design and testing](#) and [substation commissioning](#) across Australia.

Next Step

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Testing: service@megavar.com.au



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