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Production Hipot Testing

Introduction

Protecting the user of electrical equipment from shock is one of the most important aims of product safety practice. Most products are designed under the philosophy that no single failure of safety measures should cause a shock hazard to the user. This idea is incorporated into the standards that guide product design. In fact, it is so important that two aspects of protecting the user from the hazards of power-line voltages—dielectric strength testing and grounding continuity—are usually incorporated into the production line and checked on every unit produced.

What is less often appreciated is the fact that the same production line testing that protects the ultimate user of the equipment can present a hazard to the factory worker doing it. It makes sense to look into protecting the worker who makes the equipment as well as the consumer who ultimately uses it—and both are mandated by law.

In this article, we review the safety function provided by production line dielectric strength testing, and examine how it can be made safe for the worker to administer.

OSHA And Safety

In the United States, OSHA, the Occupational Safety and Health Administration, has jurisdiction over safety in the workplace. OSHA is part of the U. S. Department of Health. OSHA has a vast array of rules, but important to us for the purposes of this article are two principles:

1. Workers should use approved, safe equipment. “Safe” means approved by an OSHA approved Nationally Recognized Test Laboratory (NRTL) as meeting nationally recognized standards appropriate for the equipment.
2. As part of job safety, the workers should be properly trained for their duties.

Insulation, Grounding And Product Safety

Let’s examine the single fault problem in the context of hazardous voltage protection. The mains power can be modeled as a voltage source connected to ground. In the United States, the most common power level will be 120 VAC, with the return lead brought back

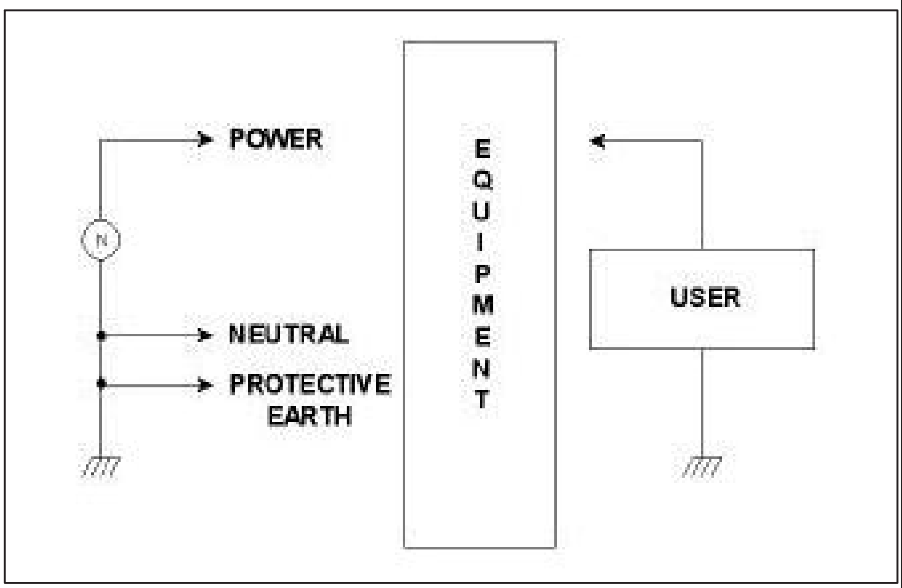

Figure 1: Mains power is delivered between the “hot” and neutral wires. Many systems are 3-wire, with a protective earth ground accompanying the neutral. The neutral wire and the protective earth are connected together to an earth ground at the power distribution panel.

to ground, where it joins the protective neutral conductor (Figure 1). Clearly, no person wants to complete this circuit, so it is the job of the electrical equipment designer to see that the user is insulated from such an eventuality.

In product safety design, the amount of insulation necessary to protect against a given voltage level is written into the standard appropriate to the product of interest. A given amount of dielectric strength and some construction requirements (e.g., thickness and suitability of material) are mandated. This level of insulation is known as "basic" insulation. But, how do we maintain protection if this insulation fails – that is, if a "single fault" occurs?

Two methods are commonly employed—either an additional level of insulation is used ("double" insulation – or equivalently, an extra-strong "reinforced" amount of insulation equivalent to double insulation), or a diverting connection is made to ground.

