5 kV, 10 kV and 15 kV insulation testing – use of guard terminal

Be on guard for effective testing: Introduction

The development of the insulation tester by Evershed and Vignoles is part of our electrical history, with insulation testers produced by Megger Instruments in Dover, UK, dating back as far as 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, the guard terminal becomes a major benefit when testing assets that have large surface leakage areas of insulation.

These include:

- Larger diameter cables
- Porcelain bushings
- Power transformers
- HV circuit breakers

Such products exhibit long creepage paths across their insulation, due to the nature of their size, and the unwanted surface leakage resistance can cause defects. This is where the guard terminal can enhance the accuracy of the measurement.

What does a guard terminal do?

During insulation testing, the resistance path on the outer surface of the insulation material often gets neglected. However, this resistance path is very much a part of the measurement and can dramatically affect the results. 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 to perform a ‘three-terminal test’, the surface leakage current can be ignored. This may be important when high values of resistance are expected, such as when testing high voltage components like insulators, bushings and cables. 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 charges the object’s capacitance

5 kV, 10 kV and 15 kV insulation testing – use of guard terminal

2. An absorption current, which is the current that 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 what needs to be excluded if just the insulation resistance measurement of the material is required. This can be done by using the guard terminal, which is available on most HV insulation testers.*

In applications with lower insulation resistance values (<100 MΩ), such as in LV building wiring applications, this is not necessary, but with values of insulation above the 100 MΩ, as found in HV 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.

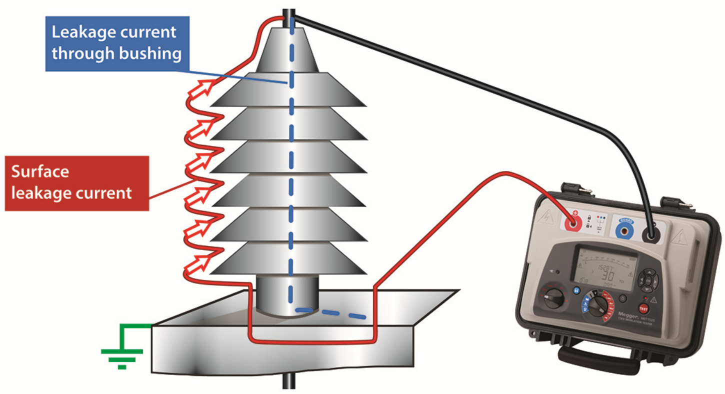

Figure 1

5 kV, 10 kV and 15 kV insulation testing – use of guard terminal

Now with the guard terminal in use:

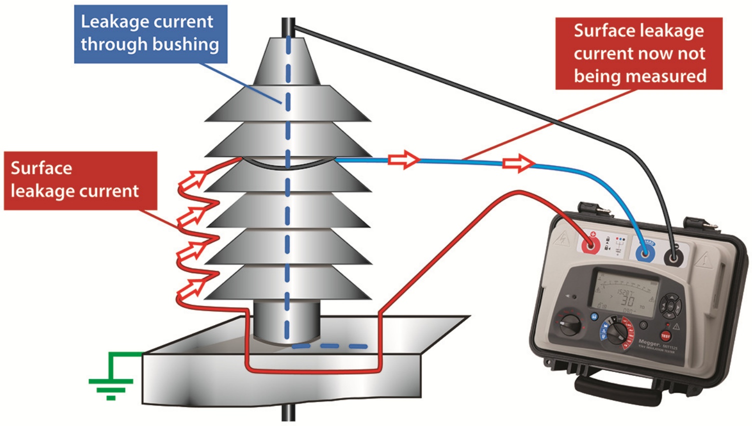

Figure 2

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 HV DC current source, the HV 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.

