5KV Insulation Testing – A review of the basics to ensure best results

AVO NEW ZEALAND

Overview

- Importance of testing insulation above 1kV
- Electrical properties of insulation
- Understanding DC diagnostics & assessments
- The use of a guard terminal
- Selecting the best IRT for your application.
- Safety, Best Practice and test equipment accuracy.
- Q&A

AVO NEW ZEALAND

Importance of testing insulation

The goal:

To ensure continuity and stability of supply while avoiding harm to people and equipment.

To keep the lights on and people safe.

Short term applications:

- Pre-commissioning new equipment
- Repair/maintenance work ensure IR is good for service.
- Outage fault investigation

Mid to Long term value of regular insulation testing:

- Insulation degrades over time …(lack of maintenance, thermal stress, mechanical stress, condition of joints, fault events etc.)
- Assists with condition assessment through year on year trending and DC diagnostics
- Supports pro-active maintenance planning and informed decisions.

Summary:

Knowing the condition of assets and equipment is paramount to delivering our ultimate goal of ongoing reliability and maximum life.

AVO NEW ZEALAND

Where do we perform DC insulation testing

- Transformers
- Circuit breakers
- Switchboards
- Bushings
- CT’s
- VT’s
- Cables
- …Any general insulation needs

AVO NEW ZEALAND

Electrical properties of insulation

- Materials: Conductors vs insulators
- No pure conductor and no pure insulator.
- Therefore resistance in insulation is expected (As high as practicable)
- Insulation resistance is determined by the leakage current through the insulation
- Insulation is also a dielectric material it has the ability to absorb and store electrical energy.
- This means insulation has resistive, capacitive and absorption properties.
- These properties behave differently during a test and therefore we need to expect and understand these differences and dynamics.
- Insulation potentially changes and degrades over time. Therefore it is best to test and monitor behaviour of insulation periodically and at key times (e.g.: commissioning)

‘Pressure’ testing

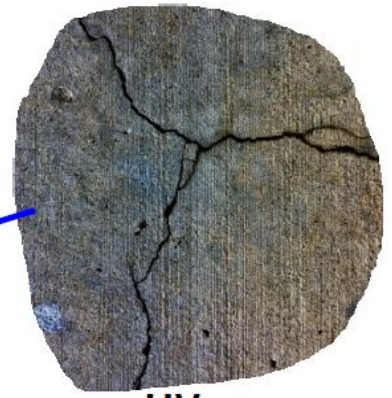
Instead of a simple pass fail approach, it is important to conduct a true condition assessment of insulation which relies on the reaction of the insulation to an elevated voltage stress (“pressure test”)