With the first method—double insulation—a failure of one level, or layer, will still leave adequate insulation to protect the user from contact with the hazardous mains voltage. Some transformers are wound with the double insulation method—a common example is the omnipresent battery eliminator. With the second method, a break in the insulation shorts the power to a protective ground, opening the product's protective fusing. Again, a transformer provides a common implementation example—the high voltage insulation is adjacent to an internal ground screen, which is in turn connected to the product protective ground lead. (Figure 2 diagrams these methods schematically.)

Production Tests

Since electric shock protection is so important, most pieces of equipment are production line checked for dielectric strength, and where applicable, ground continuity. The dielectric strength required varies with the standard and the mains operating voltage, but is of the order of 1500 volts for a single layer of insulation and 3000 volts for double or reinforced insulation. Confirming the strength of the insulation requires generating voltages of these strengths.

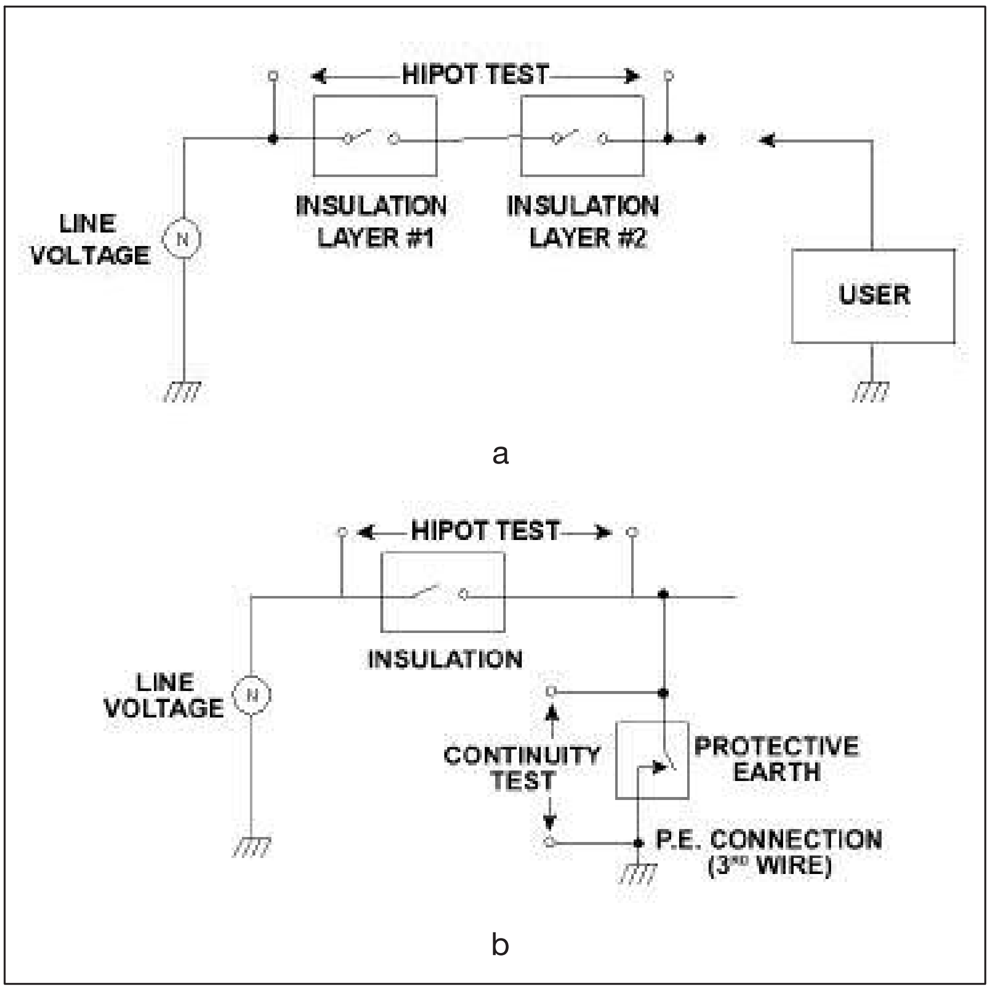

Figure 2: The "single fault" philosophy requires two layers of protection. (a) One method is to use double insulation—if one layer fails, there is still a layer of protection left. The insulation layers protecting the user are shown heuristically as open switches. (b) Another method is to use a single layer of insulation in conjunction with a protective earth connection to divert the hazardous current away from the user if the insulation fails. Production hipot testing ensures the integrity of the insulation; if protective ground is used, the ground continuity is also tested.

