Be on Guard for effective testing

Application note

- What does a GUARD terminal do?
- How does it work?
- Why does Megger specify GUARD performance?
- Where does this fit in with other instrument specifications?
- Testing transformers?
- Testing cables?
- Testing bushings on outdoor oil circuit breaker?
- What are the real benefits of using the GUARD terminal?

Introduction:

The development of the insulation tester by Evershed & Vignoles is part of our electrical history. Insulation testers produced by Megger Instruments in Dover date back to before to 1897.

Voltage outputs are now available up to 10 kV to suit all industrial and commercial applications. On the higher voltage testers (2.5 – 10 kV), which incorporate very high insulation ranges, is where the GUARD TERMINAL becomes a major benefit, when testing various devices that have large surface leakage areas of insulation.

These include:

Larger diameter cables
Porcelain bushings
Power transformers
H.V. circuit breakers

Such products exhibit long creepage paths across their insulation by the nature of their size. This will cause the unwanted surface leakage resistance to introduce errors, and is the reason the Guard terminal is used to enhance the accuracy of the measurement.

What does a GUARD terminal do?

During insulation testing we are often so preoccupied with the resistance of the actual insulator we forget the resistance path on the outer surface of the insulation material. However this resistance path is very much a part of our measurement and can dramatically affect our measurements. For example if dirt is present on the outer surface of a bush the surface leakage current can be up to ten times that flowing through the actual insulation.

The surface leakage is essentially a resistance in parallel with the true insulation resistance of the material being tested. By using the guard terminal, performing a so-called **three terminal test,** the surface leakage current is ignored. This may be important when high values of resistance are expected such as when testing high voltage components like insulators, bushings and cable. These tend to have large surface areas that get exposed to contamination resulting in high surface leakage currents across them.

The **total current** that flows during an insulation resistance test is made up of three main components:

1. The **charging current**, which is charging up the objects capacitance.

2. An **absorption current** is the current which is being drawn into the insulation by the polarising of the molecules, initially high but drops over time, but at a slower rate than the charging current

3. The **conduction** or **leakage current** which is the small steady state current which divides into two parts:
   a. The conduction path **through** the insulation
   b. The current flowing **over the surface*** of the insulation.

*Surface leakage is the component of the insulation we do not want to measure if we just want to measure the

insulation resistance of the material. By using the guard terminal, which is available on most HV insulation testers, the surface leakage can be excluded from the measurement.

In applications with lower insulation resistance values (<100MΩ), such as in L.V. building wiring applications, this is not necessary, but with values of insulation above the 100MΩ as found in H.V. insulation applications the use of the guard terminal is often very important.
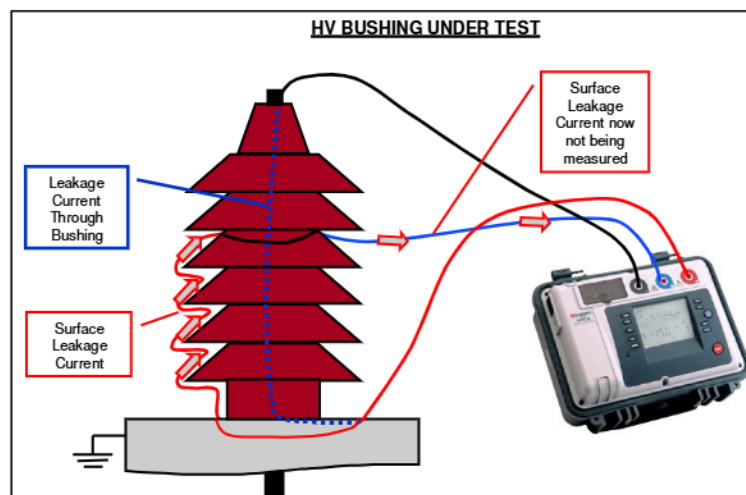
How does it work?

