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Are Your AC Hipot Leakage Current Measurements Accurate?

by Dwayne Davis, Associated Research, Inc

The Hipot or Dielectric Withstand test is routinely specified as both a "Type" test and a "Routine Production Line" test on electrical products. The type (or qualification) test stresses the insulation of an electrical product far beyond the level encountered during normal use. The assumption is that if the insulation can "withstand" the much higher voltage for a given time it should be able to function adequately at its normal operating voltage level. The duration of the Hipot test usually ranges from 60 seconds for a type test to 1 second for a routine production line test.

A basic function of any Hipot tester is to monitor excessive leakage current to ground during the test. If excessive leakage current flows it is generally an indication that there may be a defect in the Device Under Test (DUT). Hipots are designed with a circuit that allows the operator to preset a trip level for excessive current conditions. If excessive current in an amount greater than the trip point flows, the Hipot tester will go into a failure mode. The test voltage applied during the Hipot test is seldom less than 1000 volts. A common rule of thumb is 1000 VAC plus twice the typical operating voltage of the DUT. Some product safety standards specify a 1500 volt test for basic insulation and a 3000 volt test for reinforced or double insulated products.

The Hipot test not only stresses the insulation of the product but it also detects workmanship defects such as spacings of current carrying conductors that may be too close to the grounded case of the DUT. When a product operates under normal conditions, environmental factors such as humidity and dirt can close small spacings and allow current to flow from the current carrying conductor to the case of the DUT. This can create a shock hazard if these problems are not detected and corrected during the design and manufacturing process.

Hipot testers available today offer more capabilities than the instruments that were available just a few years ago. Some of these new capabilities add valuable safety and information value to the test results. Examples of such improvements include line and load regulation, no load setting of high voltage and current levels, ground fault interrupter circuits, low level arc detection, ground sense circuits and many more. Occasionally a newly introduced testing technique can cause confusion and may present a possible safety risk to the user as well as distort test results. This article will address one such test technique.

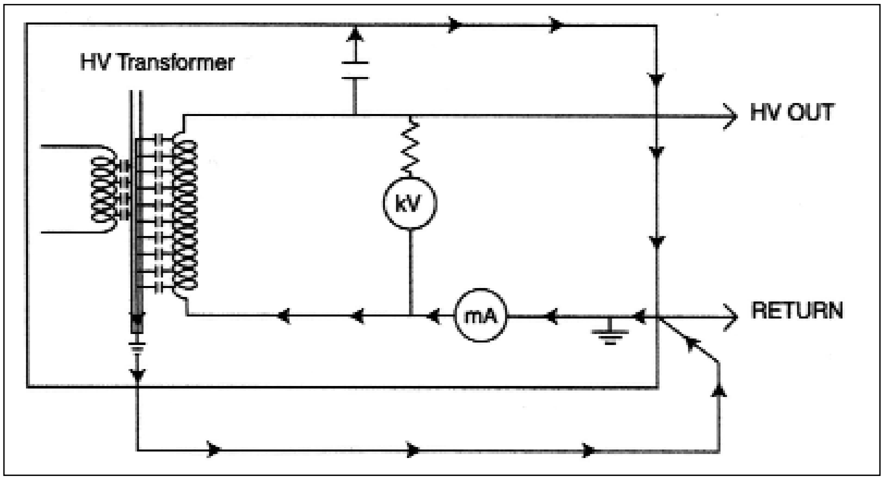

Figure 1: AC Hipot with Grounded Return
A typical hipot tester will have leakage return currents due to capacitive coupling. Shown are the paths of current flow within the hipot tester due to interwinding capacitance and due to wiring to case capacitance

Most instruments today have current meters to monitor the leakage current during the Hipot test. Normally a product failure during a Hipot test produces current well in excess of several milliamps. Occasionally manufacturers have the need to monitor leakage currents down to the microamp range. This may be necessary for a low leakage application, such as medical use, or desirable for engineering diagnostic purposes. However, normal internal leakage of the AC Hipot itself often makes it impossible to read down into the microamp range. This is easy to understand if you look at the common circuit configuration of an AC Hipot tester.

Interwinding capacitance is a common contributor to low level currents. Thus, the currents due to the hipot tester's transformer can contribute to the measured levels. At low currents, these can mask the true leakage of the DUT. The amount of leakage current is dependent upon the capacitance of the circuit, the frequency, and the applied voltage. This leakage current will flow to ground because our power systems are ground referenced. Most Hipot testers are either constructed with the return internally grounded or because the DUT is grounded the return then becomes externally attached to ground. This creates a circuit whereby the current meter will monitor any leakage through ground back to the Hipot return. (See Figure 1)

As you can see in Figure 1 the capacitance between the windings and the core of the transformer allow some current to leak to ground since the core is tied to ground. This current will then flow back through the Hipot ground. Since the Hipot's current meter is tied to ground this leakage current will be monitored as the current passes through the meter. Leakage through a fixture can also cause current readings on the Hipot to be higher than the current that is actually flowing through the DUT. This, of course, is not true leakage through the DUT, so it should not be considered when evaluating test results. Normally this current is negligible when the measured current is in the milliamp range. However, this low level "nuisance" current can become a substantial part of the total leakage current if settings in the microamp range are being used. As a result it is very possible for a Hipot tester to falsely trip on this nuisance leakage current.