It wouldn't make sense to test products to ensure they are safe for the workers who use them while at the same time endangering the workers who produce the products. It also wouldn't comply with OSHA's mandate for worker protection. Any time one works with high voltage, the danger of shock must be considered and minimized.

One of the primary standards that OSHA relies on for its electrical safety requirements (29 CFR Part 1910 Subpart S, Electrical Safety) is the National Fire Protection Association (NFPA) standard NFPA 70 E, "*Standard for Electrical Safety Requirements for Employee Workplaces.*" It requires that only qualified persons performing electrical work be permitted access to live parts. Whom does the NFPA consider a "qualified person?"

"A qualified person shall be trained and knowledgeable of the construction and operation of equipment or a specific work method, and be trained to recognize and avoid the electrical hazards that might be present with respect to that equipment or work method. Such persons shall also be familiar with the proper use of special precautionary techniques, personal protective equipment, insulating and shielding materials, and insulating tools and test equipment."

It is the employer's responsibility to provide safe workplaces. The two key components to a safe working environment are safe equipment and adequate worker training. The equipment issue is addressed by using OSHA-compliant electrical instruments—that is, equipment that has been listed by a Nationally Recognized Testing Laboratory (NRTL) to consensus based standards within the laboratory's scope of accreditation. (For more on the NRTL program, see http://www.osha.gov/dts/otpca/nrtl/). This article discusses aspects of training appropriate to production line dielectric testing, and some of the equipment issues involved in augmenting worker protection.

Worker Safety: Training And Equipment

The dielectric withstand – or hipot (as in high potential), as it is often called – test is routine, but it can be hazardous to the production worker because of the high voltages involved. Ideally, the workstation will have some degree of positive protection (e.g., ground fault protection or current limiting), and no exposed energized circuits. A qualified operator will be trained to recognize and avoid electrical hazards. Topics he/she should be aware of include:

- A basic understanding of electricity: The operator should know about voltage, current, resistance, and how they relate to each other. A qualified person should also understand conductors, insulators and grounding systems.

- A working knowledge of the test equipment, the tests that are being performed, and the hazards associated with the tests as well as the circuits that are being energized.

- An understanding of approach distances and corresponding voltages to which they may be exposed.

- A knowledge of specific hazards associated with electrical energy. They should be trained in safety-related work practices and procedural requirements as necessary to provide protection from the electrical hazards associated with their respective job or task assignments. Employees should be trained to identify and understand the relationship between electrical hazards and possible injury.

- A qualified person should understand that the three primary factors that determine the severity of electric shock are:
  - The amount of current flowing through the body
  - The path of the electrical current through the body (e.g., through the chest is worse than across a single limb)
  - The duration or length of time the person is exposed

- A knowledge of how the human body responds to the passage of current:
  A. 0.5 to 1 mA is the perception level, where the current is first noticed
  B. At 5 mA a slight shock is felt, a startle reaction is produced
  C. Inability to let go occurs at a current of 6 -25 mA for women and 9 -30 mA for men. People experiencing currents of this level are "frozen" and cannot move themselves away from the conductors they are contacting.
  D. A current of 30 – 150 milliamps results in extreme pain, respiratory arrest, ventricular fibrillation and possible death.
  E. At the level of 10 Amps cardiac arrest and severe burns can occur

- A qualified person working on or near exposed energized electrical conductors or circuit parts should be trained in methods of release of victims from contact with exposed energized conductors or circuit parts.

- A qualified person should understand that the test instrument is a variable voltage power source and the current will flow to any available ground path. They should be aware that contacting the device under test (DUT) during the test can result in a dangerous shock hazard under certain conditions.

- A qualified person should understand that if the return circuit is open during the test then the enclosure of the DUT can become energized. This can occur if the return lead is open or the operator lifts the return lead from the DUT while a test is in process.

