

THE DANGERS OF ARC FLASH INCIDENTS

By Linda K. Fischer

The flash is instantaneous, almost too fast for the eye to comprehend. But the end result of this incident could be more than \$15 million in direct and indirect costs to a company.

So, companies cannot afford to ignore the safety issues surrounding arc flash explosions, as the Occupational Safety & Health Administration (OSHA) enforces new standards for employee safety protection in potential arc flash situations.

WHAT IS ARC FLASH?

An arc flash is a short circuit through the air, explained George Gregory, industry standards manager at Square D/Schneider Electric, Palatine, IL. When insulation or isolation between electrified conductors is breached or can no longer withstand the applied voltage, an arc flash occurs. As employees work on or near energized conductors or circuits, movement near or contact with the equipment, or a failure of the equipment, may cause a phase-to-ground and/or a phase-to-phase fault.

The temperature of an arc can reach more than 5000 F as it creates a brilliant flash of light and a loud noise. An enormous amount of concentrated radiant energy explodes outward from the electrical equipment, spreading hot gases, melting metal, causing death or severe radiation burns, and creating pressure waves that can damage hearing or brain function and a flash that can damage eyesight. The fast-moving pressure wave also can send loose material such as pieces of equipment, metal tools, and other objects flying, injuring anyone standing nearby.

Regulations require the calculation of the “flash protection boundary” inside which qualified workers must be protected when working. Gregory said this boundary is an imaginary sphere surrounding the potential arc point, “within which a person could receive a second-degree burn if an electrical arc flash were to occur,” according to the National Fire Protection Association (NFPA) 70E stan-



dard. This standard also defines incident energy as “the amount of energy impressed on a surface, a certain distance from the source, generated during an electrical arc event”. That surface could be a person.

Incident energy is expressed in calories per cubic centimeter squared (cal/cm²). The flash protection boundary

is the point at which the energy number is 1.2 cal/cm², equating to a second-degree burn. As workers get closer to the energized equipment, that energy figure rises. This boundary is different for different types of equipment and depends, in part, on the voltages involved. Typically, the higher the voltages, the larger the danger zone. A 10,000 A arc at 480 V is equiva-

lent to 8 MW or approximately eight sticks of dynamite, noted John Lane, electrical safety engineer at AVO Training Institute, Dallas, TX. The photograph shows a side view of an equipment rack during an arc flash explosion. (Photograph provided by Square D/Schneider Electric.)

MEDICAL COSTS HIGH

Between five and 10 times a day, an arc flash explosion occurs in electric equipment somewhere in the United States that sends a burn victim to a special burn center, according to statistics compiled by CapSchell, Inc., a Chicago-based research and consulting firm that specializes in preventing workplace injuries and deaths.

That number does not include cases sent to regular hospitals and clinics, or unreported cases and “near misses”, estimated to be many times that number. There are one or two deaths a day from these multi-trauma events, noted Dr. Mary Capelli-Schellpfeffer, principal investigator.

The costs of these incidents are staggering. According to a 1999 Electric Power Research Institute (EPRI) study cited by CapSchell, a utility company’s total spending estimate for electrical incidents over a two-year period was \$15.75 million per case when related indirect costs were considered along with the direct expenses.

One manufacturer, as reported by the Institute of Electrical and Electronics Engineers (IEEE), reported it has experienced an average of 2.2 arc flash injuries per year over the past 10 years.

DEVELOPMENT OF STANDARDS

Serious study of arc flash began in the early 1980s, with publication of an IEEE paper by Ralph Lee, a former consultant from DuPont. His work on blast burns convinced companies, especially in the petrochemical industry, to take steps to establish the first set of practices to protect employees working on electrical equipment.

Since then, work has evolved with OSHA, the NFPA, the IEEE, and other organizations to compile a set of regulations specifically to address arc flash (see accompanying section “Standards Relating to Arc Flash Incidents and Safety”).

Now companies must perform a hazard analysis to determine flash protection boundaries and appropriate protection for employees, and electrical equipment with potential for arc flash must be marked with a warning label. Companies must have electrical safety programs in place.

SAFETY PROGRAMS ARE KEY

OSHA, in enforcing worker safety procedures, cites the NFPA 70E guide as the “how to” source for compliance. One basic requirement is that an electrical safety program must be established for each facility with specific elements included. See accompanying section “Requirements for Safety Program Under NFPA 70E”.

The safest way to address maintenance and repair situations with electrical equipment is to work only when equipment is de-energized and verification has been made that de-energization has occurred. But with facilities operating 24/7 and systems often required to operate continuously, that is not always possible. So the safety program must stipulate procedures to address the hazards of working on energized equipment.

Proper protective equipment must be worn when any of

this work is conducted within the established flash protection boundary for that equipment.

