



VT Testing Guide



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About This Guide

VT testing proves that a voltage transformer delivers a secondary voltage that is a true, correctly phased image of the primary voltage, and that its insulation and secondary circuit are fit for service. A test set applies a known voltage to one winding and measures the other. This guide covers inductive VTs and capacitive voltage transformers (CVTs): ratio and polarity, insulation, tan delta, burden, safety and judging a result.

What VT Testing Is

Ratio and polarity, phase displacement, insulation resistance, tan delta and capacitance, and secondary burden checks on an inductive or capacitive voltage transformer. Also called potential transformer or PT testing.

When It Is Used

At factory and site acceptance, at commissioning before any protection or metering scheme is energised, at the asset owner's routine interval, after secondary wiring work or a VT replacement, and after a misoperation.

Why It Matters

Every protection, metering and control function downstream sees the system through the VT. A wrong ratio, reversed polarity or shorted capacitor layer in a CVT corrupts all of them at once, and secondary injection cannot find it.

Guide at a Glance

Measures

Ratio and phase displacement, polarity, insulation resistance, capacitance and tan delta, secondary burden.

Method

Low voltage applied to one winding and measured on the other; capacitor stacks measured with a tan delta set.

Test Voltage

Typically 2 kV for a CVT ratio test and up to 10 kV for tan delta, never above the line-to-earth rating (OMICRON).

Typical Limits

Class 0.5: $\pm 0.5\%$ and ± 20 minutes; class 3P: $\pm 3\%$ and ± 120 minutes (AS 61869.3, Tables 301 and 302).

Judged Against

The nameplate and accuracy class, the factory certificate, sister units and the VT's own history.

Need VTs tested, or the instruments to do it? Megavar tests instrument transformers across Australia and hires every instrument in this guide.



Why Test a Voltage Transformer?

VT Testing in Four Numbers

±0.5%

Voltage error limit for a class 0.5 measuring VT (AS 61869.3, Table 301)

±3%

Voltage error limit for a class 3P protective VT (AS 61869.3, Table 302)

200 MΩ

Secondary winding insulation resistance at 1 kV DC (AS 61869.1, cl 5.4.5.3)

10%

Capacitance rise on a CVT stack considered dangerous (OMICRON)

Why a Fraction of a Percent Matters

One Error, Every Function

A VT feeds protection, revenue metering, synchronising and control at the same time. A ratio or phase error is copied into every one of them, and a reversed polarity turns a directional or distance element the wrong way.

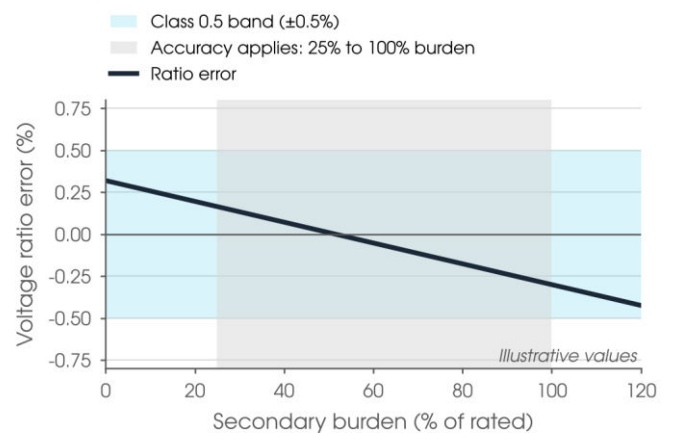
What Secondary Injection Cannot See

A relay test injects into the relay, not through the VT. A crossed phase, a wrong tap or a shorted turn in the VT passes a relay test and fails in service.

Faults That Stay Hidden

Shorted capacitor layers in a CVT stack and shorted turns in an inductive VT are often undetected until the unit fails, and some end in a complete breakdown (OMICRON).

Burden Moves the Error



Ratio error of a class 0.5 VT across its burden range. For range II, the error must stay inside the class band from 25% to 100% of rated burden (AS 61869.3, 5.6.301).

When to Test



Where Is It Used?