Here we have a typical application for the GUARD terminal, testing an HV bushing. Without the GUARD terminal the leakage current flowing though the bushing and across the surface is combined and therefore measured together by the instrument.
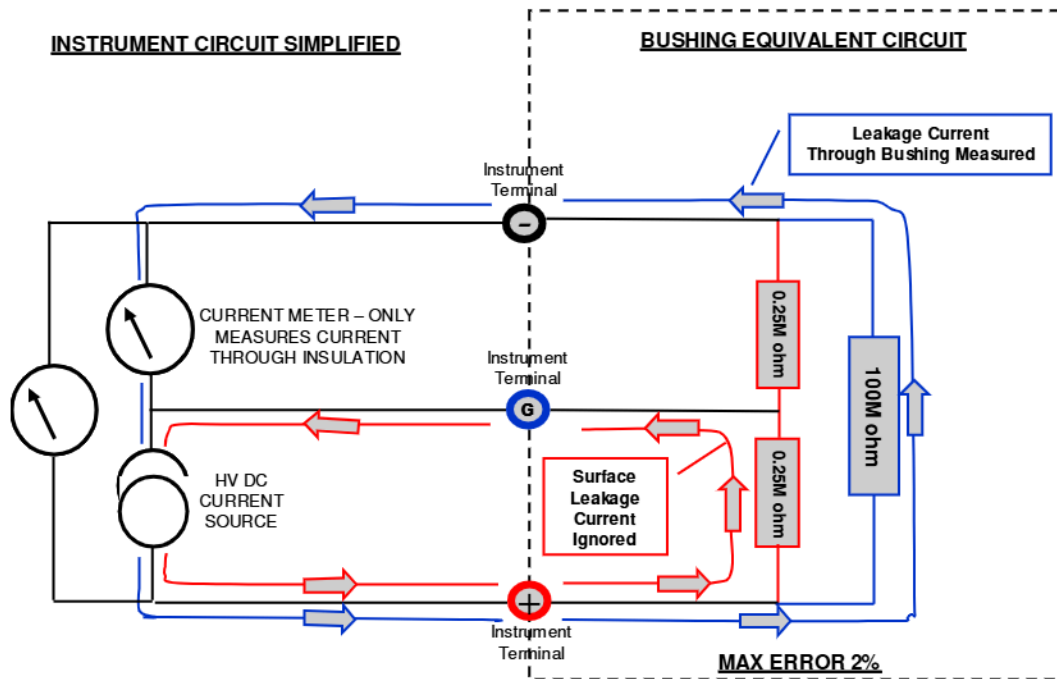

HV BUSHING UNDER TEST
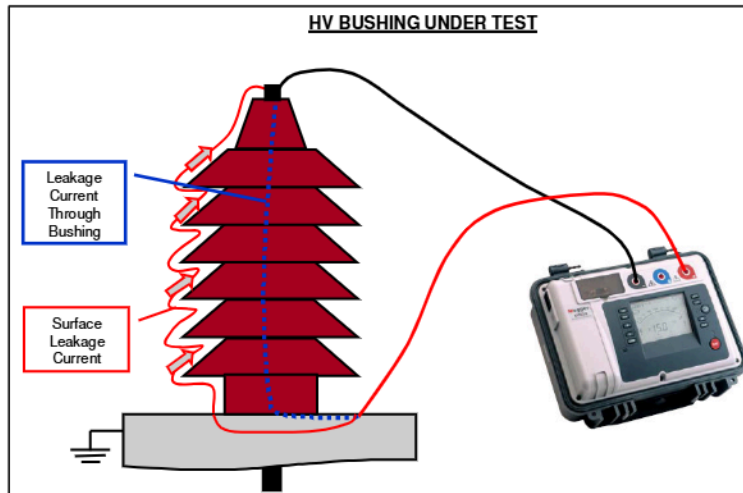
Now with the GUARD terminal now in use:

HV BUSHING UNDER TEST

Wire has been wrapped around the centre of the bushing and connected to the GUARD terminal, now the surface leakage flows to the GUARD terminal. Current flowing into the GUARD terminal is NOT measured by the instrument and so is ignored by the insulation resistance measurement.

