EATON | Cutler-Hammer

The Power Sheet

Consulting Engineer Edition

ARC FLASH

INTRODUCTION

In the past several years, new regulations are instituted to help protect personnel against the hazards of arc blasts. These hazards have always been with us but, with 5-10 people a day being hospitalized from arc blast injuries, the electrical industry finally is addressing electrical safety from arc flash incidents. In this issue of *The Power Sheet*, a summary of the standards and requirements are discussed, including the most recent revisions to the 2005 NEC.

ARC FLASH

In recent history, the dangers of arc flash was brought to the forefront by Ralph Lee, who in 1982 published a paper for the IEEE titled "The Other Electrical Hazard: Electric Arc Blast Burns". This IEEE paper made the case for protection of employees who work with energized equipment. Prior to this paper, electrical safety primarily addressed interrupting ratings, coordination, and proper installation procedures as outlined in the National Electrical Code (NEC).

What is an arc flash and how does it differ from a short circuit? An arc flash is uncontrolled electrical energy traveling through open air where a short circuit is uncontrolled electrical energy traveling through the electrical system (cables, distribution equipment). The arc flash consists of a high amount of radiant energy exploding outward from the electrical gear which creates a pressure wave. This high temperature pressure wave can damage hearing, damage eye sight, and severely burn skin. Further, the temperature of pressure waves can reach temperatures as high as 35,000 ºF.

Because metals within electrical gear melt and vaporize at approximately 2000 ºF, a catastrophic arc flash incident will spray metal droplets. During an arc blast, copper expands from solid to vapor at a rate of about 67,000 times, which approximately is the same expansion rate of dynamite.

ARC FLASH STANDARDS

Today there are four separate standards concerning prevention of arc flash.

OSHA 29 CFR 1910.132: Although OSHA does not directly state how to address arc flash hazards, they do require employers to evaluate the workplace for hazards and provide the proper personal protective equipment (PPE). Based on these assessments, the employer must select and require the use of proper for its employees. This standard also requires electrical safety training to qualify employees for servicing live electrical gear, an arc flash study to define the level of hazard, and signage on the electrical gear.

NFPA 70 (2005 National Electric Code): Article 110.16 spells out its requirements for signage on electrical equipment to warn workers of the existence of arc flash hazards. Figure 1 is the generic arc flash label provided with electrical gear. Below is the NEC code requirement.

"Switchboards, panelboards, industrial control panels, meter socket enclosures, and motor control centers in other than dwelling occupancies, that are likely to require examination, adjustment, servicing, or maintenance while energized, shall be field marked to warn qualified persons of potential electric arc flash hazards. The markings shall be located so as to be clearly visible to qualified persons before examination, adjustment, servicing, or maintenance of the equipment".

NFPA 70E—2004, Standard for Electrical Safety Requirements for Employee Workplaces: Article 130.3 of

continued from page 1

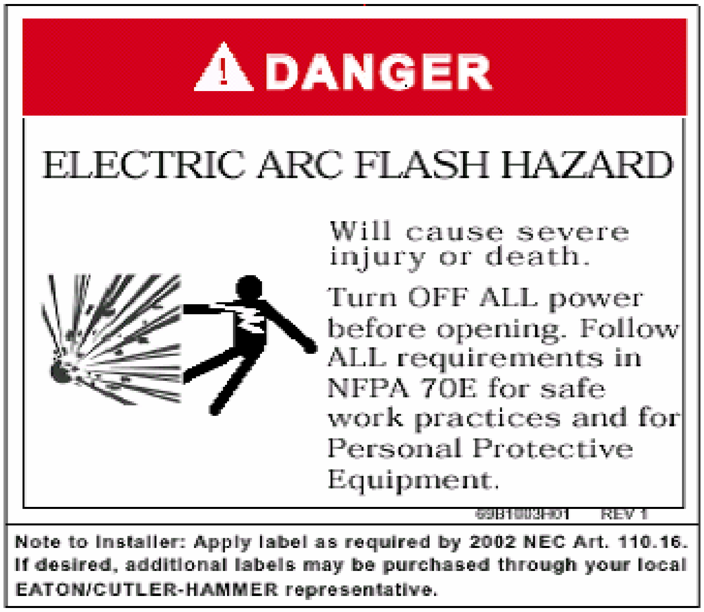

FIGURE 1 - Genaric Arc Flash Label

this standard states the following, "A flash hazard analysis shall be done in order to protect personnel from the possibility of being injured by an arc flash. The analysis shall determine the Flash Protection Boundary and the personal protective equipment that people within the Flash Protection Boundary shall use."

IEEE 1584-2002, Guide for Performing Arc Flash Calculations*:* This standards provides guidance for calculation of incident energy and arc flash protection boundaries; It presents formulas for numerically quantifying the values and the Guide also includes an Excel spreadsheet to perform the actual arc flash calculations.