Items Tested

Item	What a bad result points to	Site tests
Single-phase inductive VT, earthed (A-N)	Wrong ratio or tap, shorted turns, reversed polarity, moisture in oil-paper insulation	Ratio and polarity, IR, tan delta above 72.5 kV
Unearthed (phase-to-phase) VT	As above; insulation of both primary terminals must be checked, each in turn	Ratio and polarity, IR, tan delta
Three-phase VT, usually 36 kV and below	Phase markings not matching the primary, wrong category of burden connection	Ratio per phase, phasing, burden (AS 61869.3, Appendix ZA)
CVT capacitor stack (C1, C2)	Shorted capacitor layers, moisture: capacitance up, tan delta up	Capacitance and tan delta of C1 and C2
CVT electromagnetic unit	Intermediate transformer or compensating reactor fault, ferroresonance damage	Ratio through the stack at 2 kV, IR
Residual voltage (open-delta) winding	Reversed polarity on one phase: a false residual voltage, or none under an earth fault	Polarity on all three phases, burden
Secondary circuit	Short circuit, second earth, over-burden or excessive lead drop	IR, burden and voltage drop, single-point earth

Choosing the Tests and Test Voltages

AS 61869.3:2021

Accuracy is type tested at 80%, 100% and 120% of rated voltage for measuring classes (7.2.6.301), and at 2%, 5%, 100% and the rated voltage factor times rated for protective classes (7.2.6.302), at 25% and 100% of rated burden for burden range II (Table 305).

Site Ratio Check

A site ratio check at low voltage is a functional test and is generally not comparable with the standard's accuracy tests (OMICRON). It proves the nameplate ratio, the tap and the polarity.

AS 61869.1:2024

Secondary winding insulation resistance, where requested, is 200 M Ω or more at 1 kV DC, or 500 V DC where the secondary withstand rating is below 1 kV (5.4.5.3). A repeat withstand test on a VT that has been in service is at 80% of the rated value, with a minimum of U_m (7.3.1).

Our Recommendation

At commissioning: IR, ratio and polarity on every winding and tap, burden and voltage drop, and capacitance and tan delta on every CVT and on oil-paper VTs above 72.5 kV. The asset owner's testing standard sets the rest.

Higher or Lower Test Voltage

Why Not Rated Voltage

A ratio check does not need it. Site test sets apply from a few hundred volts to 2 kV, which gives the ratio and polarity without a high voltage source in the yard (OMICRON).

Never Above the Rating

For a CVT ratio test and for tan delta, the test voltage must not exceed the line-to-earth rating of the unit; tan delta on a CVT is typically 10 kV, and the C2 measurement is held to 500 V where the carrier terminal rating is unknown (OMICRON).

Where Low Voltage Misleads

Protective classes are specified down to 5% of rated voltage, and at 2% the limits double (AS 61869.3, Table 302). A low voltage check cannot stand in for the factory accuracy test.

Good to Know

Record the test voltage, the winding tested, the tap and the burden with every result.

Repeat future tests at the same voltage and connection, or the results cannot be compared.

How Does It Work?

The Voltage Method

Ratio

The VT is a step-down transformer. A known voltage is applied to one winding and the voltage on the other is measured; the ratio is U_1/U_2 and the turns ratio n_1/n_2 (OMICRON). The secondary is open-circuited for the ratio test unless the ratio under burden is wanted.

Ratio Error and Phase Displacement

Accuracy is stated as a voltage (ratio) error in percent and a phase displacement in minutes between the secondary and primary phasors (AS 61869.3, Tables 301 and 302). IEEE C57.13 expresses the same thing as a ratio correction factor, $RCF = 1$ minus the ratio error divided by 100 (clause 5.2).

Polarity

A sinusoidal voltage applied to one side and compared as a phasor with the other side gives polarity and ratio in one test (OMICRON). A DC kick test with a battery also works but can generate a dangerous voltage when the battery is disconnected (USBR FIST 3-8).

Which Side to Energise

Apply the source to the high-turn winding. Energising the secondary induces full ratio times the applied voltage on the primary (USBR FIST 3-8).

Connection Rules

Terminal Markings

Capital A, B, C and N are primary terminals; lower case a, b, c and n are the corresponding secondaries, and da-dn the residual voltage winding. Terminals with corresponding capital and lower case markings have the same polarity at the same instant (AS 61869.3, 6.13.301). IEEE practice marks them H1 and X1 (IEEE C57.13, 4.9).

One Earth Per Secondary

Earth one terminal of each secondary winding during the test and leave the rest floating (OMICRON). In service the secondary circuit is earthed at one point only (USBR FIST 3-8, 5.2).