To better understand what is actually happening within the instrument we can look at the following diagram. Put simply the insulation tester has three main elements; the H.V. d.c. current source, the H.V. voltmeter and the current meter. The insulation resistance measurement is simply Ohm's law, measured voltage divided by the measured current. The GUARD terminal allows leakage current to bypass the current measurement, and so be ignored in the measurement.

INSTRUMENT CIRCUIT SIMPLIFIED

BUSHING EQUIVALENT CIRCUIT

Leakage Current
Through Bushing Measured

Instrument
Terminal

(−)

CURRENT METER – ONLY
MEASURES CURRENT
THROUGH INSULATION

0.25M ohm

100M ohm

Instrument
Terminal

(G)

HV DC
CURRENT
SOURCE

Surface
Leakage
Current
Ignored

0.25M ohm

Instrument
Terminal

(+)

MAX ERROR 2%

However the story doesn't end there, as you can see we have added example values to the above diagram. In this circumstance any instrument in the Megger MIT or S1 range of insulation testers will provide measurements with no more than 2% additional error. This is an important part of the comprehensive specification these instruments provide.

MIT and S1 5 kV and 10 kV range specify the GUARD terminal performance as:

- 2% Error when guarding leakage current 200 times the load current, for example:
  - 2% Error guarding 500 kΩ leakage with 100 MΩ load at 500V
  - 2% Error guarding 5MΩ leakage with 1.0GΩ load at 5,000V
  - Note: with guard connected at mid point on surface leakage path

Why does Megger specify GUARD performance?

The performance of the Guard terminal depends on, amongst others, a couple of key of issues. Firstly how well the instruments protection circuits have been designed. In other words the EMC and CATIV protection circuits must be of low impedance. Secondly the resistance the instrument's current measurement circuit must also be of low resistance. Sounds easy but the reality these issues are not inconsiderable design

challenges to solve. The Megger specification reassures the user of its ability to provide meaningful results, and therefore properly diagnose the true condition of the insulation. Remember effective predictive maintenance relies on reliable trending of test results to provide early indication of failure. Time taken to carefully compensate for temperature variation can easily be wasted by poor results due to surface leakage not being correctly guarded.

Where does this fit in with other instrument specifications?

Safety?

These days we are more and more recognising the importance of test instrument safety. Insulation testers are not an exception. The complete range of Megger MIT and S1 5 kV and 10 kV insulation testers are CATIV 600 V to give the user maximum confidence.

So how does this relate to the performance of the GUARD terminal? Well, to be able to meet the stringent

requirement of CATIV 600 V set out in IEC1010-1: 2001 the instrument has to be protected against 8 kV high-energy impulses on ALL terminals. The challenge is to maintain both impulse protection and the test performance of the instrument. Imagine trying to absorb the high energy levels from 8kV transients in CATIV environments without adding any series resistance to the Guard terminal.
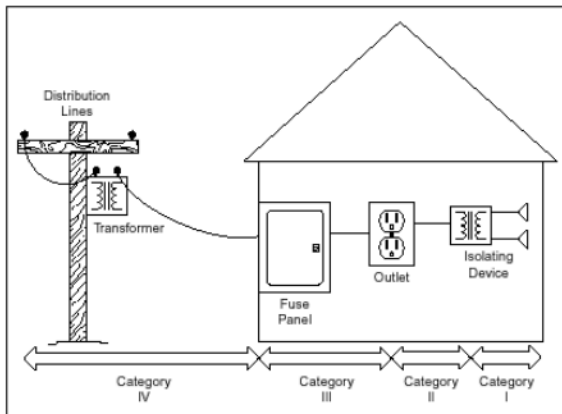
- IEC1010-1:2001
  - •Protection against input transients between any terminals

- CATIV 600 V
  - •8 kV transient protected

- **Challenge is to maintain protection and GUARD terminal performance**

Short circuit test current?