COMPLIANCE

Beyond the signage required in the NEC, it is NFPA 70E that outlines worker safety requirements and is the standard OSHA sites to meet safety requirements. There are two basic requirements:

1. **Training for Qualification of Personnel -**

✓ Ability and skill level to deenergize equipment, determine nominal voltage, determine approach distances

✓ Ability and skill to determine hazard level, required PPE, and safety plan

✓ Proper PPE training

2. **Arc Flash Warning label on all equipment -** (to include the below information)

✓ Level of arc flash hazard – in Calories per cm² as determined in arc flash study

✓ PPE required when working on the energized equipment

✓ Define approach boundaries

BOUNDARY DEFINITIONS

An analysis, based on the ark flash available energy, defines the boundaries beyond where workers are not allowed to cross without proper qualifications and PPE. The four boundaries address in NFPA 70E are defined below and shown in Figure 2.

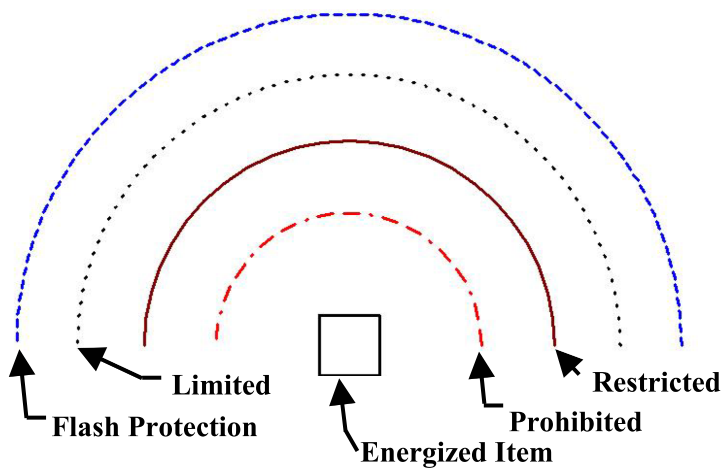

FIGURE 2 - Boundary Definitions

Flash boundary - Unqualified persons are not allowed beyond this point. At this point a worker's injuries would be limited to second degree burns if electrical flash occurred and they did not have PPE.

Limited Approach Boundary - Qualified persons are allowed to this point without PPE. A Shock hazard exists.

Restricted Approach Boundary - Qualified persons with

continued from page 2

PPE and risk assessment are allowed to this point. There is increased risk of arc flash and shock due to inadvertent movement.

Prohibited Approach Boundary - Only qualified person with PPE and risk assessment who is performing work. Work is considered same as contact with live parts.

NFPA 70E provides detailed calculation methods and a simplified table for application of the boundaries.

ARC FLASH CALCULATIONS and PROTECTION

The hazard analysis sited in NFPA 70E requires calculations of the **incident energy** available at a given location. This energy is calculated in cal/cm² and, based on amount of energy available, a risk category is assigned, and based on that risk category, certain levels of PPE are required. These risk categories are designed to limit worker injuries to second degree burns which occur at energy levels of 1.2 cal/cm².

The calculations have two components: magnitude fault current and duration of the fault. The specifics of the formulas are beyond the scope of this newsletter, but several factors included in the calculations need understanding. The conventional thinking is that faster clearing times significantly reduce the incident arc flash energy. This is true!

However, an equivalent bolted fault incident is extremely rare, at less than .01% of all fault conditions. Because both fuses and circuit breakers are inverse time versus current (meaning, the higher the current flow the faster the protective device will open), the far more common faults have less current than the "worse case" arc flash current incident. In these far more common, low current fault incidents, the time/current curves of a *breaker can actually open faster* than a current limiting fuse. Further, the time/current characteristics of a breaker can be adjusted and changed to account for arc flash hazards where a fuse cannot.

Figure 3 show the time/current curve for a typical circuit breaker. Note the clearing time of less that .07 seconds at 120 Amps and the increase of incident energy as the fault magnitude drops. This occurs because the clearing time increases. Also, the breaker clearing time is adjustable at lower level fault currents.