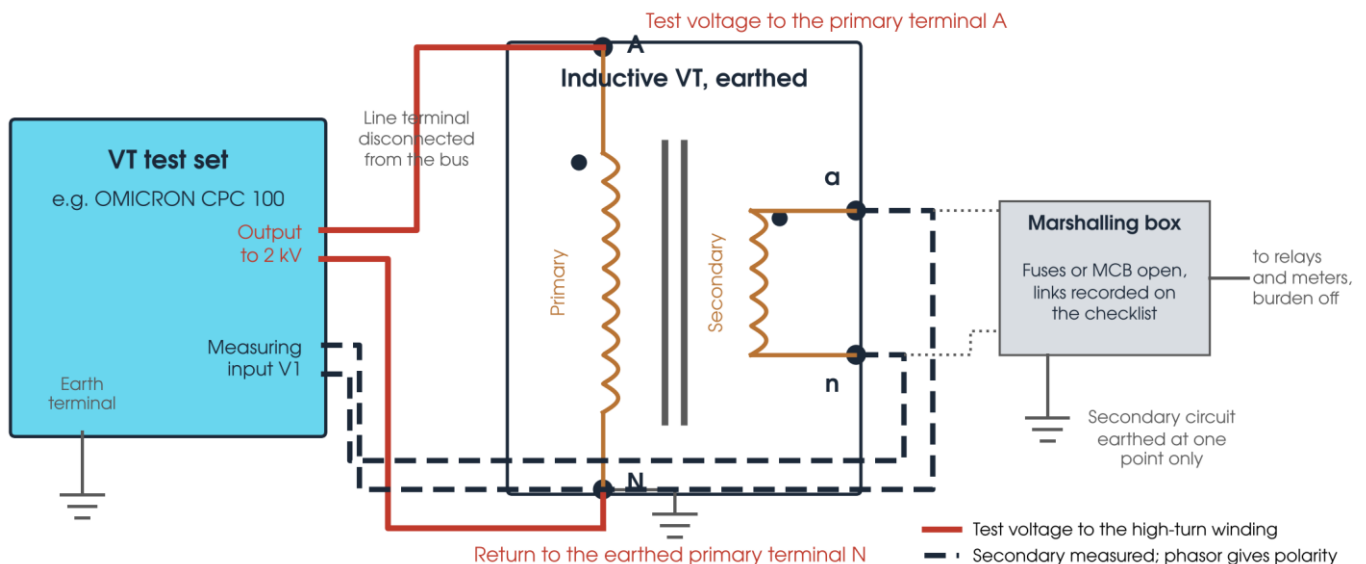
CVT Ratio

The ratio is measured through the capacitor stack with the potential earth switch open and the carrier earth switch closed, typically at 2 kV (OMICRON). Measure the capacitive ratio and the intermediate transformer ratio separately to tell a divider fault from an electromagnetic fault.

Good to Know

Shorted turns change the winding resistance, so a DC winding resistance check on the secondary adds a second view of the winding. Demagnetise the core afterwards (OMICRON).

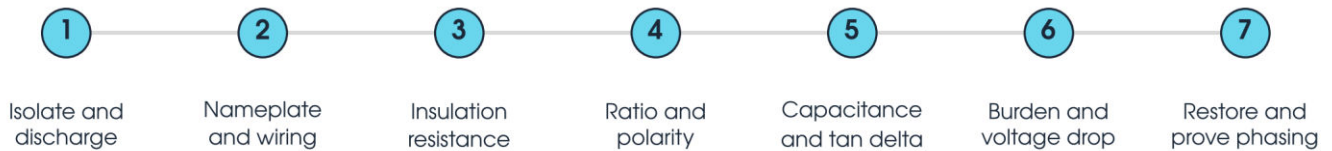
Ratio and Polarity Test Connection



Ratio and polarity test on a single-phase earthed VT. The test set energises the primary A-N and measures the secondary a-n; the secondary circuit is isolated and the burden disconnected.

How Do I Make the Measurement?

Seven Steps



Steps 1 to 4

1 Isolate and Discharge

Primary disconnected and earthed, secondary circuit open at the fuses or links, CVT stack discharged. Remove the primary earth only when the test needs it.

2 Nameplate and Wiring

Ratio, class, burden, voltage factor and terminal markings against the drawings; confirm the VT sits where the circuit diagram says it does and that secondary equipment ratings match it (TasNetworks, 8.4).