The Megger range of MIT and S1 5 kV and 10 kV insulation testers have at least 3 mA into short circuit capability. This is not just to allow the instruments to quickly charge capacitive loads such as long cables. This also means the instruments have the power to maintain test voltage across lower resistances

$$\frac{5000V}{2M\Omega} = 2.5mA \text{ (MIT can supply 3mA maximum)}$$
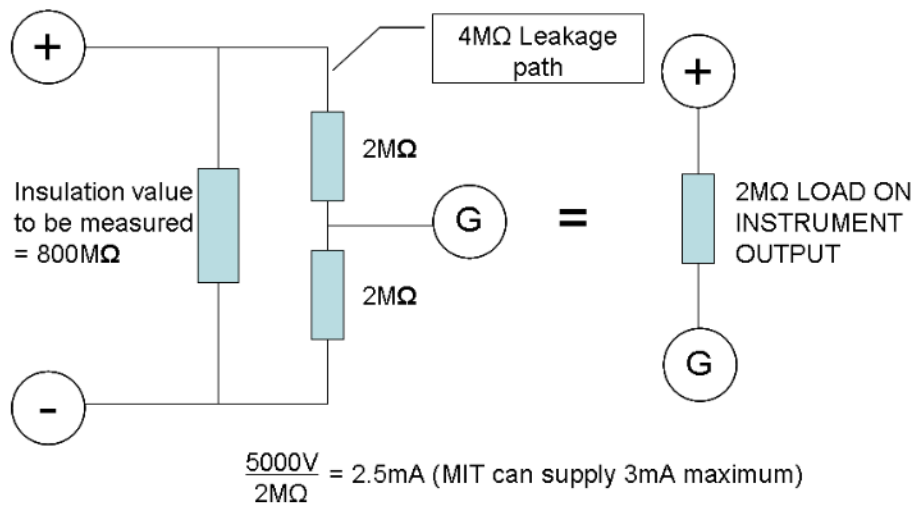
This circuit quickly demonstrates how an 800MΩ insulation resistance can soon present a 2 MΩ load to the instrument with surface leakage. High power of MIT range maintains the test voltage across the insulation and provides enough test current to accurately measure the insulation.

- 5000V / 2MΩ = 2.5mA (MIT can supply 3mA max.)

Testing transformers?

The two windings both H.V. and L.V. of any particular phase, in a three phase transformer can be measured with respect to each other, the guard terminal eliminates the surface leakage current flowing over the outside of contaminated insulators, hence the value of the inter winding resistance will be read more accurately by the insulation tester.
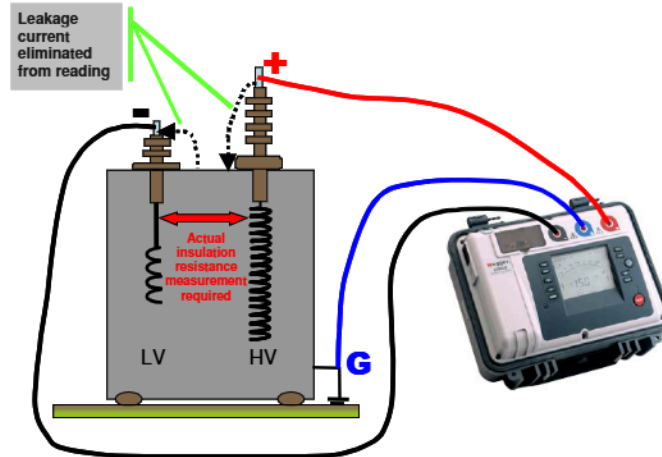
Transformer winding insulation test with the Guard used ' to eliminate leakage current',
due to the surface path - across dirty porcelain insulators