The goal of an electrical safety program is to remove the worker from the danger zone or remove or eliminate the intensity of the arc flash. Thus, the plan should consider use of long-handled tools to put the worker further from the electrical circuit, infrared windows to allow inspection with cabinets and doors closed, remote racking, current-limiting circuit breakers, and other options.

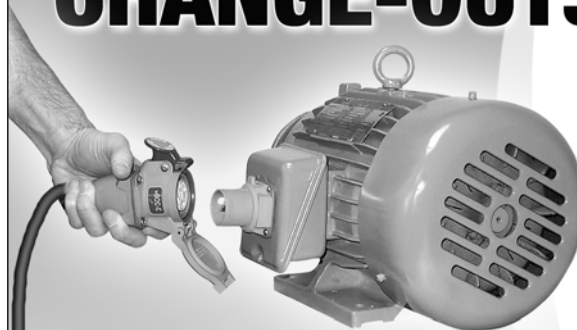
HAZARD ANALYSIS PROVIDES FACTS

But the specifics of the plan need to follow the completion of the hazard analysis; “you have to know the facts before you make decisions,” as Gregory put it. This analysis determines the flash protection boundary distance and the type of personal protective equipment (PPE) required for working in various situations.

IEEE 1584 standard establishes nine key steps in the analysis process:

- Collect system and installation data
- Determine system modes of operation
- Determine bolted fault current
- Find protective device characteristics and arc duration
- Document system voltages and equipment class
- Determine arc fault current
- Select the working distances
- Calculate the incident energy

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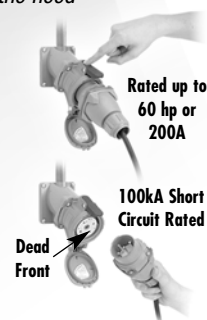
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- Calculate flash protection boundary

As Lane explained, an arc flash hazard analysis “starts with gathering up-to-date equipment information, then performing a detailed analysis comprised of a load-flow study, short circuit study, and protective device coordination study as well as an equipment evaluation to determine that the current withstand rating is acceptable. For facilities with generators and large motors (100 hp or larger), a motor starting and fault contribution analysis also should be performed.”



An arc flash test used a circuit adjusted to deliver 20,000 amperes at 480 V, 3 phase. The bright light is the arc developing (top left), indicating the energy in the arc that is radiating outward as heat. As the arc develops (top right), it melts and vaporizes the metal of the electrodes and the box. This vaporizing metal (bottom left) expands outward with the pressure wave, and the test stand is enveloped in the arc flash explosion (bottom right) as smoke and debris spread from the test stand. The duration of the arc was about 0.045 sec. The test was set up at the Square D High Power Lab in Cedar Rapids, IA.

At the end of this analysis procedure, companies will have incident energy calculations and arc flash boundaries for each location in their power systems. Warning labels and safety programs then can follow.

Regulations do not dictate any specific method of analysis. Tables and guidelines for a simple approach to calculating incident energy are available in NFPA 70E, although more detailed calculations are explained in IEEE 1584 as well as a number of shortcuts for low voltage circuit breakers.

There are also consulting services available to handle analysis as well as

published values from manufacturers and commercial software.

“The more accurate the analysis, the more likely that proper preventive measures can be taken,” Gregory said.

And incident energy figures can vary widely. Daniel R. Doan and Ronald A. Sweigart in an IEEE technical paper studied 33 plants with 4892 buses or switching points under 600 V. The median incident energy was 2.1 cal/cm², but that energy figure varied dramatically: 24 percent of buses were over 8 cal/cm², 10 percent over 50, 5 percent over 85, and 1 percent over 205. Employers cannot assume that similar equipment will have similar flash protection boundaries.

In those cases where incident energy is over the 40 cal/cm² that is considered safe for work with PPE, no work should be done with equipment energized; engineering or operating changes may be needed, noted Craig Wellman and Bruce McClung in an article “Performing Arc Flash Hazard Calculations” in *Electrical Contracting & Engineering News* magazine (March 2003). Wellman is an electrical consultant and project engineer with DuPont Co. and McClung is vice-chair of IEEE 1584 Working Group.

Engineering options, according to their article, might include replacing switchgear with arc resistant switchgear, adding a secondary main relay that can trip a primary circuit breaker, or changing fuses. Operating changes might include adding a provision for remote racking and remote operation, and changing the sequence of switching operations to reduce the time when exposure is high.

Accurate incident energy levels are vital in setting the level of PPE required for work inside the flash protection boundary. PPE categories range from 0 (untreated cotton clothing) to 4 (cotton underwear plus fire resistant shirt and pants plus double layer switching coat and pants).

COMPANIES ARE RELUCTANT

“Economics is constraining safety” in many companies, Dr. Capelli-Schellpfeffer said. In this global economy, other countries have lower safety standards and it is difficult to compete. “Arc flash is a low probability/high cost event. Therefore, it is difficult to argue for prevention dollars.”