AVO NEW ZEALAND

Scale

Low Voltage

High Voltage

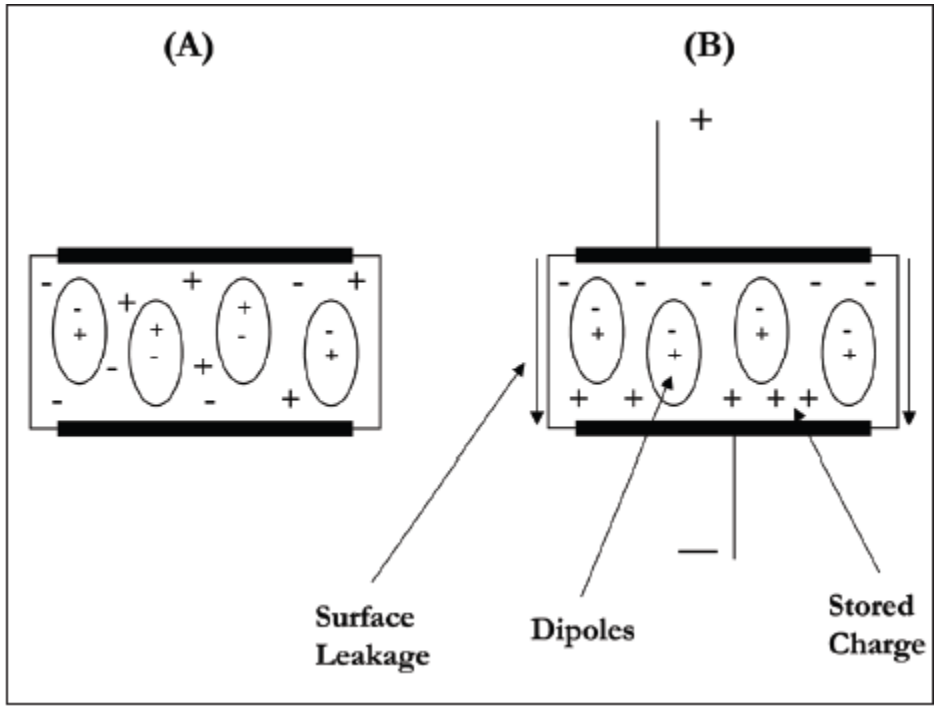


HV

- Scale and consequence…
- Different insulation assessment methods exist…some performed at low & some at high voltages
- …DC, VLF, AC Hi-pot, Tan Delta, DFR, Damped AC, Partial discharge diagnostics.
- This presentation focuses on DC insulation analysis.

AVO NEW ZEALAND

Understanding DC diagnostics ('Current curves')…



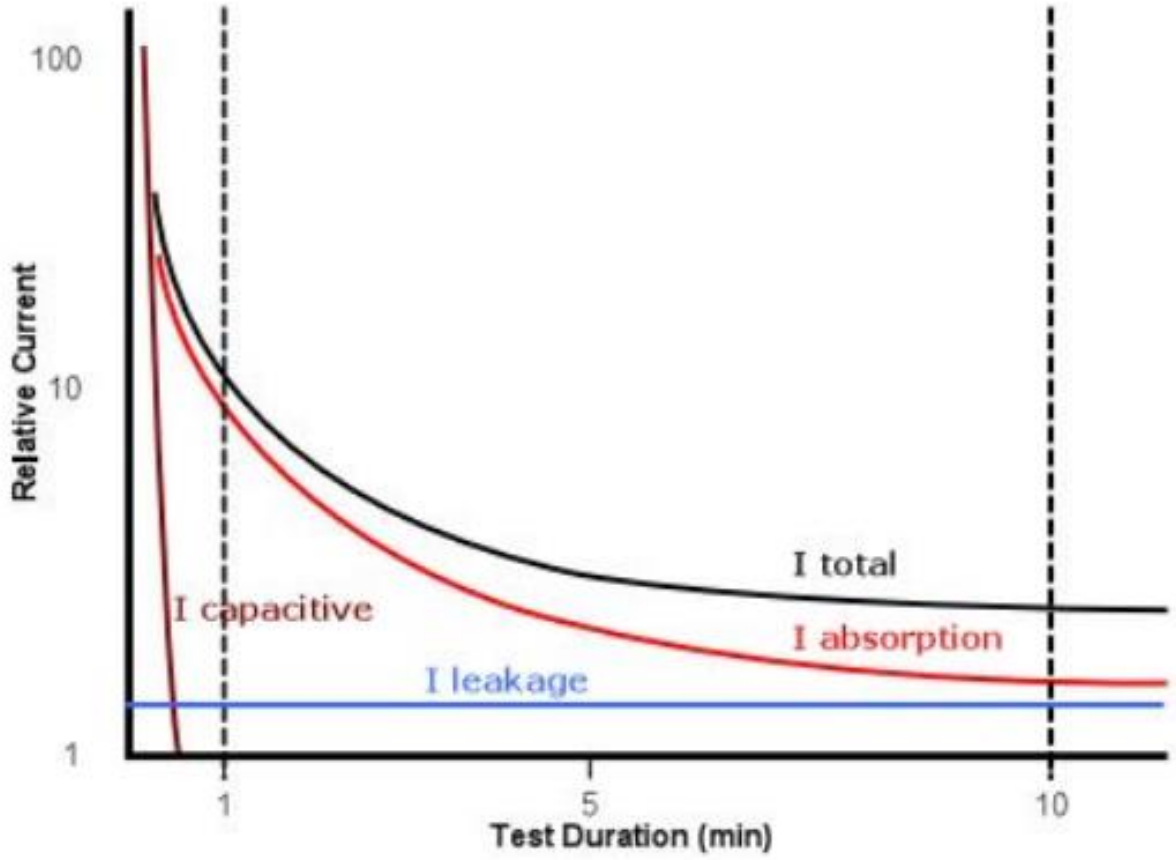
Dipoles aligning with polarity of test voltage