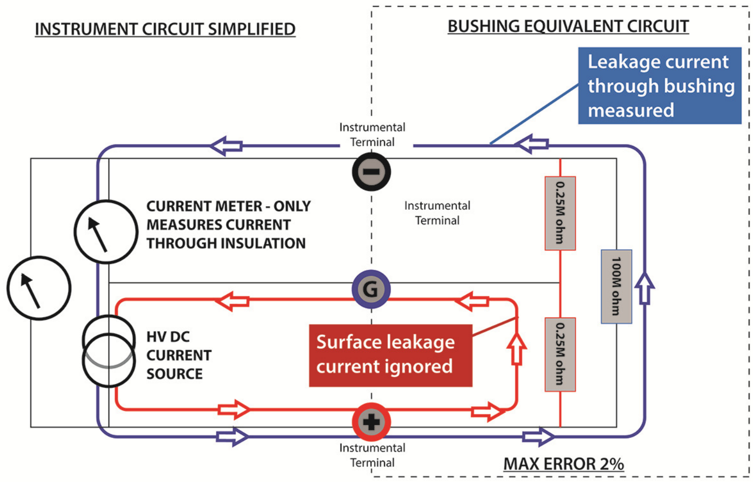

Figure 3

5 kV, 10 kV and 15 kV insulation testing – use of guard terminal

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 within the Megger MIT or S1 range of insulation testers will provide measurements with no more than 1% 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 1% error when guarding leakage current 400 times the load current, for example, 1% error guarding 250 kΩ leakage with 100 MΩ load

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 a number of key issues. Firstly, how well the instrument's protection circuits have been designed; the EMC and CATIV protection circuits must be of low impedance. Secondly, the instrument's current measurement circuit must also be of low resistance. Unfortunately, this is not as simple as it sounds. The Megger instrument's specification gives it the 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 Megger instrument specifications?

Safety?

The importance of test instrument safety is increasingly being recognised, and 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? 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 8 kV transients in CATIV environments without adding any series resistance to the guard terminal.

- IEC1010-1:2001
    - Protection against input transients between any terminals

5 kV, 10 kV and 15 kV insulation testing – use of guard terminal

- CATIV 600 V
  - 8 kV transient protected
- Challenge is to maintain protection and GUARD terminal performance

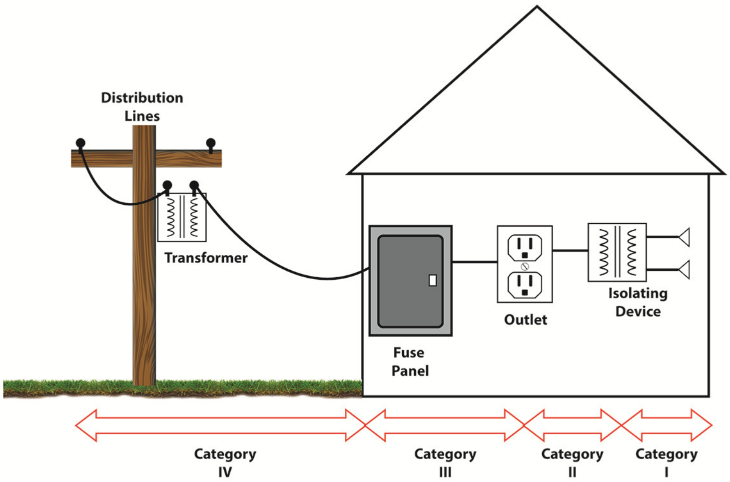

Figure 4

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, but also means the instruments have the power to maintain test voltage across lower resistances.

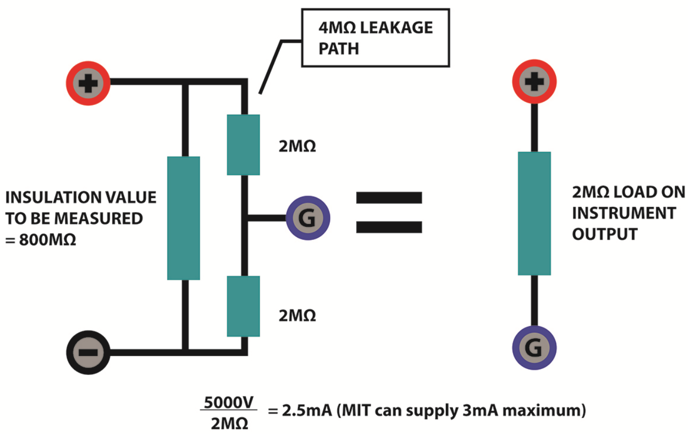

Figure 5

This circuit quickly demonstrates how an 800 MΩ insulation resistance can soon present a 2

5 kV, 10 kV and 15 kV insulation testing – use of guard terminal

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.