3 Insulation Resistance

Each secondary winding to earth and to the other windings at 1 kV DC, or 500 V DC where the secondary withstand is below 1 kV, held until the reading settles and for at least 30 s (AS 61869.1, 7.4.5). Primary to earth at the voltage the previous test used.

4 Ratio and Polarity

Energise the primary and measure every secondary winding and tap. Compare the ratio with the nameplate and the polarity with the markings. On a three-phase VT, confirm the secondary phase markings against the primary first (TasNetworks, 12.3).

Common Mistakes

Secondary Not Isolated

The test energises the relays and meters, or the whole bus through the VT.

Source on the Secondary

Full primary voltage on the open primary terminal (USBR FIST 3-8).

Burden Left Connected

The ratio reads low and is not comparable with the nameplate.

Second Earth on the Secondary

Circulating current under fault, and the IR test earths itself (USBR FIST 3-8).

Steps 5 to 7

5 Capacitance and Tan Delta

On a CVT: C1 and C2 in series, then C2 at 500 V (carrier switch open), then C1 at 10 kV; on an oil-paper VT above 72.5 kV, the primary insulation at the approved field voltage, compared with the factory reference at that voltage, with the ambient temperature recorded (OMICRON; AS 61869.1, 7.3.10).

6 Burden and Voltage Drop

Disconnect the VT winding and prove it isolated, then inject into the burden wiring only. Measure the current per phase for the connected burden, and the voltage drop to the device supplied (TasNetworks, 10.4.1).

7 Restore and Prove Phasing

Restore every isolation from the checklist. After livening, confirm phasing against a known VT, check phase rotation at the VT terminals and measure the on-load burden against the injected value (TasNetworks, 15.3).

Good to Know

Discharge the stack between every tan delta measurement, not only at the end.

More Common Mistakes

CVT Earth Switches Wrong

Potential earth switch closed during the ratio test gives no ratio; carrier switch open leaves the HF terminal floating (OMICRON).

Damp or Dirty Porcelain

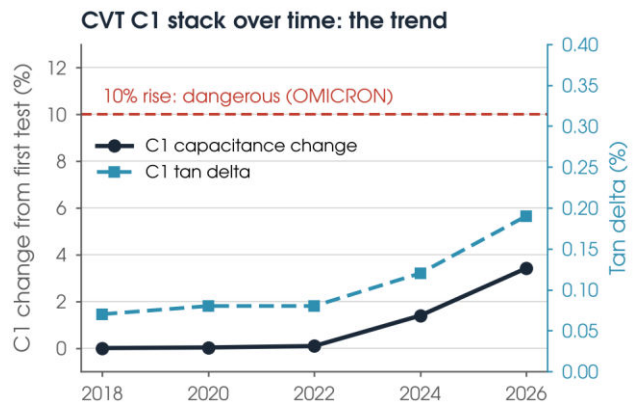
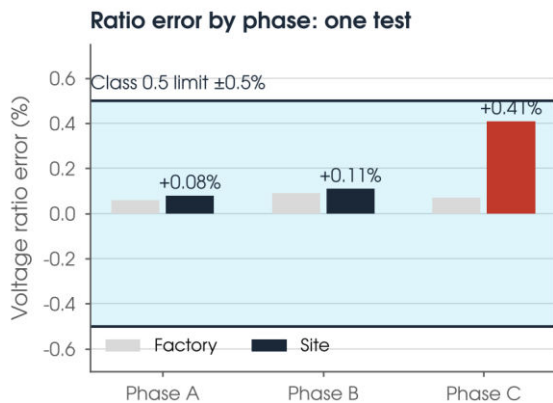
Surface leakage makes the tan delta and IR readings meaningless. Clean and dry the housing first (OMICRON).

Test Voltage Not Recorded

The next test cannot be compared, and a tan delta at 10 kV is compared with a limit set at $U_m/\sqrt{3}$ (AS 61869.1, 7.3.10).

How Do I Read the Result?

Ratio Error by Phase, and the CVT Stack Trend



Illustrative values

Phase C is inside the class 0.5 band but well away from the other two phases and from its factory value. The C1 stack on the right is inside the 10% line but its capacitance has stepped up and its tan delta is climbing: investigate now.