When a DC test polarity is applied to an insulation sample there are three distinct currents arising, all of which contribute to the final insulation resistance value and its profile with time

- **Capacitive charging current** is the current required to charge the capacitance of the test sample
- **Absorption current** is the current required to align the molecules of the insulation ("dipoles") to the electric field applied. This measurement is particularly sensitive to moisture
- **Leakage current** is the essentiality constant current required to support surface or insulation leakage, or both.

AVO NEW ZEALAND

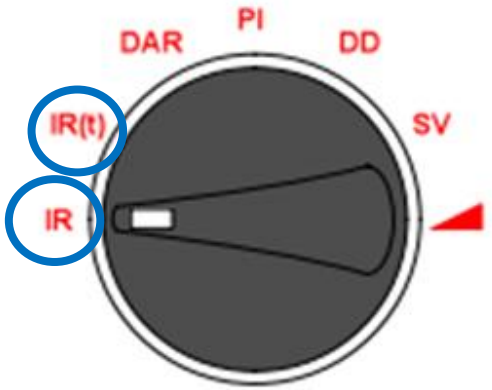
…Understanding DC diagnostics (Current curve)



- **Capacitive charging current** is the current required to charge the capacitance of the test sample
- **Absorption current** is the current required to align the molecules of the insulation (“dipoles”) to the electric field applied. This measurement is sensitive to moisture particularly
- **Leakage current** is the essentiality constant current required to support surface or insulation leakage

AVO NEW ZEALAND

Different tests & diagnostic methods (‘Resistance curve’)

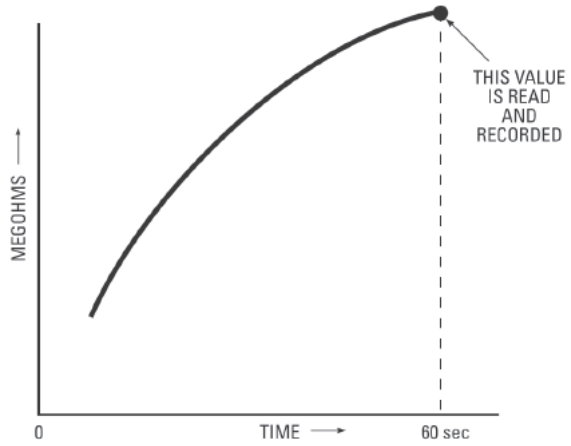


- **IR - Insulation Resistance (Not timed)**

Typically looking for a threshold (pass/fail). Even this is an art as the concept of pass fail is often relative to other phases or subjective!!

- **IR(t) - Insulation Resistance (time)**

Used for timed IR test...e.g.: 1min spot test



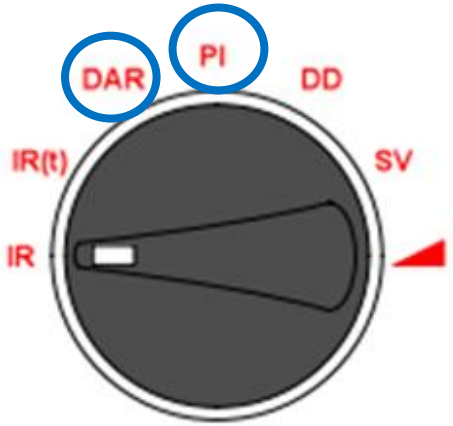
Assessment will require desired pass/fail criteria for specific equipment. Spot test values can also be monitored during year-on-year trending ***but are not seen as diagnostic testing per se***.