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

Testing transformers?

Both the HV and LV windings 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 insulation tester will be able to provide a more accurate value of the inter-winding resistance.

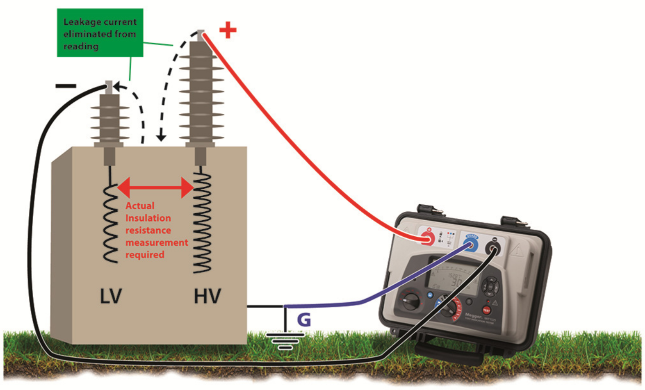

Figure 6: Transformer winding insulation test, with the guard used to eliminate leakage current, due to the surface path across dirty porcelain insulators

Here the HV winding is measured without the effects of leakage current between the HV and LV windings using the guard terminal.

5 kV, 10 kV and 15 kV insulation testing – use of guard terminal

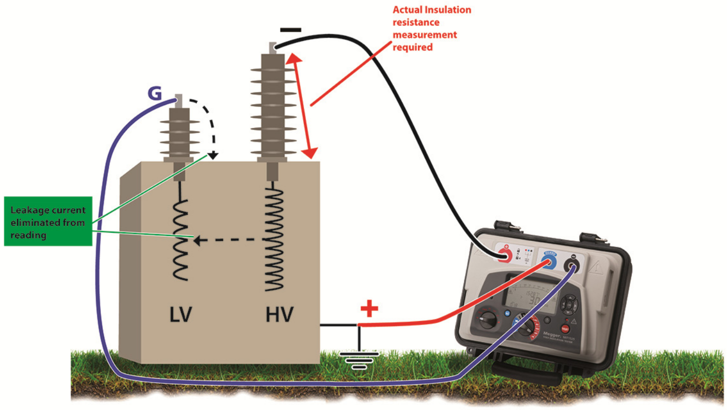

Figure 7: Transformer winding insulation test, with the guard used to eliminate leakage current between windings and across LV bushing

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, hence the need to test the insulation between the two.

Testing cables?

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

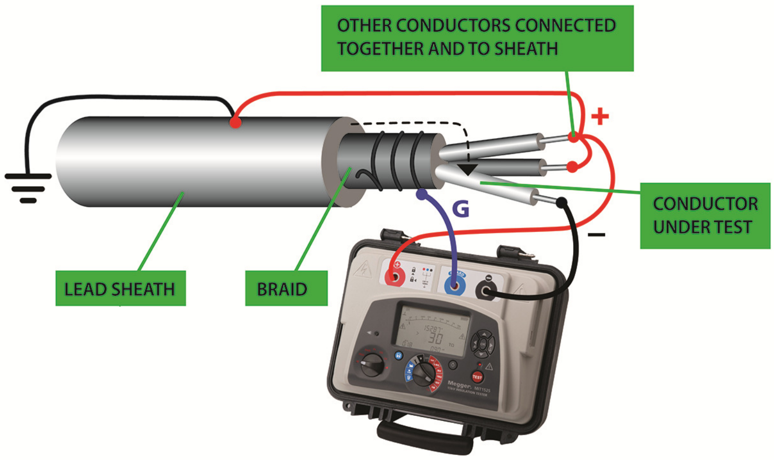

Figure 8: The guard terminal is connected to wire wrapped around the exposed insulation to pick up surface leakage

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.