Comparing the Result

Accuracy Class

Measuring classes: 0.1 to 1.0 percent voltage error with 5 to 40 minutes phase displacement; class 3.0 has no phase limit (AS 61869.3, Table 301). Protective classes 3P and 6P: $\pm 3\%$ and ± 120 minutes, $\pm 6\%$ and ± 240 minutes, from 5% of rated voltage to the voltage factor (Table 302). A low-voltage site check is functional and does not show class conformity.

Factory Certificate and Sister Units

Compare the ratio, capacitance and tan delta with the factory values and with the other phases. OMICRON's CVT examples show capacitance within about 0.1% to 0.7% of the nameplate and ratio within about 0.4%.

Capacitance and Tan Delta

A capacitance rise of more than 10% against previous results is normally considered dangerous: part of the stack is shorted and the rest is overstressed (OMICRON). For oil-impregnated paper the tan delta limit is 0.005 at $U_m/\sqrt{3}$ and ambient temperature (AS 61869.1, Table 5); compare a 10 kV site reading with the factory 10 kV value, not with that limit (7.3.10).

Insulation Resistance

200 M Ω or more at 1 kV DC where requested, noting that site humidity can lower the reading (AS 61869.1, 5.4.5.3). USBR FIST 3-8 expects much more than 1 M Ω on a secondary circuit at 500 V and investigates anything below it.

Burden

Within 25% to 100% of rated output for range II burdens (AS 61869.3, 5.6.301). TasNetworks sets the same range where the nameplate does not, and limits the secondary lead drop to 0.2 V for metering and 2.5 V for protection (10.4.1).

What a Bad Result Looks Like

Ratio Out on One Winding

Wrong tap, wrong nameplate reading or shorted turns. Check the tap and the winding resistance before condemning the VT.

Polarity Reversed

Leads crossed at the test set, the marshalling box or the VT. Trace the wiring; a reversed residual winding gives a false residual voltage.

Capacitance Up, Tan Delta Up

Shorted layers or moisture in the stack. Compare C1 and C2 separately and with the other phases.

Ratio Right, Capacitance Wrong

Both C1 and C2 have shifted together, or the electromagnetic unit is compensating. Measure the capacitive and inductive ratios separately (OMICRON).

Low or Unstable IR

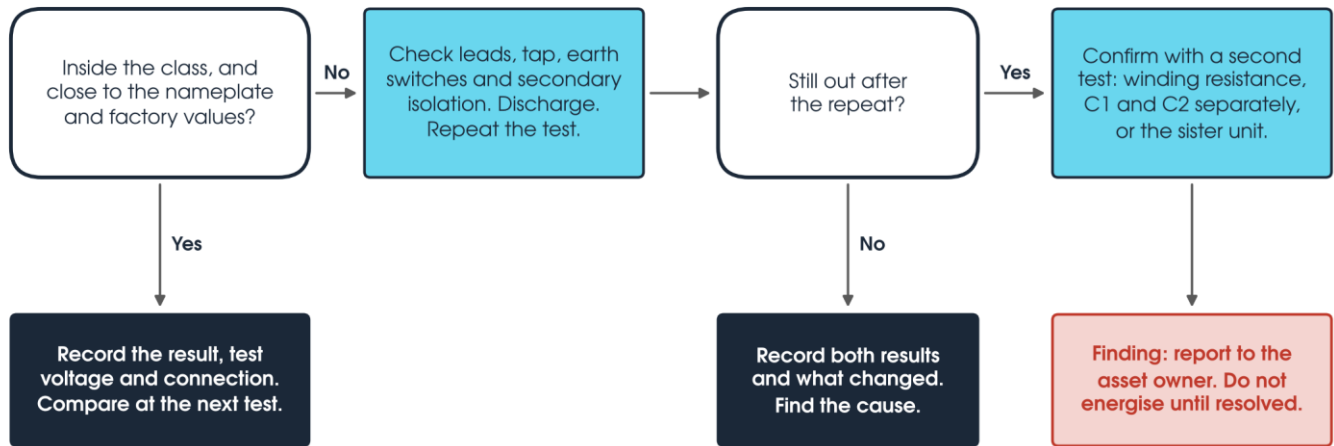
Moisture, damp porcelain or a second earth on the secondary circuit.

Burden Below 25%

Check the burden range first: range I includes zero burden, range II is 25% to 100% (AS 61869.3, 5.5). Add a burden only where the design needs it, rated for every winding; TasNetworks suggests about 50%.

Is My Result OK?