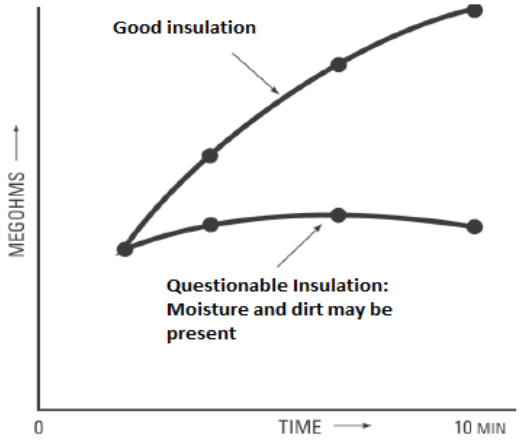
AVO NEW ZEALAND

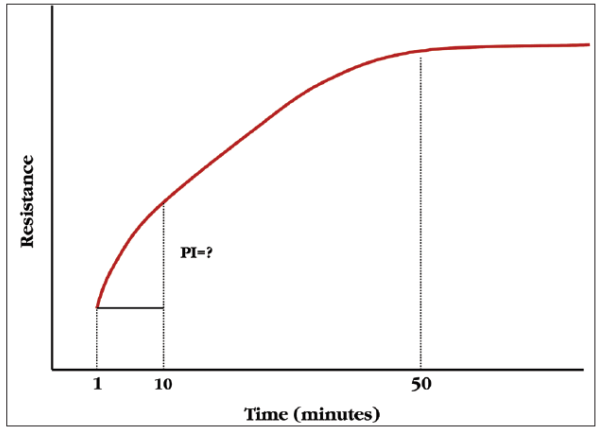
Different tests/diagnostics: ‘Resistive ratios’…

- **PI - Polarization Index (10 min)**

  Ratio of 10min/1min





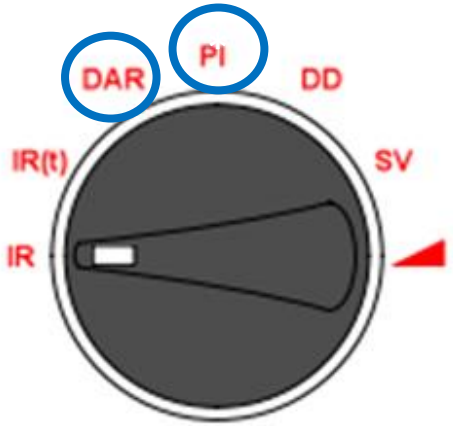


Ideal for older insulation types but potentially has less relevance for short lengths of XLPE cable (as IR at >1 min. is generally already stabilised).

- **DAR - Dielectric Absorption Ratio**
  - Typically either a ratio of 60sec/30sec or 30sec/15sec
  - DAR is more influenced by the absorption current

AVO NEW ZEALAND

…Different tests/diagnostics: ‘Resistance ratios’



- **PI and DAR Assessment guide (general comment)**

TABLE I — Condition of Insulation Indicated by Dielectric Absorption Ratios*

INSULATION CONDITION	60/30-SECOND RATIO	10/1-MINUTE RATIO (POLARIZATION INDEX)
Dangerous	—	Less than 1
Questionable	1.0 to 1.25	1.0 to 2***
Good	1.4 to 1.6	2 to 4
Excellent	Above 1.6**	Above 4**