- A qualified person should be made aware of the importance of discharging a DUT. Lifting the high voltage lead from the DUT before the test is complete can leave the DUT charged. When you are performing a Hipot test you are testing the insulation between two conductors, which forms an unintended capacitor. This capacitor can act as a storage device and hold a charge even after the DUT is disconnected. With a DC insulation test this is obvious; however, it can also occur with an AC test. If the circuit is opened at or near the peak of the applied voltage then the DUT hold a significant charge. If the test is allowed to finish rather than being abruptly stopped by disconnection, the test voltage will be reduced to zero and the charge is dissipated through the impedance of the high voltage transformer or the power supply. Most DC Hipot testers today employ an output-shorting device to discharge the DUT, but the tester must remain connected to the DUT for the entire the test cycle.

This list isn't all-inclusive. Many accidents occur when the employee deviates from the optimally safe procedure, either because (s)he is distracted or takes a short cut in an effort to save time. Sometimes the test setup is designed to maximize productivity rather than safety. Here is where safety measures built into the test equipment can help.

Test-Setup Protective Measures

Multiple, automatic shut-down circuits are an excellent way to improve safety. Many current-generation hipot testers have high and low limit current sense circuits with adjustable thresholds. Acting in combination, these will shut off the voltage source if current in the expected range is not found. Excessive current indicates a wrong connection or an insulation failure; current below the expected level can indicate an open or incorrectly placed lead, either of which should be further investigated.

One manufacturer has introduced an additional safety feature—its Smart GFI® circuit is monitors whether the DUT (device under test) is floating or referenced to earth ground. If it is floating, a GFI (ground fault interrupter) circuit is enabled which will shut down the high voltage if any earth ground current exceeding 0.5 mA is detected, protecting the operator through whom the current could be flowing. Note that this current would be independent of any trip setting for the DUT dielectric strength test—that is a differentially applied current, where as the GFI would respond to a common mode ground current.

Conclusion

Engineering and work practice controls should be the primary factor in safeguarding against the risk of injury. In order to provide for the highest level of protection safety controls should automatically be in place and not rely on the involvement of the operator. Likewise, personal protective equipment should not be the only, or even, primary means of protecting the operator. These types of safeguards are only effective when the operator utilizes them. ■

About The Author

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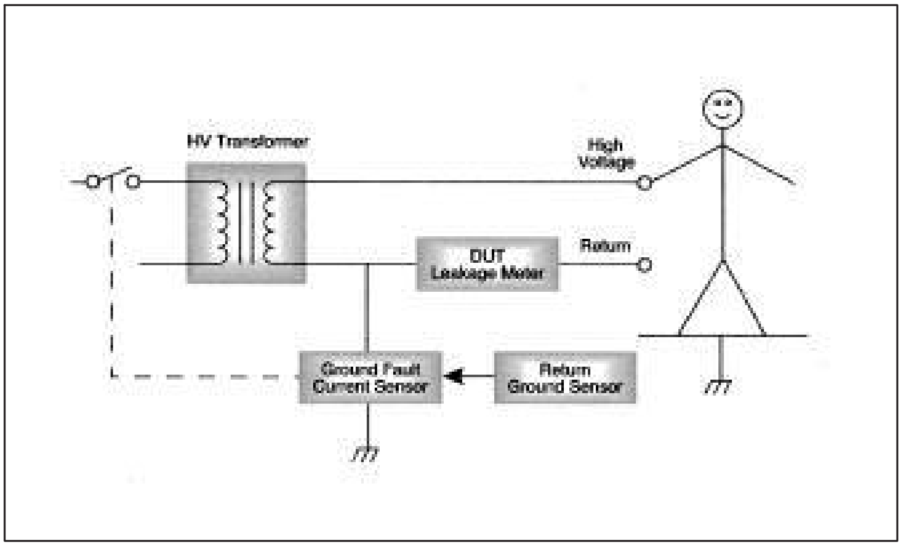

Figure 3: Adding a GFI to a production line dielectric strength test can provide additional protection to the worker. If current flows through the worker to ground, power is interrupted.