Decision Path



Ratio Error and Phase Displacement

IEEE C57.13 (clause 5.2) relates the ratio correction factor, the ratio error and the phase angle γ in minutes through the transformer correction factor:

$$RCF = 1 - (\pm \text{ratio error} / 100); \quad TCF = RCF + \gamma / 2600$$

RCF is the true ratio divided by the marked ratio. Phase displacement in radians $\times 3438$ gives minutes (IEEE C57.13, 10.1.2).

Worked Example

A 66 kV/ $\sqrt{3}$: 110 V/ $\sqrt{3}$ VT, marked ratio 600, is energised at 2,000 V and reads 3.3447 V on the secondary. The measured ratio is 597.96, so RCF is 0.9966 and the ratio error is +0.34%. With a phase displacement of 12 minutes, TCF is 1.0012. At about 5% of rated voltage and without rated burden this is a functional check: it does not show class 0.5 conformity (AS 61869.3, 5.6.301). Compare with a reference at the same voltage.

What to Report

Nameplate and Conditions

Ratio, class, burden, voltage factor, serial number, ambient temperature and humidity, and the time since de-energisation.

Every Result

Each winding and tap: applied voltage, measured voltage, ratio, ratio error, polarity and phase displacement; IR by winding; capacitance and tan delta by stack unit.

The Comparison

Against the class, the nameplate, the factory certificate, the other phases and the previous test.

Traceability and Isolations

Instrument models, serial numbers and calibration dates, the earth switch positions used, and the signed alteration and isolation checklist (TasNetworks).

What About Capacitor Voltage Transformers?

How a CVT Is Built

Divider and Electromagnetic Unit

Capacitors in one or more housings, C1 above C2, divide the line voltage to a few kilovolts; a two-housing unit has C1-2, C1-1 and C2. In the base box a compensating reactor and an intermediate transformer bring it to the secondary voltage (OMICRON).

Ferroresonance

The capacitance and the intermediate transformer can ferroresonate. Inductive VTs can use residual voltage windings to damp it (AS 61869.3, 3.1.308); a CVT has its maker's own damping circuit. Damping resistors and de-tuning are the remedies in AS 60071.2 (5.3.2.4).

Testing the Stack

Three Tan Delta Measurements

C1 and C2 in series at up to 10 kV with the potential switch open and the carrier terminal isolated from earth; then C2 from the carrier terminal at 500 V with the potential switch closed, the carrier switch open and the line terminal guarded; C1 at 10 kV to the maker's connection (OMICRON; Megger). Compare each capacitance with the nameplate.

Good to Know

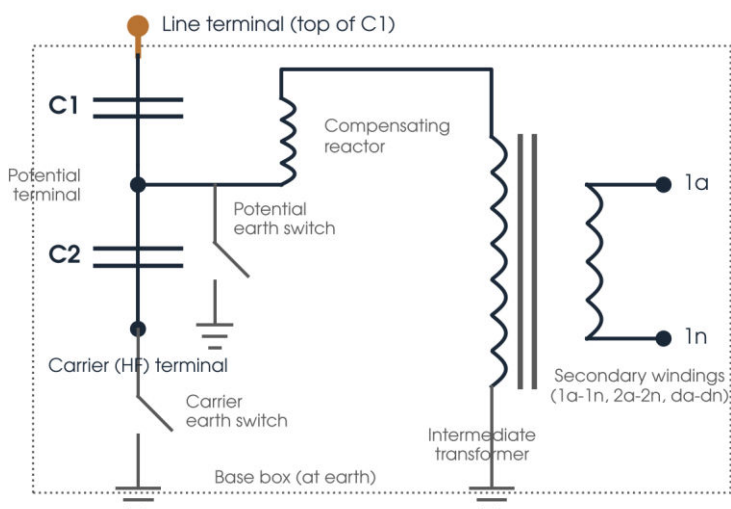
A ratio check alone often misses shorted capacitor layers; the capacitance measurement finds them (OMICRON).

CVT Schematic and Test Points

Single-housing CVT

Capacitive divider (C1, C2) down to a few kilovolts, then the electromagnetic unit in the base box to the secondary voltage.

Two-housing units add C1-2 above C1-1.