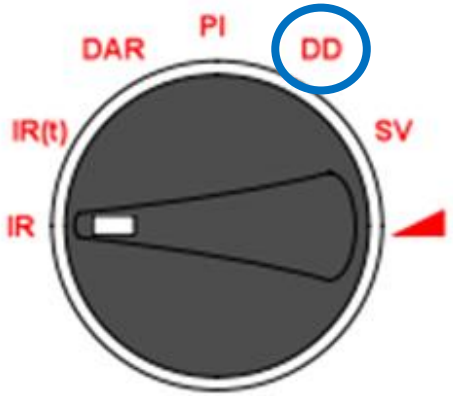
Note: In making such assessments it is vital to consider your test object (Size, age, materials), and test times.

For example: Short/new XLPE piece of cable, DAR might be more appropriate. 30/15 ratio. (because the absorption current is very short lived in XLPE cable)

Its worth noting that the test techniques haven’t changed, but the test equipment has become more sophisticated to deal with the wide range of insulation quality and dielectric materials found in todays electrical systems.

AVO NEW ZEALAND

Different tests/diagnostics: ‘Dielectric Discharge’



- **DD - Dielectric Discharge**

  Developed about 15 years ago by Electricity de France to test large hydro power generator stators and all “wound” insulation…many capacitors in series.

  Technique:

  -The insulation is charged up for 30min at a fixed voltage.
  -The test equipment then connects a resistive load to the charged insulation and measures the capacity of the discharge of the insulation over a fixed time period.

  -The size of the motor/generator will present an expected charge for good insulation. The expected discharge capacity is compared to the actual measured results and compared for pass/fail.

  Assessment:

  Poor insulation (e.g. where some of the wound insulation may have poor capacitance) will show a weak discharge capacity.

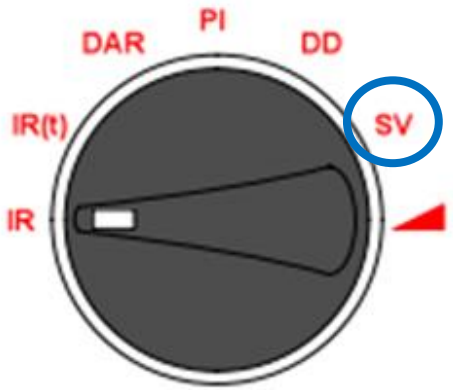
  Excellent for large motors, generators.

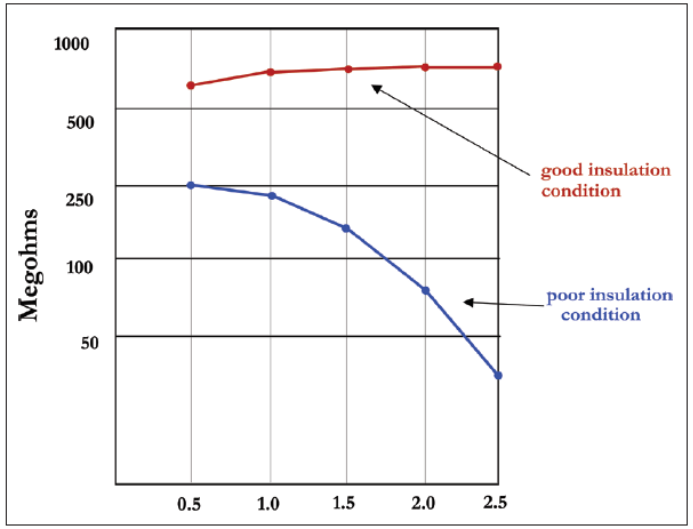
AVO NEW ZEALAND

Different tests/diagnostics: ‘Step and Ramp’…

- **SV - Step voltage**

  The test voltage is increased in five equal steps at one-minute increments, with the final insulation resistance at each level being recorded. *Ideally the measured insulation should not decrease as the test voltage is increased.*