Some Hipots use a "CURRENT OFFSET CIRCUIT". This circuit is intended to offset both the internal leakage current of the instrument and the leakage current of the test fixture. As we will see, in a completely capacitive or a completely resistive application this might work. However, in the real world this circuit produces inaccurate readings because total leakage current is actually a combination of capacitive leakage current and resistive leakage current. The total current is a vector sum relationship based upon the phase angle of the capacitive current and the resistive current which are 90 degrees out of phase from each other.

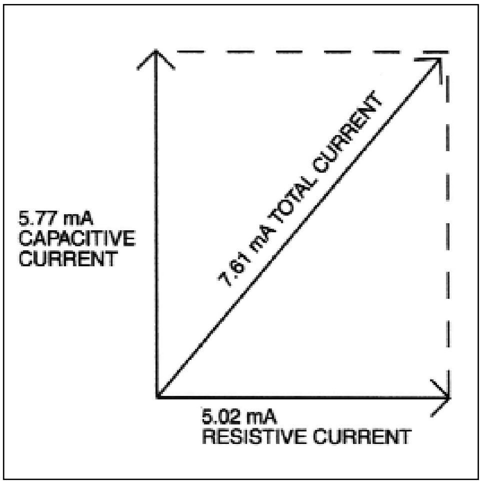

Figure 2: Vector Sum Relationship Capacitive Current vs. Resistive Current
Simple subtraction of currents which occur within the hipot tester from those measured with a DUT connected will not in general yield an accurate measurement because the current components may vary in phase. The current for a 300K + .01 uF capacitor has the in-phase resistive and reactive components shown above.

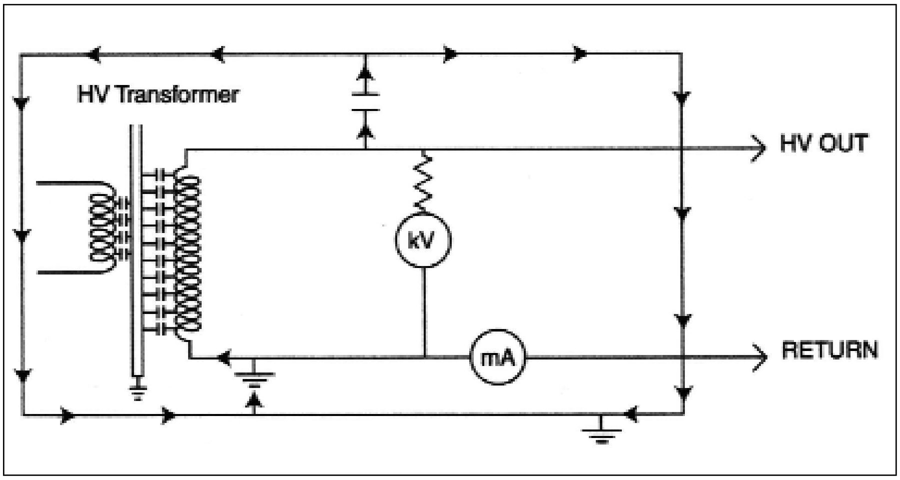

Figure 3: AC Hipot with Floating Return
A hipot tester which measures the current in a floating return lead can minimize the problem of internal capacitive coupling. The meter only measures the current flowing from the DUT. This eliminates the need for an offset calculation of dubious accuracy.

An offset circuit works in the following way. First you perform a Hipot test without the DUT connected. This reading includes internal Hipot leakage and any leakage due to the test leads and the test fixture. This current is offset to zero automatically and subtracted from the total current when the DUT is connected. Typically this reading is in large part due to capacitive leakage current. If the DUT leakage current is more resistive than capacitive this introduces a greater error due to the phase angle. This circuit does not take into account the phase angle of the current.