5 kV, 10 kV and 15 kV insulation testing – use of guard terminal

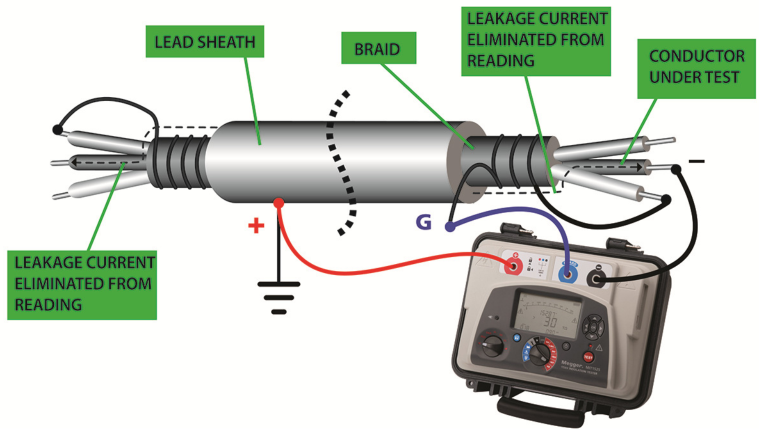

Figure 9

The guard terminal can also be used to eliminate leakage current between other adjacent conductors in the cable.

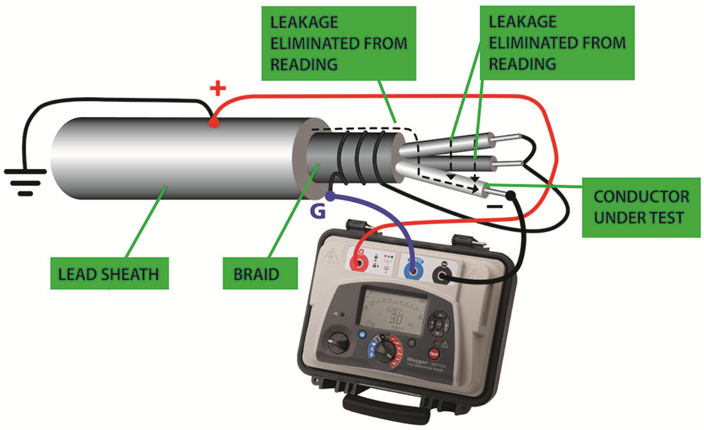

Figure 10

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.