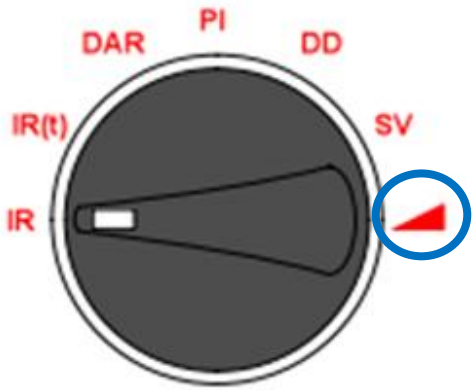




Any marked or unusual resistance reduction is an indication of incipient weakness (cracks or voids). Modern electronics allows these readings to be captured automatically. A good test for older insulation…especially older PILC cables.

AVO NEW ZEALAND

…Different tests/diagnostics: ‘Step and Ramp’



- **Ramp** (Steady increase of voltage)

A gentler alternative to the SV test.

When using this test method, the test voltage is gradually increased at a set rate to a final level, which results in an increase in the current.

Assessment:

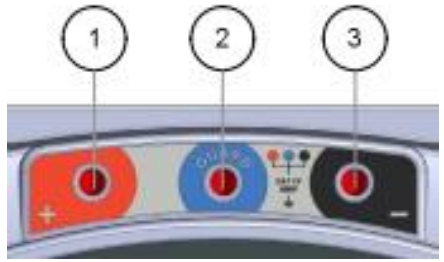
Any variations in current compared to the increase in applied test voltage can provide useful diagnostic information about the condition of the insulation.

Commonly used on rotating machinery, detecting defects such as:

Cracks, Surface contamination, Uncured resin, Moisture absorption, Delamination.