Test points (OMICRON)

C1 and C2 series

Line terminal, 10 kV, UST to carrier terminal; potential switch open, carrier terminal isolated from earth

C2

Carrier terminal, 500 V, GSTg; line guarded; potential switch closed, carrier switch open

C1

Line terminal, 10 kV, GST; to the maker's connection

Ratio

Line terminal, 2 kV; potential switch open, carrier closed; measure 1a-1n, 2a-2n

The three capacitance measurements and the ratio test on a single-housing CVT. Here C1 and C2 are the divider capacitors, not bushing insulation.

Recommended Solutions

Instrument	Test	Best used for
OMICRON CPC 100	Ratio and polarity to 2 kV	VT and CVT ratio, polarity and burden
OMICRON CP TD1	Tan delta to 12 kV	CVT stacks and oil-paper VT insulation, with the CPC 100
OMICRON CPX 200	Ratio, polarity, resistance	Compact multi-function VT and CT testing
OMICRON HVX10	10 kV AC and DC source	Tan delta, capacitance and IR with the CPX 200
Megger MIT1020 10 kV	IR to 10 kV, PI and DAR	Primary insulation of transmission VTs
Megger MIT520 5 kV	IR to 5 kV	Secondary windings at 500 V or 1 kV; distribution VTs

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

Frequently Asked Questions

Common Questions

What is VT in testing?

In HV work, VT testing is the testing of a voltage transformer: ratio, polarity, insulation, tan delta and burden. In non-destructive testing the same letters mean visual testing, which is unrelated.

Are voltage transformers and potential transformers the same?

Yes. Potential transformer, or PT, is the IEEE term (IEEE C57.13); voltage transformer, or VT, is the IEC and Australian term (AS 61869.3). The tests are the same.

What is a capacitive voltage transformer (CVT)?

A VT for transmission voltages that uses a capacitor stack to divide the line voltage to a few kilovolts, then an intermediate inductive transformer in the base box to bring it to the secondary voltage.

What is an acceptable VT ratio error?

The accuracy class on the nameplate: for example $\pm 0.5\%$ and ± 20 minutes for class 0.5, or $\pm 3\%$ and ± 120 minutes for class 3P (AS 61869.3, Tables 301 and 302). A low-voltage site check is functional only: compare it with the factory value.

Standards and References

AS 61869.1:2024, Instrument transformers, Part 1: General requirements (IEC 61869-1:2023 MOD).

AS 61869.3:2021 Amd 1:2026, Instrument transformers, Part 3: Additional requirements for inductive voltage transformers (IEC 61869-3:2011 MOD).

AS 60071.2:2024, Insulation co-ordination, Part 2: Application guidelines, clause 5.3.2.4.

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

IEEE Std C57.13-2016, Standard Requirements for Instrument Transformers, clauses 4.9, 5.2, 8.3 and 10.

IEEE Std C57.13.1-2017, Guide for Field Testing of Relaying Current Transformers, clause 10.

OMICRON, Power Factor Testing of Instrument Transformers: CCVTs, PTs and CTs, 2019; Diagnostic Testing of Instrument Transformers, 2025.

US Bureau of Reclamation, FIST 3-8, Operation, Maintenance, and Field Test Procedures for Protective Relays and Associated Circuits, 2011 (revised 2021), clauses 5.2, 5.3 and Appendix F.

TasNetworks, Secondary Equipment Testing Standard, 2021, clauses 3.5, 8.4, 10.4.1, 12.3 and 15.3.

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

More Questions

What insulation resistance should a VT secondary have?

AS 61869.1 (5.4.5.3) gives 200 M Ω or more at 1 kV DC where requested. USBR FIST 3-8 investigates any secondary circuit reading below 1 M Ω at 500 V.

Can I inject into the VT secondary?

For ratio and polarity, use the primary-side method. Inject a burden circuit only with the VT winding disconnected; a connected secondary can back-energise the primary at full voltage (TasNetworks).

How often should VTs be tested?

The asset owner's plan sets it. USBR FIST 3-8 verifies secondary earthing and insulation resistance at commissioning, after wiring changes and at least every 6 years. CVT stacks are trended on a multi-year cycle.

Does Megavar test as well as hire?

Yes. Megavar tests VTs and CVTs with every protection and commissioning scope, from 11 kV distribution to 500 kV transmission. Call 1300 730 499.

Hire or Have It Tested

Have It Tested

Megavar's engineers test VTs and CVTs as part of [protection relay testing](#) and [substation commissioning](#) across Australia.

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Testing: service@megavar.com.au



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