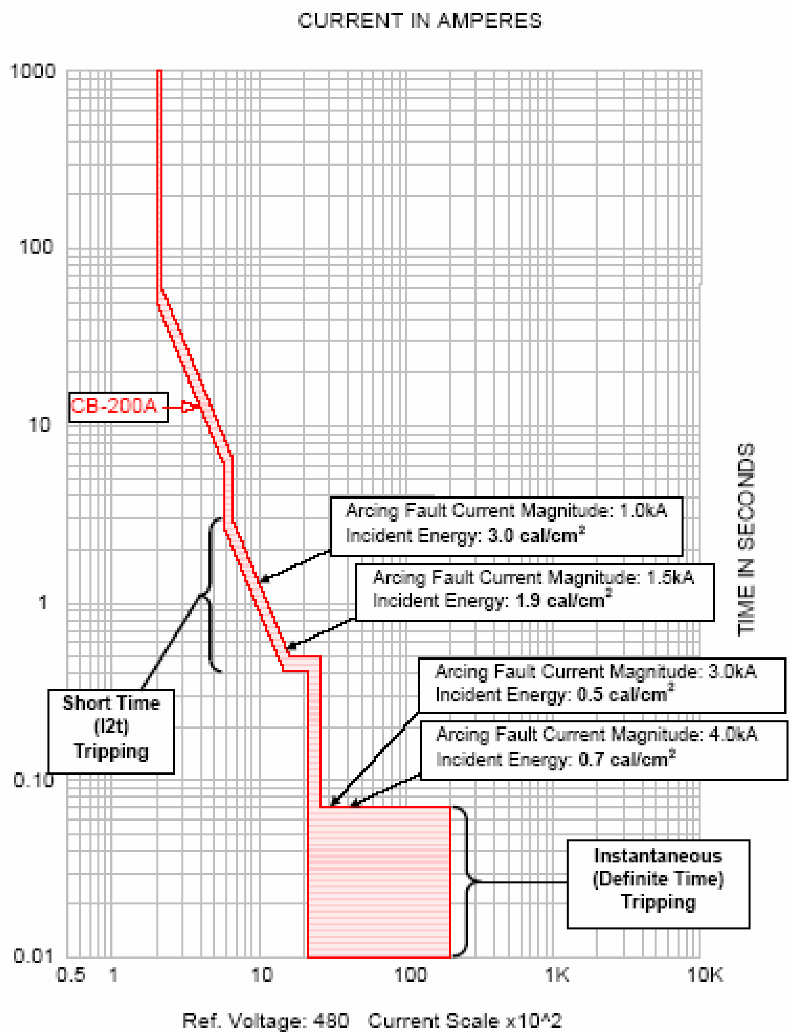

FIGURE 3 - Example Incident Energy Values

DESIGN CONSIDERATIONS

To better understand how we can design systems to limit arc flash hazards, there are a couple of concepts that are important to consider. First, arcing currents are always less in magnitude then their corresponding short circuit (bolted fault) magnitudes. IEEE has established a formula for calculating arcing faults but typical arcing faults for a 480 volt system range from about 40% to 60% of the available fault current.

Second, higher fault currents do not necessarily mean higher levels of incident energy. Clearing time of the fault

continued from page 3

plays a large part in determining the hazard level, and to know the clearing time it is important to accurately calculate the arcing fault currents. The following curve illustrates this point by showing the incident energy at different points on the trip curve of a molded case circuit breaker.

The incident energy released is actually higher when arcing current is at 1500 amps and breaker trips in short time mode, then when the arcing current is above 4000 amps and breaker trips instantaneously.

We can see that limiting fault current is only part of the answer to minimize arc flash dangers. To maximize worker protection we need to clear faults in shortest duration possible, and when feasible, move the worker away from the danger area.

WHAT to SPECIFY

With improving technologies and better understanding of arcing currents, the design engineer has many choices that can help maximize worker safety. The system requirements and customer needs have to be evaluated and balanced to create a practical, safe and reliable electrical system.

Following are a few techniques and products that are available to help accomplish this task. This is by no means a comprehensive list but, hopefully it provides a basis to start thinking about this issue.

High Resistance Grounding - Resistor at neutral of transformer limits fault current downstream to acceptable levels. This system greatly reduces fault current but may require secondary circuit for loads that require neutral.

Maintenance Switches - Allows remote switching to a lower protective settings while the servicing of live equipment is performed. This lowers arc danger to lowest point that protective devices will allow, but a hazard analysis is still needed to determine risk category. Coordination of protective devices is lost while in maintenance mode. Eaton offers a switch that can be retrofitted onto existing breakers that have Digitrip style trip units.

Zone Selective Interlocking - Through use of communicating trip units, this allows coordination of upstream and downstream breakers when both are equipped with instantaneous fault protection. This method still requires hazard analysis to determine risk category and is more costly and complicated to setup and maintain. Also, because of communication processing, the clearing time of fault is not as quick as maintenance switch.

Remote Racking Devices - Workers can rack circuit breakers into and out of their respective cell from safe working distance. Obviously, this works only with draw-out breakers and there are limitations which equipment draw-out breakers are available. Typically remote racking devices are used on medium voltage gear

Specify Arc Hazard Study - By specifying an arc flash study performed during construction phase, the burden is placed on contractor, and the owner receives system with extra level of safety. The owner needs to be aware that results of study will change over time as system is upgraded and electrical services change. The Eaton Service group has developed a large experience base by performing hundreds of these studies over the last couple of years.