AVO NEW ZEALAND

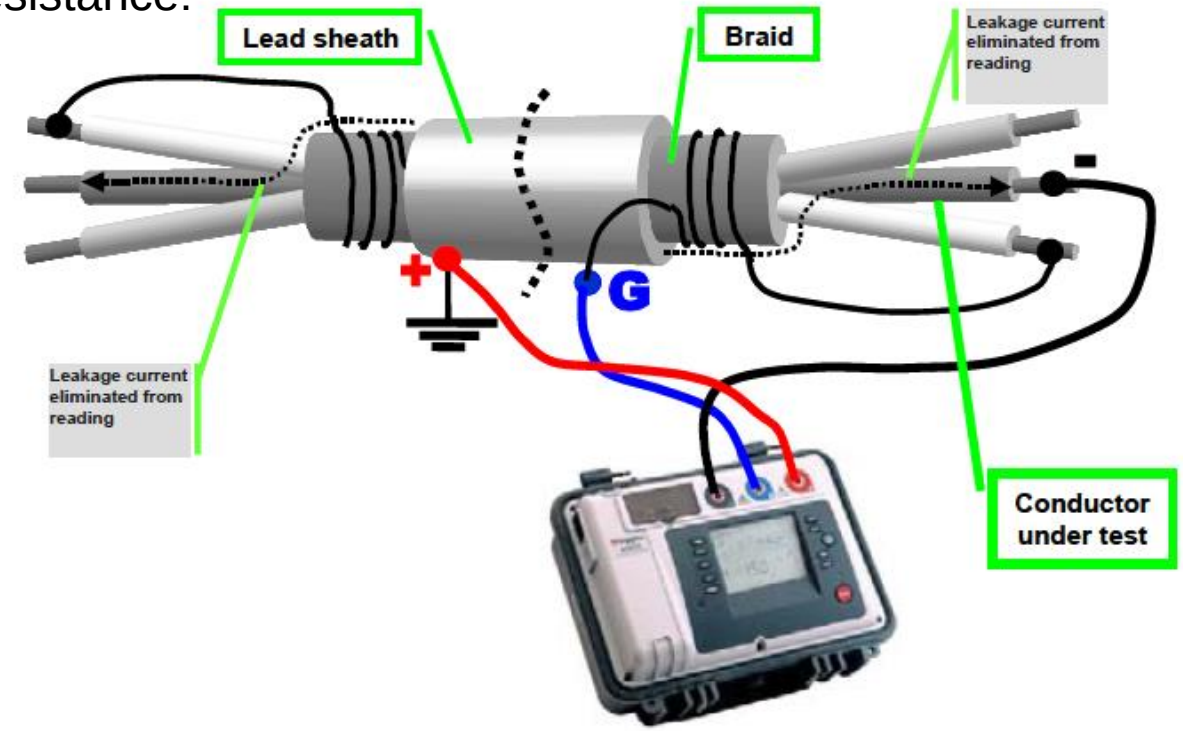
Use of Guard terminal…Example 1



NOTE

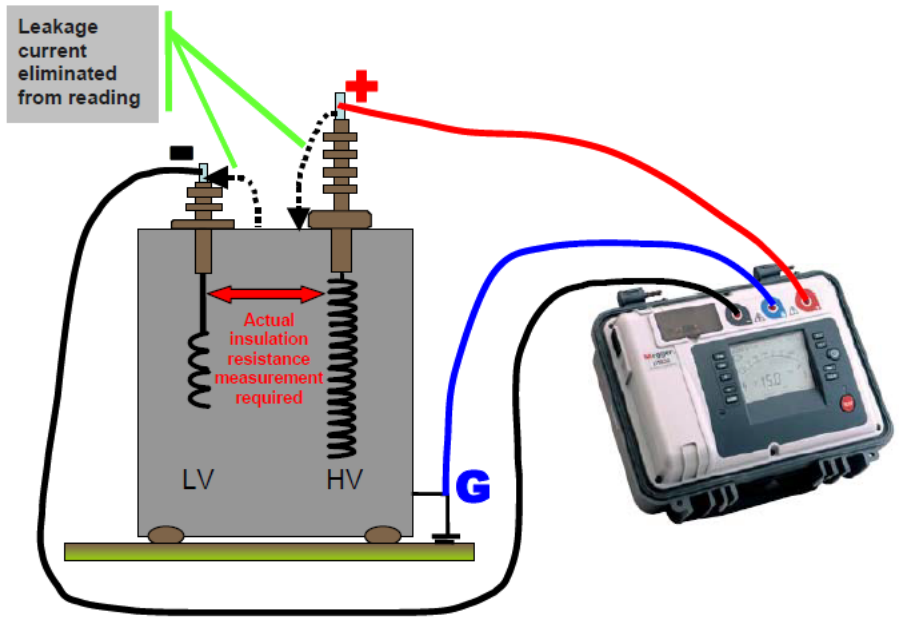
The additional **blue** test lead is not included as a spare lead!

- Total Leakage current = Insulation leakage plus surface leakage:
  - **Insulation leakage:** Current through the insulation.
  - **Surface leakage:** Current across the surface of the insulation.
- The guard terminal permits the surface leakage to be subtracted from the total leakage, giving a true reading of the insulation resistance:

