

Line Leakage Testing Is it right for your application?

Introduction

The Line Leakage test (LLT for short) is most often specified to be performed as a type test in a design or engineering laboratory or as a routine production line test on medical devices right before they ship. Not as commonly performed as a Dielectric Withstand or Ground Bond test in a production environment, LLT can cause some confusion for engineers & technicians alike. However, technological advancements have begun to lessen the outward complexity of the test. What used to be complicated set-ups and testing procedures has now been simplified with the use of multi-function testing instruments. For instance, all-in-one testing solutions such as our 6330 now come equipped with the components and relay switching networks to perform leakage tests in an automated sequence with little or no input from the test operator. This makes for safer and more efficient testing.

Electrical products including anything from appliances to handheld tools, must be tested during the design and development phase in order to receive a safety agency listing. In these laboratory environments, the LLT is used to help ensure that the product's manufacturing processes and assembly practices are satisfactory. Along with other common tests such as the Hipot and Ground Bond tests, the Line Leakage test is used in this situation primarily as an indicator of design quality.

Some products, such as medical equipment, are designed with the intention of direct contact with a patient. Line Leakage tests should be performed on these products as a 100% routine production line test. Due to the sensitive nature of the applications for which this type of equipment is used, it is easy to see why rigorous testing must be performed as a routine test.

Whether the LLT is being performed as a type test or as a production test, the purpose of the test is same: to determine if a product's insulation has the integrity to prevent any current from reaching the operator. When current does find its way through or across any part of a product's insulation system, it is known as leakage.

There are several methods manufacturers employ to prevent leakage, such as utilizing reinforced or double insulation systems and providing sufficient spacing between current-carrying conductors. Despite these measures, leakage current will be present in every product to some degree. Indeed the electrical relationships between the very materials used in a product's construction are what account for a substantial portion of any resulting leakage. While the resistance of the insulation will account for some leakage, using an insulating material in between conductors creates a certain amount of distributed capacitance which helps to facilitate leakage to ground. This current will look to travel through a product's insulation system and return to ground by any means available, whether that is through a safety earth ground connection, or through an operator who is at ground potential.

For example, medical devices that run off of line power have components that are in direct contact with a patient. In this case a wall outlet, an almost unlimited power source, has a direct connection to a patient who could already be sick or frail. It is of vital importance in this scenario that the leakage current produced by the product be small enough so as not to be perceived by the individual to whom the device is connected. More importantly, the insulation of the device needs to have the integrity to prevent any current from reaching the patient.

A closer look at the Line Leakage Test

The Dielectric Withstand (Hipot) test or Insulation Resistance (IR) test are common safety tests performed in both production line and lab environments. These tests do a good job of determining whether a product is manufactured correctly with good insulation, but they don't tell us how much leakage current could be flowing through a product while it is running. Furthermore, these tests cannot tell us how that leakage current might change under different conditions. There is no way to determine what might happen if the product is connected to a power source incorrectly, if the operator plugs the product into an outlet that is wired incorrectly, or if the neutral side of the line opens up. The Line Leakage test was developed as a way of determining how leakage current would act conditions such as these.

The Line Leakage test is actually a general term that is used to describe a series of tests. There are 4 different types of LLT's: Earth Leakage test, Enclosure Leakage test, Patient Leakage Current test, and Patient Auxiliary Current test (we will discuss each type of test later in the document). Each test is performed under nominal operating conditions as well as in a variety of fault conditions. These fault conditions provide us with valuable information about how a product's leakage current will behave if operated incorrectly.



Figure 1.0:
Model 6330 6-in-1 Electrical Safety Tester (including LLT)

While the test setup may vary from test to test, the actual test methodology doesn't change. One-box solution testers such as the our 6330 come equipped with the components and relay switching networks to perform all Leakage tests in an automated sequence with little or no input from the test operator. The 6330 also has the capability to record leakage using Peak or RMS measurements, a feature beneficial for manufacturers who must comply with standards such as IEC 60990. (See Figure 1).

Measuring Devices

Since the LLT is designed to measure the leakage current of a product while it is running, the way in which the current is measured is of vital importance. Therefore, Line Leakage tests incorporate measuring devices (MD's), which simulate the impedance of the human body. The placement of the measuring device is the factor that distinguishes one type of LLT from another. Measuring devices are specified by safety agencies depending on product classification and the standard to which the product is being tested. For the most part, MD's are resistive and capacitive networks designed to simulate the impedance of the human body in certain conditions. In most of today's testers these measuring devices are incorporated in the circuitry of the tester.

During Line Leakage tests for example, MD's can be used to approximate full hand-to-hand or hand-to-foot contact. Figure 2.0 shows the network that should be used when testing to EN60601-1.

