Weekly Whitepaper
Week #53

Understanding the Grounding Continuity Test

The "Understanding the Product Safety Tests" Series

The *Grounding Continuity Test* (aka Earthing Continuity Test) is one of the most common product safety tests. It is performed on products that have a ground (earth) connection by Certification labs as part of the product Certification and by electrical product manufacturers on 100% of production. Let's review the elements of this test.

Key Definitions:

a) Grounding vs. Earthing: Grounding & Earthing are interchangeable terms with identical meaning. In the US & Canada, the term "grounding" is used, while most other countries use the term "earthing". Accordingly, UL & CSA standards use the term "grounding" while IEC & EN standards use the term "earthing". This whitepaper uses the term "grounding" which can be replaced throughout with the term "earthing".

b) Protective Current Rating: Some standards specify using a test current level that is based on the "protective current rating". The protective current rating is the current rating for the device that provides "branch-circuit overcurrent protection". It is the rating of a circuit breaker or cartridge fuse = this device can be part of the product, but it is usually part of the building electrical system (i.e. the circuit breaker in the breaker panel).
   - Branch circuit rated circuit breakers and fuses can handle high short-circuit current and are therefore much larger than "supplementary" protectors = the types of circuit breakers and fuses included in many products do not provide branch circuit protection and therefore are not considered when identifying the protective current rating.

c) Protective Earth Terminal (P.E.): The P.E. terminal is the connection point for the mains grounding connection and is one of the two connection points during testing. For a cord connected product, the P.E. is the point where the ground connection from the mains power terminates at the product enclosure.

Purpose of the Test:

- This test is performed on the product's electrical grounding system. It is the grounding system that protects the user from a shock hazard during an electrical fault condition.
- The test is used to identify excess resistance in the grounding system that could limit the effectiveness of the ground to perform its intended level of shock hazard protection.

Test Objectives: There are two objectives to keep in mind:

1. Low Resistance: The main objective of the Ground Continuity Test is to verify that the protective ground system has minimal electrical resistance. Should there be an internal electrical fault within the product while the user is touching the product, the goal is for all fault current to flow to ground (earth). This is done by insuring the grounding system is the path of least resistance for the fault current = to prevent the fault current from flowing through the person. Also, the intent with keeping the ground resistance extremely low is to cause as high of fault current as possible = so that the circuit breaker or fuse trips as fast as possible.
2. Reliable at High Current: In addition, the high current test aims to insure that the grounding system will continue to operate as intended during a fault condition = if there is an electrical fault to ground within the product, the grounding system needs to be able to hold the fault current until the overcurrent protection for the product is tripped (i.e. circuit breaker). Note that if all parts of the ground system are properly sized and bonded together, compliance with this test should not be a problem.

Test Method:

1) Not Powered: The product is not connected to power during this test.
2) Two Different Methods: The Ground Continuity test has two different test methods – check your standard to determine which applies to your product.
    a) A Low Current test that focuses solely on verifying continuity rather than measuring the impedance of the grounding system. It is primarily found in UL standards.
    b) A High Current test that includes measurement of the grounding system impedance using a low voltage source.
3) Low Current Test Method: The low current version of the test is used by many UL standards for product certification. It is also the basis for most production line ground continuity tests. For the low current version of the test, any reliable means to verify ground continuity is all that is required. The continuity setting on handheld voltmeters will suffice, as will any other commercial continuity checker.
    - Most automated hipot testers (dielectric voltage testers) include a ground continuity feature aimed at meeting this requirement while also insuring a good ground before energizing the high voltage. For production testing, you want to make sure you have this type of hipot tester as it will accomplish both required production tests for most UL standards.
4) High Current Test Method: The high current test requires a Ground Continuity tester or other means to generate the specified test current. The test voltage is adjusted to achieve the desired test current, and then ohms law is used to calculate the test impedance. The test current and the test time can vary and are each discussed in detail below.
    - The test current is to be provided by a low voltage source, with most standards specifying a maximum voltage of 10 or 12 V.
5) Test Limit: For the high current test, the maximum impedance of the grounding system is 0.1 ohms. A few standards allow for higher limits, but this is usually as an offset for power cord impedance for products with a permanently connected power cord. In addition, standards that anticipate test currents over 25A sometimes specify the limit as a maximum voltage drop across the P.E. grounding system of 2.5V instead of the 0.1 ohm limit (note that a 2.5V drop @ 25A equals 0.1 ohms).
    - Some standards have voltage drop limits that are even higher for hard wired products and products with an extremely high input current rating and protective current rating (4.0 – 10.0V).
6) Test Current: For the high current test, the test current is usually 2X the protective current rating. An AC or DC test voltage is permitted.
    - Note that products intended for Canada must comply with the Standard for Bonding of Electrical Equipment, CSA C22.2 No. 0.4. This standard also specifies a 2X test current.
7) Test Time: The test time can vary from 2 minutes to as high as 10 minutes. The higher the protective current rating, the longer the test time. Consult your standard for the test time vs. protective current rating table.
8) Test Locations: The ground impedance limit applies between the P.E. terminal and the following test points. For convenience, the test can be performed from the grounding pin of the plug to the following test points:
    a) Operator accessible grounded surfaces.
    b) A transformer ground shield when the ground shield is relied on for a level of shock hazard protection for a secondary circuit (i.e. SELV method 2).
    c) A grounded secondary circuit when the ground is relied on for a level of shock hazard protection for a secondary circuit (i.e. SELV method 3).

Test Method: Continued

9) Avoid Contact Resistance: Make sure you are using a suitable probe tip for contact with the surface being tested = a clamp works much better than a pointed probe tip to avoid contact resistance (although at times it may be difficult to find a place that a clamp can grip).
10) Test Leads: Be sure to use test leads and connectors suitable for the test current. Note that the lead impedance is not part of the grounding resistance limit – some ground continuity testers will allows you to "zero out" the test lead resistance thereby excluding it from the displayed result. A "zero" feature can also be used to remove the power cord impedance from the measurement when testing cord connected products.
11) P.E. Trace: If your P.E. system includes a trace on a printed circuit board, the trace must also comply with the Limited Short-Circuit test of CSA C22.2 No. 0.4.

Test Exceptions: See your standard to determine if any of these exceptions apply:

- In some standards, if the grounding (earthing) system only consists of a grounding conductor that is properly sized, this test is not required.
- In some standards, stationary products with instructions to insure reliable grounding are not required to be ground continuity tested.
- In some standards, "permanently connected products" (conduit connected) are not required to be ground continuity tested.
- In some standards, cord connected products for use in commercial or industrial installations, with an industrial style plug, are not required to be ground continuity tested.

Production Testing: Many standards require the Grounding Continuity Test be performed on 100% of production. Some UL standards only require the production test on products with a grounding type plug, specifying a test between the grounding pin of the plug and accessible dead metal parts. All other aspects of the test methods specified above apply. Production testing is not required by some standards on products that are field wired (conduit connected) and provided only with terminals or leads for electrical connection.

As you can see, we don't simply perform the tests because they are in the standard. Each test in the standard has a set of objectives that relate to the 6 Hazards of Product Safety. The Ground Continuity Test is performed as part of the Risk of Shock compliance review. Verifying reliability of the product's grounding system is crucial to insuring it continues to provide protection from a Risk of Shock during a product fault condition, a potentially serious hazard that could lead to death by electrocution. It is therefore a very important test – another test that directly saves lives. This is why the Production Ground Continuity Test is required on 100% of certified products that have a power cord with a grounding type plug.