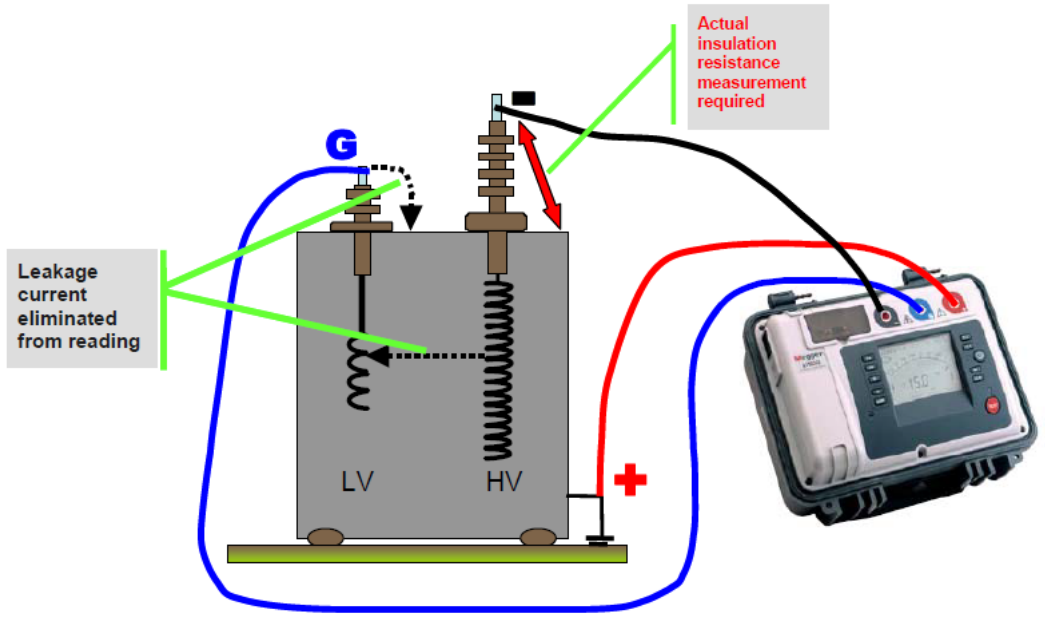


AVO NEW ZEALAND

Use of the guard terminal…Example 2



Transformer winding insulation test with the Guard used ' to eliminate leakage current due to the surface path - across dirty porcelain insulators



Transformer winding insulation test with the Guard used 'to eliminate leakage current', between windings and across LV bushing

The selective use of the Guard Terminal allows one to test specific insulation paths on a more complex test object.

AVO NEW ZEALAND

Selecting the best IRT for your application

Important factors to consider:

- Safety: Equipment CAT rating.
  - Automated discharge… ideally with remaining voltage indicated
- Appropriate Voltages
- Sufficient Range for the insulation types to be tested
- Capacity: Available s/c current (important on higher capacitance loads)
- Noise filtering
- Averaging filters
- DC diagnostic capability
- Result storage
- Allowance of a temperature input
- Portability factor
- IP rating
- Leads and clamps

AVO NEW ZEALAND

Safety, Best Practice and test equipment accuracy

Important factors / tips to consider.

- Safety: Even though IRT are small they pack a punch.
  - Stored energy of test objects poses a high risk.
  - Ensure test object is discharged for typically 5 times the test time

  Training, and understanding of these risks, is essential!
- Test Polarity: always connect the positive lead to earth (due to “electro-end-osmosis” effect)
- Note the test sample temperature and, where possible, normalise the readings to 15 Deg. C
- Best Practice in managing test leads… a bad lead setup can effect test results:
  - Do a quick no lead test.
  - Opposite polarity leads should not be in contact or coiled on the ground.
  - A final quick test with leads connected but safely isolated from ground before testing will confirm functionality and ensure most accurate results.
  - It is best to have spare leads available!!
- Equipment accuracy: Portable calibration boxes are available and should be used regularly.

AVO NEW ZEALAND

Further reading…

- For more information,
ask about our insulation testing guide.

- Available to PPA members.

AVO NEW ZEALAND

AVO NZ

At AVO New Zealand we pride ourselves on having arguably the most comprehensive range of electrical test and measurement equipment available from a single source in New Zealand.

Through our commitment to a ‘total solutions' service we provide for the wider needs of the Industry through comprehensive training programmes, industry seminars, news updates, technical and applications advice, repair, backup, and calibration.

The focus of AVO New Zealand is the provision of suitable equipment and applications expertise to permit adequate testing and assessment of electrical and power system assets to determine or assess their condition, safety, and reliability. From such information, effective asset management decisions may follow.

AVO NEW ZEALAND