Here the H.V. winding is measured without the effects of leakage current between the H.V. and L.V. windings using the guard terminal.
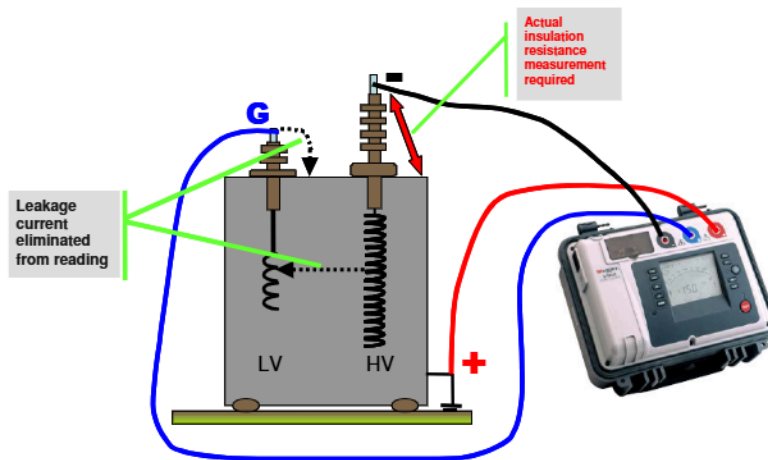
Transformer winding insulation test with the Guard used 'to eliminate leakage current',
between windings and across LV bushing

NOTE: In practice both windings on a three phase transformer are wound concentrically on an insulated former on the same limb of the iron core, they are therefore subject to inter-turn or inter-winding breakdown, and hence the need to insulation test between the two.

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Testing Cables?

The guard terminal is also used to remove the effects of surface leakage across exposed insulation at the ends of a cable.
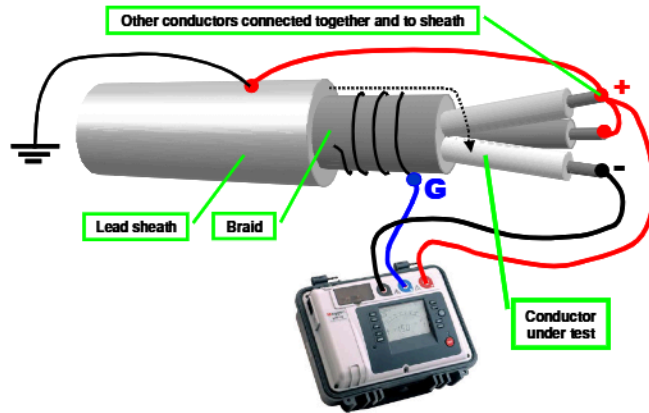

In the diagram above, the guard terminal is connected to wire wrapped around the exposed insulation to pick up surface leakage.

