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Any work conducted near live electrical circuits poses its share of risk and electrical measurement jobs are no exception. In commercial and industrial settings today, electricians commonly work with circuits up to 600V. Though they are officially classed as "low voltage," these powerful circuits can deliver a deadly punch.

In addition to the danger of electrical shock, such circuits have enough power available to fuel an electric arc explosion, which can generate the searing heat called arc flash and the noise and pressure wave caused by the arc blast. When arc flash occurs, personal protective equipment is the only thing that can defend the electrician from horrific injury, pain and even death.

Voltage transient dangers

The presence of voltage kickback spikes, called transients, is a characteristic of electrical supply systems that creates important safety implications. When transients occur while a person is taking electrical measurements, they can lead to an arc explosion.

Transients are present in almost every electrical installation. In industrial settings they may be caused by the switching of inductive loads and by lightning strikes. While transients may last only sub-milliseconds, if they cause an arc flash, that installation could now suddenly carry tens of thousands of amps of energy. For anyone taking measurements on electrical equipment, the consequences can be devastating.

When such spikes occur while measurements are being made, they can cause a plasma arc to form — inside the measurement tool or in the air outside. The high fault current available in 480V and 600V systems can generate an extremely hazardous arc flash.

Understanding arc flash

How can such a problem develop? A transient of sufficient magnitude can cause an arc to form between conductors within an instrument or across test leads. Once an arc occurs, the total available fault current can feed the arc and cause an explosion.

The result is an arc flash, which can cause a plasma fireball fueled by the energy in the electrical system. Temperatures can reach about 3,000° C or 5,000° F, instantly burning or melting any non-retardant clothing and causing beyond third-degree burns. The arc can also cause a sonic and pressure wave capable of spraying a bystander with molten metal inducing further, deeper burns.

Transients are not the only source of arc-flash hazard. A very common misuse of hand-held multimeters can trigger a similar chain of events. If the multimeter user leaves the test leads in the amps input terminals and connects the meter leads across a voltage source, that user has just created a short through the meter. While the voltage terminals have a high impedance, the amps terminals have a very low impedance. This is why a meter's amps circuit must be protected with fuses.

Another common and dangerous misuse of test equipment is measuring ohms or continuity on a live circuit. These measurements should be made only on circuits that are not energized.

The National Fire Protection Association (NFPA) 70E Standard for Electrical Safety in the Workplace 2004 emphasizes that working on live parts is the last alternative. "OSHA [Occupational Safety and Health Administration] has said for a long time now that you couldn't work with stuff live unless there was some major compelling reason," said Joseph V. Sheehan, PE, NFPA chief engineer and staff liaison to the NFPA 70E committee. "It was never based on convenience. It was never based on economics. It was based on the fact that you would avoid a greater hazard if you shut it off. The simplest thing is to shut it off, lock it off: lockout-tagout. Nobody gets hurt, nobody needs PPE, have a nice day and everybody goes home for dinner."

But there are times, as both OSHA and 70E acknowledge, when working on live equipment is necessary. According to OSHA, equipment must be de-energized unless the employer can demonstrate that de-energizing introduces additional or increased hazards or is infeasible due to equipment design or operational limitations. Examples include circuit testing, as well as work on circuits that form an integral part of a continuous industrial process.[1]

"OSHA is the shall, and 70E is the how," said Palmer Hickman, director of safety, codes and standards for the National Joint Apprenticeship and Training Committee (NJATC). A joint program of the National Electrical Contractors Association (NECA) and the International Brotherhood of Electrical Workers (IBEW), the NJATC develops the courses used to train the majority of union electricians. "NFPA 70E steps in and says we have a solution," Sheehan added. "How to shut it off safely with a lockout-tagout program, and then if you have to work it live, how to dress, how to act, and what tools to use. It's really a very prescriptive standard that deals with a performance requirement."

PPE to the rescue

The primary purpose of personal protective gear is to protect you from arc flash burns. Standards organizations such as the American National Standards Institute (ANSI) and American Society for Testing and Materials (ASTM) have developed detailed requirements and specifications for such protective equipment as eye and hearing protection, insulated hand tools, insulated gloves and fire resistant clothing. NFPA Standard 70E provides the guidelines about when and where this approved safety equipment should be used. NEC (National Electrical Code) Article 110.16 further defines PPE. Also be aware of possible additional local government and country requirements.

What many people have only recently understood is that electrical test tools and equipment must also meet safety requirements. Standards for these tools are established by such organizations as ANSI, the Canadian Standards Association (CSA), and the International Electro-Technical Commission (IEC). Together they have created stringent standards for test equipment used in environments up to 1,000V.[2] According to the NFPA, "test instruments, equipment, and their accessories shall be designed for the circuits and equipment they'll be connected to, and the environment where they'll be used."[3]

Using the proper tools

ANSI, CSA and IEC define four measurement categories covering over-voltage transient impulses. The rule of thumb is that the closer the technician is working to the power source, the greater the danger and the higher the measurement category number. Lower category installations usually have greater impedance, which dampens transients and helps limit the fault current that can feed an arc.

Every time you need to make a live electrical measurement, start by determining which of the CAT levels below applies and then verify that all of your test and measurement equipment is rated for that level.

- CAT IV is associated with the origin of installation. This refers to power lines at the utility connection, but also includes any overhead and underground outside cable runs, since both may be affected by lightning.
- CAT III covers distribution level wiring. This includes 480V and 600V circuits such as three-phase bus and feeder circuits, motor control centers, load centers and distribution panels. Permanently installed loads are also classed as CAT III. CAT III includes large loads that can generate their own transients. At this level, the trend to using higher voltage levels in modern buildings has increased the potential hazards.
- CAT II covers the receptacle circuit level and plug-in loads.
- CAT I refers to protected electronic circuits.