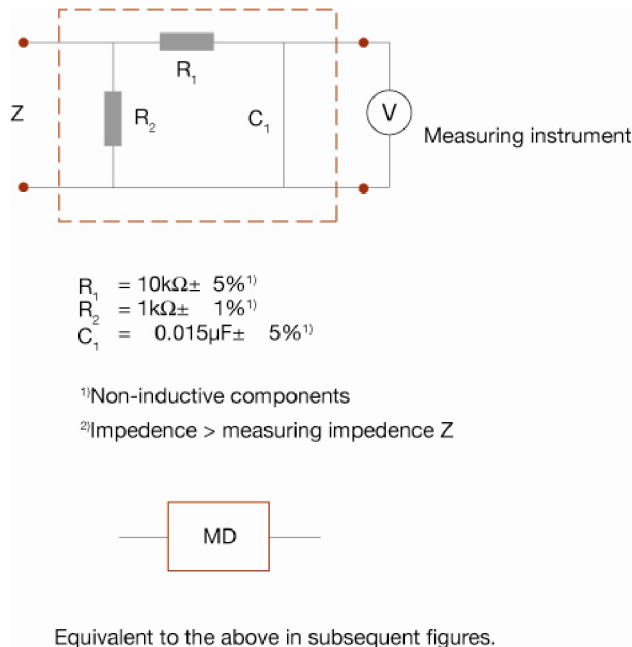


Figure 2.0: MD Schematic for EN60601-1

Many safety agencies differ in their interpretation of how the test's MD should be configured. Regardless of where the MD is placed or how it is configured, the test should measure how much leakage current would flow through a person if they were to come into contact with the device under test (DUT). Below is an example of an internal switching network that may be found in a Line Leakage Tester.

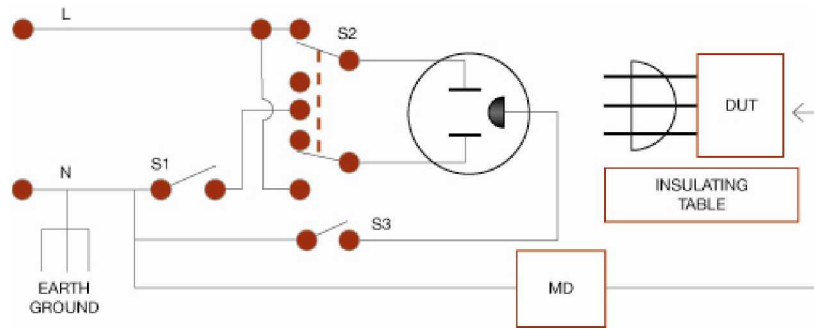


Figure 3.0: 6330 Internal Switching Network

In this internal switching network the MD can be any one of 8 built-in measuring devices as specified by safety agency standards. Relays S1, S2, and S3 are used to simulate the various fault conditions during testing. S1 corresponds to the open neutral condition, S2 to the reversed polarity condition, and S3 to the open ground condition.

Fault Conditions

The LLT is performed in both normal and single fault operating conditions. Measuring leakage current during fault conditions is important in order to determine if a product fails "safely," if it fails at all. A product that fails safely will not produce excessive leakage current even if one of the following combinations of fault conditions occurs. Table 1.0 below shows the various combinations of relay closures that will simulate up to 8 total testing scenarios.

| Neutral (S1) | Polarity (S2) | Ground (S3) |
|--------------|---------------|-------------|
| OPEN | NORMAL | OPEN |
| OPEN | REVERSED | OPEN |
| OPEN | NORMAL | CLOSED |
| OPEN | REVERSED | CLOSED |
| CLOSED | NORMAL | OPEN |
| CLOSED | REVERSED | OPEN |
| CLOSED | NORMAL | CLOSED |
| CLOSED | REVERSED | CLOSED |

Table 1.0: Line Leakage Test Fault Conditions



Test Setup and Procedure

Earth Leakage Test

The Earth Leakage test places the MD from the earth ground pin of the DUT to the neutral side of the line (which is referenced to ground). In this configuration, power is applied to the DUT at 110% of the nominal voltage level using an isolation transformer. The MD is used to measure the amount of leakage current flowing from the mains-input line and returning to ground through the product's insulation under normal and single fault conditions.

Enclosure Leakage Test

The Enclosure Leakage test places the MD from one or more points on a DUT's chassis to the neutral side of the line. In this configuration, power is applied to the DUT at 110% of the nominal voltage level using an isolation transformer. The MD is used to measure the amount of leakage current flowing from the enclosure, excluding applied parts accessible to the operator or patient to ground or to another part of the enclosure under normal and single fault conditions.

Applied Part Leakage Test

The Applied Part Leakage test, also known as the Patient Leakage test places the MD from a patient-applied part (usually some sort of probe or meter that comes into direct contact with a medical patient's body) to the neutral side of the line. In this configuration, power is applied to the DUT at 110% of the nominal voltage level using an isolation transformer. The MD is used to measure the amount of leakage current flowing from applied part to ground under normal and single fault conditions.

Patient Auxiliary Leakage Test

The Patient Auxiliary Leakage test places the MD in between 2 different applied parts that come into contact with a patient's body. In this configuration, power is applied to the DUT at 110% of the nominal voltage level using an isolation transformer. The MD is used to measure the amount of leakage current flowing from one applied part to another under normal and single fault conditions.

Conclusion

Although the Line Leakage test can seem somewhat confusing at times, it is an important test that should be given due consideration in any electrical safety testing routine. Technological advancements have made LLT much easier to perform and more manufacturers are performing LLT in both a lab and production environment. With some research and the right equipment, Line Leakage testing can be performed as quickly and easily as more common tests such as a Hipot or Ground Bond test. This means that the LLT can be added to a safety testing routine, without negatively impacting throughput and the addition of the LLT to any safety testing routine will help make electrical products safer and more reliable. This will save money in the long run.