In this case a spare conductor in the cable has been used to connect the guard to the exposed insulation at the other end of the cable.
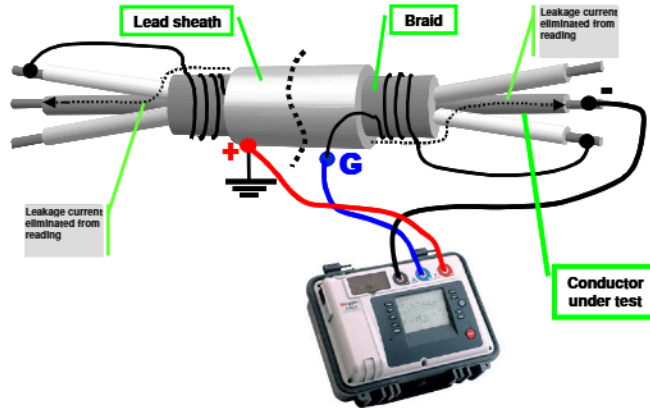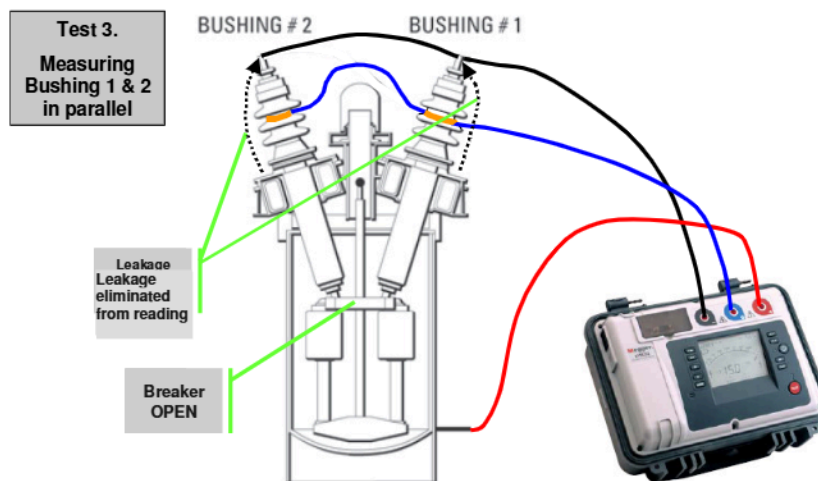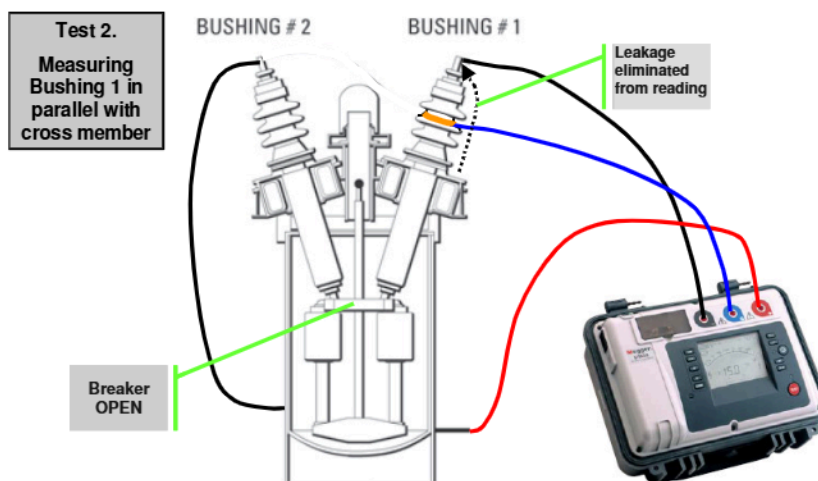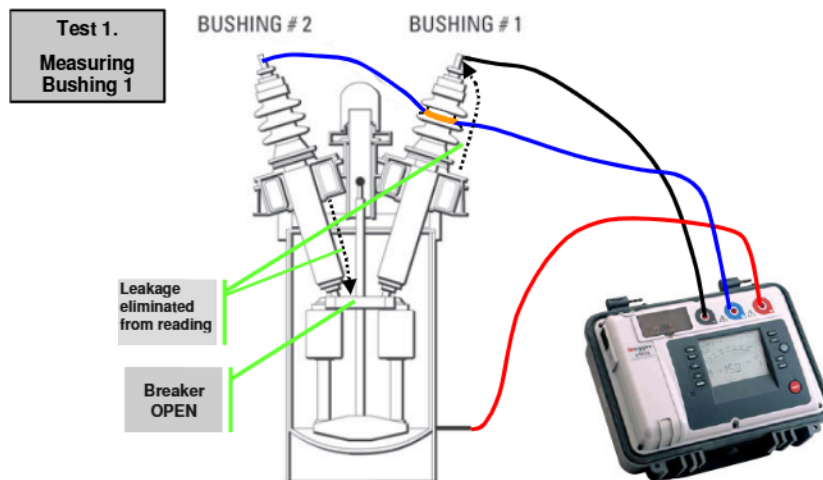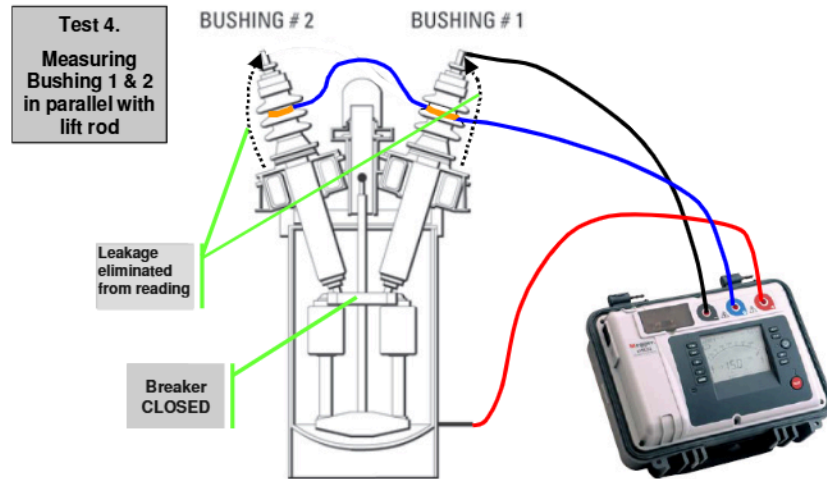