Megger

5 kV, 10 kV and 15 kV insulation testing – use of guard terminal

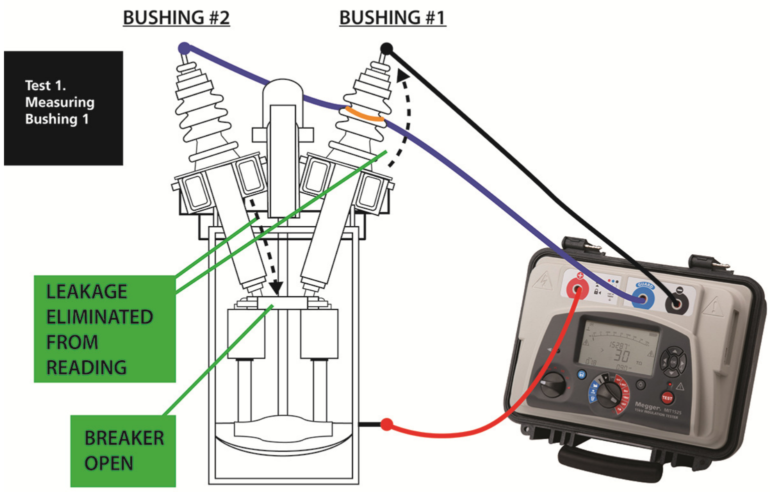

Figure 11: Measuring bushing 1

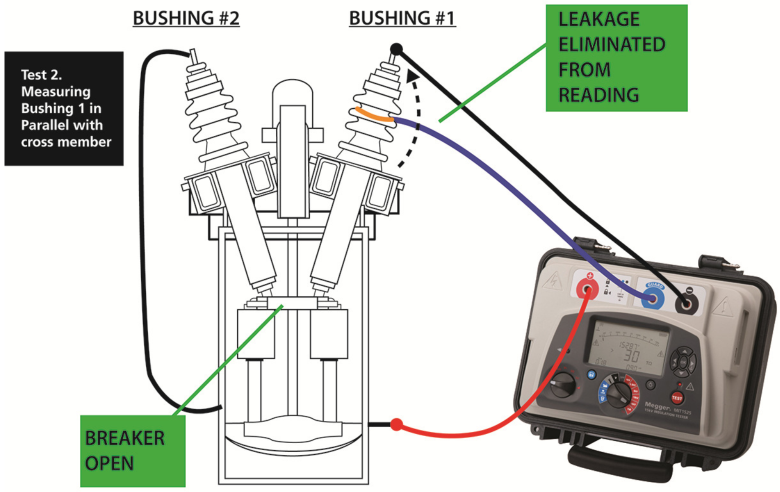

Figure 12: Measuring bushing 1 in parallel with cross member

5 kV, 10 kV and 15 kV insulation testing – use of guard terminal

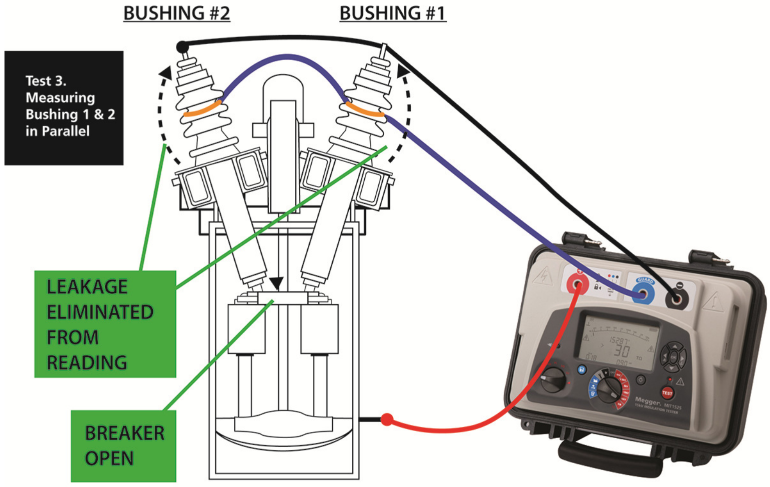

Figure 13: Measuring bushing 1 and 2 in parallel

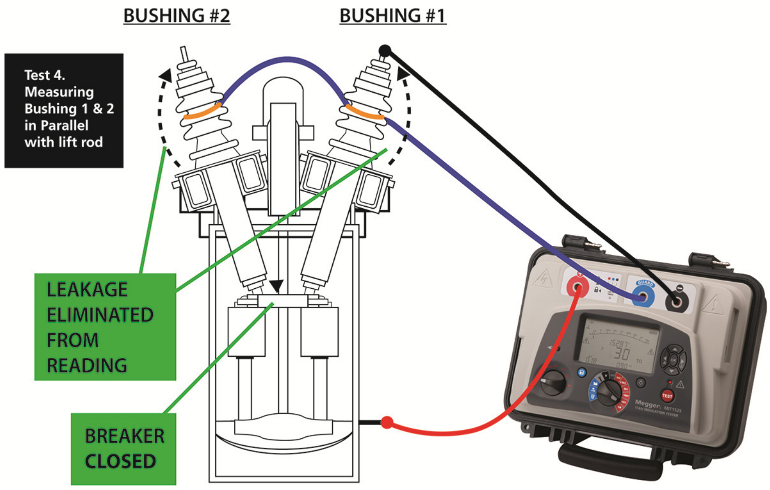

Figure 14: Measuring bushing 1 and 2 in parallel with lift rod

The real benefits of the guard terminal

In addition to the big improvements in the reliability of insulation condition diagnosis and predictive maintenance discussed, the guard terminal is an important diagnostic tool.

The amount of current that is surface leakage can be quickly identified simply by performing two tests; one using the guard terminal and one without, and calculating the difference in measurements.

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

Don’t throw away, use your guard and know when to clean.