Wellman stressed that there must be a “culture for safety” throughout the entire company. “Management must pro-

mote safety first all the time, and safety excellence must be everyone’s job.” He added, too, that companies “do not recognize (the arc flash) hazard to business and the potential costs of it.”

“Electrical workers are working on the basis of decisions made by others, for better or worse,” said Palmer Hickman, director of safety, training, and curriculum development of the National Joint Apprenticeship and Training Committee (NJATC). “A company should not expect to get work done energized.”

A comparison was made to police bomb squads. These specialized workers do not go into an “energized” situation without careful planning, proper protection, and training. Employees facing work on electrical equipment should be similarly prepared.

STANDARDS RELATING TO ARC FLASH INCIDENTS AND SAFETY

Four separate industry standards establish procedures for preventing arc flash incidents and ensuring employee safety:

OSHA 29 Code of Federal Regulations (CFR) Part 1910, Subpart S

This regulation states, in part, “Safety related work practices shall be employed to prevent electric shock or other injuries resulting from either direct or indirect electrical contacts....”

OSHA also addresses the qualification of workers exposed to electrical shock hazards and the provision for protective equipment appropriate for the work to be performed.

OSHA enforces safety practices and cites to the NFPA requirements.

NFPA 70-2002, NATIONAL ELECTRICAL CODE

Section 110.16 requires that companies place a warning label on equipment likely to cause arc flash conditions. This field marking can be generic or very specific, whichever the company selects. Future revisions of the NEC standard may require more detailed information on this label.

NFPA 70E-2000, STANDARD FOR ELECTRICAL SAFETY REQUIREMENTS FOR EMPLOYEE WORKPLACES

NFPA 70E can be considered the “how to” standard behind OSHA enforcement. It provides the detailed actions companies must take to be in fed-

NEC Code Changes

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ditch. Additionally, compression doesn't create heat build-up, eliminating the need for a special "hot" permit that is sometimes required.

Mechanical connections are inexpensive, readily available and easy to install, making them a reasonable solution to consider for some grounding applications, including attaching the pigtail to rebar — but not the extension of a pigtail that cannot reach the service loca-

tion.

CONNECT WITH ONE SOURCE

When specifying a grounding connection, it is helpful to seek out companies that offer all three methods of grounding. For example, certain applications require an exothermic method for one connection and a mechanical connection for another. Having a one-source supplier saves a considerable amount of time.

Also, companies that offer all three options can offer an unbiased opinion about which method best suits your ulti-

mate needs that extend beyond the job in question without strong-arming you into selecting an option that doesn't exactly fit.

The phrase change in Article 250.50 of the NEC code has made phrases like "grounding to rebar" a more prominent part of a contractor's vocabulary, but this change doesn't have to be grounds for great concern. Once the ramifications of the change are clear, half the battle is won. The rest of the solution can be narrowed down to simply making the right connections.

Arc Flash Safety

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eral compliance. Specifically:

- Safety program with defined responsibilities
- Calculations for the degree of arc flash hazard
- Personal protective equipment (PPE) for workers
- Training for workers
- Tools for safe work
- Warning labels on equipment

IEEE STANDARD 1584-2002, GUIDE FOR ARC FLASH HAZARD ANALYSIS

In order for the warning labels to carry enough information to show the danger zone for arc flash conditions, companies must determine that area within which only qualified workers should enter — the flash protection boundary. IEEE 1584 provides a method to calculate the incident energy in order to specify the level of PPE required for workers.

REQUIREMENTS FOR SAFETY PROGRAM UNDER NFPA 70E

OSHA and NFPA 70E require equipment be in an electrically safe work condition before employees work on or near it. Equipment, therefore, should be de-energized before any work is done. In some cases, however, work cannot be done on de-energized systems, such as in a hospital or a 24 hr continuous operation.

There are specific steps NFPA 70E dictates to ensure an electrically safe working condition exists:

- Determine all possible sources of supply
- Open disconnecting device(s) for each source
- Where possible, visually verify device is open
- Apply lockout/tagout devices
- Test voltage on each conductor to verify that it is de-energized
- Apply grounding devices where stored energy or induced voltage could exist or where de-energized conductors could contact live parts.

Establishing these safety procedures is part of the company safety plan that must be in effect for each facility:

- Employers must formalize procedures and practices such as the qualification of employees to work in hazardous areas,

tasks they may perform, steps needed to secure management approval for work to be done, and audits.

- Employers must provide training for employees in the skills and techniques needed to work with electrical equipment, equipment details, and emergency procedures.
- Employees must implement the practices according to the training.
- Companies must perform a flash hazard analysis before work is done on any energized equipment.

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