Important note: CAT ratings on test tools are different than hazard/risk category ratings on PPE gear. CAT ratings are determined by the potential transient impulse in the workplace that a connected test tool might experience. PPE requirements are determined by the surface energy level a user might experience.

Safety gear categories

NFPA 70E covers safe work practices in Chapter 1, right up front. It also includes a formula to calculate the arc flash energy available and determine a "flash protection boundary" (calculations that must be performed by a professional engineer). Inside that boundary, flash protective PPE is required, and 70E includes tables that specify what gear is required to protect workers in five hazard/risk categories. Here's a summary of that information for live electrical measurement situations. In all cases, PPE selection depends on the work being performed and the electrical environment.

Hazard/Risk Category 1: < 240 V electrical environments. (110V/120V/208V/220V panels, 0 hp to 50 hp motors and drives):

- Flame-resistant (FR) long-sleeved shirt and/or jacket with sleeves rolled down and front fully buttoned up (FR clothing must fully cover all skin and ignitable clothing).
- Natural fiber work pants.
- Rubber insulating gloves with leather protectors worn over top.
- Safety glasses.
- Hard hat.
- Leather work boots.
- No jewelry, keys or watches.
- Insulated hand tools.

Hazard/Risk Category 2*: 240V to 600V electrical environments. (270/480/600V electrical panels, MCCs, switchgear, transformers, bus bars, UPS, and lighting; 100+ hp motors and drives):

- FR long sleeved shirt and/or jacket with sleeves rolled down and front fully buttoned up.
- FR work pants (not denims) or coveralls over natural fiber.
- Rubber insulating gloves with leather protectors worn over top.
- Leather work boots.
- Switching hood with hearing protection.
- No jewelry, keys or watches.
- Insulated hand tools.

Hazard/Risk Category 3: High voltage environments — 1,600A or higher. (Substations, utility transformers, big facility service entrances):

- Full flash suit (Jack, overalls and hood).
- Rubber insulating gloves with leather protectors worn over top.
- Leather work boots.
- No jewelry, keys or watches.
- Insulated hand tools.

Note: If test occurs in the proximity (within 4 feet) of an energized environment, then the PPE standards for the energized environment apply.

Note: Category 2* is a higher energy environment than Category 2. These guidelines only list PPE for Category 2*. For the specific distinction between 2 and 2*, reference NFPA (National Fire Protection Association) Standard 70E Tables 130.7 (c)(9)(a), (c)(10), (c)(11).

Electrical contractors and facility maintenance managers are taking electrical measurement safety seriously. If you haven't had electrical safety training, consider taking a course from industry and labor groups like NFPA, IEC, NECA, IBEW, from insurers, from manufacturers such as Salisbury and Fluke or from a host of private training contractors. Protect yourself from the hazardous conditions of arc flash and arc blast. Evaluate your environment, wear PPE, and select your electrical test tools carefully.

Footnotes

1. NFPA 70E "Standard for Electrical Safety in the Workplace", 2004 Edition, Chapter 1, Section 130.1.

2. The pertinent standards include ANSI S82.02, CSA 22.2-1010.1 and IEC 61010. These standards cover systems of 1000 volts or less, including 480 V and 600 V, three-phase circuits. These standards differentiate the transient hazard by location and potential for harm, as well as the voltage level.

3. NFPA 70E "Standard for Electrical Safety in the Workplace", 2004 Edition, Chapter 1, Section 110.9.

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In Brief

In commercial and industrial settings today, electricians commonly work with circuits up to 600V. Though they are officially classed as "low voltage," these powerful circuits can deliver a deadly punch.

Related Products: Personal protective equipment such as eye and hearing protection, insulated hand tools, insulated gloves, fire-resistant clothing, hard hats, leather work boots, full flash suit, rubber-insulated gloves with leather protectors.

Safety standards for measurement tools

Many older and cheaper electrical test and measurement tools just don't meet contemporary standards for insulation, impulse protection from transient voltage spikes and excessive voltage misuse (through internal design and proper fusing), and effective single fault protection.

- Beware of vintage tools — Old test instruments, while they may be perfectly accurate, may not meet today's safety requirements and should be replaced.
- Demand independent testing and certification — Some tools may not deliver the performance promised by the manufacturer. Measuring devices rated for a high-energy environment may not actually deliver the safety protections, such as adequate fusing, claimed on their specification sheets.

A meter designed to a standard may not have been actually tested and proven to meet that standard. It is not uncommon for meters under test to fail before achieving the performance their manufacturers claim for them.

To determine the safety rating for your test tool:

- Look for the 1,000V, CAT III or 600V, CAT IV rating on the front of meters and testers, and a "double insulated" symbol on the back.
- Look for approval symbols from two or more independent testing agencies, such as UL, CSA, CE or TUV.[1]
- Make sure that the amperage and voltage of meter fuses is correct. Fuse voltage must be as high or higher than the meter's voltage rating and able to support the full surge current of the maximum listed voltage in the voltage input terminals. The second edition of IEC/ANSI/CSA standards states that test equipment must perform properly in the presence of impulses on volts and amps measurement functions. Ohms and continuity functions are required to handle the full meter voltage rating without becoming a hazard.
- Check the instrument's manual to verify that the ohms and continuity circuit is protected to the same level as the voltage test circuit. If the manual does not include that information, your supplier should be able to determine whether the meter complies with IEC61010 2nd edition or ANSI S82.02.
- Check the overall condition of the meter or tester. Look for such problems as a broken case, worn test leads or a faded display.

[1]*For more information on these testing organizations, visit their websites: http://www.ul.com/ , http://www.csa.ca/Default.asp? language=English, http://www.tuvamerica.com/services/electrical.cfm*

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