Here is an example of a test run on an instrument with a leakage current offset circuit. For the purpose of this test, a .01 microfarad capacitor and a 300 K ohm resistor were used to represent our fixture and our DUT. First the capacitor was connected to the Hipot that was adjusted for a potential of 1500 volts and gave a reading of 5.77 milliamps of leakage current. The capacitor was then disconnected and a 300K ohm resistor was connected to the Hipot. The leakage current at 1500 volts now read 5.02 milliamps. The resistor and the capacitor were then connected in parallel with each other and the total leakage current read 7.61 milliamps. The 5.77 milliamps of capacitive current was "offset" and the test was repeated. This resulted in a reading of 1.84 milliamps of leakage current. The 5.77 milliamps of current was subtracted from the total current reading of 7.61milliamps, which equals 1.84. Yet there is still 5.02 milliamps of resistive current flowing through the 300K ohm resistor. This is the leakage current value that the meter should read. (See Figure 2)

It is important to note that an offset circuit basically subtracts a fixed value of leakage current from the total current measurement. It cannot compensate for the change in phase angle when a DUT is added which changes the capacitance and resistance of the complete circuit. As shown by the above example the actual current flowing in the circuit can be much higher than the offset adjusted value shows. This could create a safety hazard. A DUT with excessive leakage may actually PASS the Hipot test when the current offset is activated. This presents a potential safety risk when an OFFSET circuit is used for leakage current measurements.

The most accurate method of obtaining leakage current readings during an AC Dielectric Withstand test is to use a Hipot that has the return lead floating. This is where the return is not directly connected to earth ground (see Figure 3). This also requires that the DUT be on an insulated surface and isolated from ground. If the DUT is grounded the current metering circuit is shorted out and there would be a ground connection on both sides of the current meter. In this setup the current monitoring circuit is connected between the return lead of the Hipot and ground; therefore any leakage current that flows back to ground is bypassed around the current meter. Only the leakage current that flows through the DUT is monitored. This is like having an external current meter connected to the DUT. By using this configuration only leakage current through the DUT is actually read on the Hipot's current meter.

In conclusion leakage current offset circuits present an easy and convenient way to eliminate test fixture leakage currents but as shown in this paper they also create erroneous test results and pose a potential safety risk. The most accurate and proven method to avoid measuring the nuisance current due to internal Hipot leakage or fixture leakage is to use a Hipot with a floating return. In the real world only circuits that are accurate under all testing conditions should be considered in the design of a Hipot tester. ■

About the Author

Dwayne Davis is the Technical Services Manager at Associated Research Inc. For more than 30 years, he has been involved in the design, development and manufacture of high voltage products including transformers, power supplies, and safety testing instruments. Mr. Davis also has conducted seminars and industrial presentations throughout the world.

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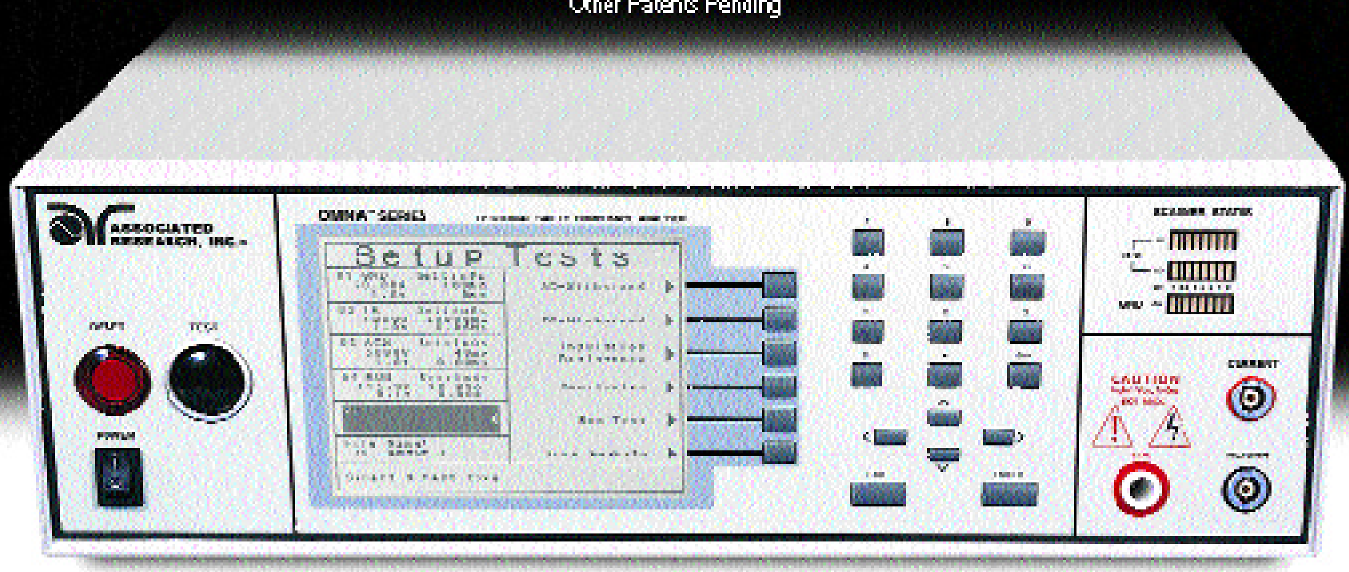

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