The guard terminal can also be used to eliminate leakage current between other adjacent conductors in the cable
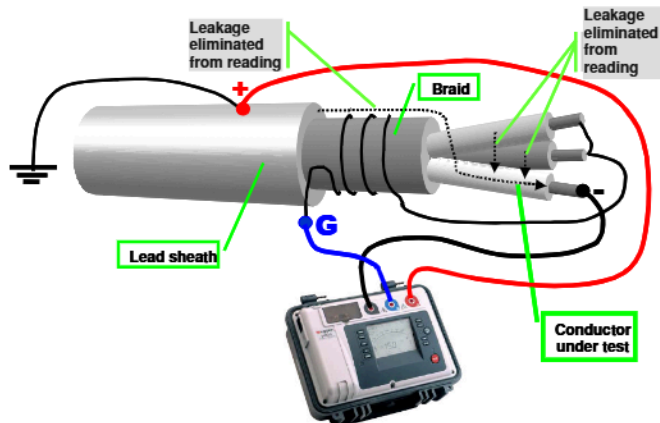
Testing bushings on outdoor oil circuit breaker?

The following four illustrations show the usual methods of testing bushings and associated parts of an outdoor circuit breaker.

Test 1.
Measuring Bushing 1

BUSHING # 2   BUSHING # 1

Leakage eliminated from reading

Breaker OPEN

Test 2.
Measuring Bushing 1 in parallel with cross member

BUSHING # 2   BUSHING # 1

Leakage eliminated from reading

Breaker OPEN

Test 3.
Measuring Bushing 1 & 2 in parallel

BUSHING # 2   BUSHING # 1

Leakage
Leakage eliminated from reading

Breaker OPEN

Test 4.

Measuring Bushing 1 & 2 in parallel with lift rod

BUSHING # 2   BUSHING # 1

Leakage eliminated from reading

Breaker CLOSED

What are the real benefits of using the GUARD terminal?

In addition to the big improvements in the reliability of insulation condition diagnosis and predictive maintenance discussed above there's one more big benefit:

The GUARD terminal is an important diagnostic tool!

By performing two tests, one using the GUARD terminal and one without we can quickly identify when surface leakage is present and how much. Setting the instrument to display leakage current makes it easy to subtract the measurement taken with the GUARD in place from the measurement without. The result tells you exactly how much current is surface leakage.

There have been many instances of poor insulation resistance measurements leading to bushes etc. being replaced needlessly at huge cost. Only to find later, by employing the GUARD terminal, that they simply needed a good clean!

- Easily identify contaminated surfaces
- Don't throw, use your GUARD and know when to clean

For more detailed information on using the GUARD terminal see the Megger Limited publication 'A Stitch in Time' the complete guide to Electrical Insulation Testing available at www.Megger.com.

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