Commonwealth of Massachusetts
Arc Flash

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Agenda

- Introductions
- Grainger
- Brady
- NFPA 70E 2015
- Arc Flash Assessment
- Components of Arc Flash Assessment
- Common mistakes in an Arc Flash program
- Proposed NFPA 70E 2018
Supporting the Commonwealth of Massachusetts

- Statewide contract holder FAC94 - MRO
- Stateside contract holder HSP41 – Lab Supplies
- More than 1 million products
- Inventory Management Solutions
- Grainger.com and CommBuys
- Branches
- Technical Support
2015 NFPA 70E

2012
- Electrical hazard analysis
- Shock hazard analysis
- Hazard identification and risk assessment

ARC FLASH HAZARD ANALYSIS

2015
- Electrical hazard risk assessment
- Shock risk assessment
- Risk assessment

ARC FLASH RISK ASSESSMENT
Risk Assessment - “An overall process that identifies hazards, estimates the potential severity of injury or damage to health, estimates the likelihood of occurrence of injury or damage to health, and determines if protective measures are required.”
What is required? NFPA 70E 2015

- Arc Flash Risk Assessment to determine if there is an Arc Flash Hazard
- If there is a hazard, employers must determine the risk to employees, safe work practices and levels of personal protective equipment (PPE)
  - OSHA General Duty Clause
What Requires a Label?

- SWITCHBOARDS
- DISCONNECT SWITCHES
- PANEL BOARDS
- PRODUCTION LINE EQUIPMENT CABINET
- INDUSTRIAL CONTROL PANELS
- MOTOR CONTROL CENTERS

AND MORE!
Methods for Performing Your Arc Flash Risk Assessment

Incident Energy Analysis (IEEE)

IEEE 1584 provides details on the theory and calculations used to determine the danger a worker could be exposed to.

Specific to the actual installation and represents all tasks.

PPE Categories (NFPA)

Categorizes tasks and equipment condition to indicate if PPE is required.

If required, the PPE category (1 through 4) is then determined based on equipment type, voltage, short-circuit current, and fault clearing time.

<table>
<thead>
<tr>
<th>Task</th>
<th>Equipment Condition*</th>
<th>Arc Flash PPE Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reading a panel meter while operating a meter switch</td>
<td>Any</td>
<td>No</td>
</tr>
</tbody>
</table>
| Normal operation of a circuit breaker (CB), switch, contactor or starter | All of the following:  
The equipment is properly installed  
The equipment is properly maintained  
All equipment doors are closed and secured  
All equipment covers are in place and secured  
There is no evidence of impending failure | No                     |
| One or more of the following:  
The equipment is not properly installed  
The equipment is not properly maintained  
Equipment doors are open or not secured  
There is evidence of impending failure | Yes                      |
## Comparing the Two – Short Circuit Study

<table>
<thead>
<tr>
<th>IEEE</th>
<th>NFPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Establishes the calculated short-circuit current which allow the calculation of specific incident energy levels</td>
<td>• Often applied without knowing the short circuit</td>
</tr>
<tr>
<td></td>
<td>• Assume short circuit current is within NFPA limits</td>
</tr>
</tbody>
</table>

**Panelboards or other equipment rated >240 V and up to 600 V**

Parameters: Maximum of 25 kA short-circuit current available; maximum of 0.03 sec (2 cycles) fault clearing time; working distance 455 mm (18 in.)

Assuming short circuit current may leave worker over or under protected
Comparing the Two – Equipment Evaluation

**IEEE**
- Short Circuit Study = Identify equipment that is insufficient to withstand ratings
- Specific Incident Energy = Arc flash risk level reduction strategies

**NFPA**
- This method does not calculate short-circuit study
Comparing the Two – Overcurrent Protective Device Coordination Study

**IEEE**
- Looks at specific overcurrent protective device characteristics and arc flash duration
- Allows for overcurrent protective device coordination study

**NFPA**
- Does not take into account overcurrent device settings
- Assumes fault clearing times

- Assuming fault clearing times may leave worker over or under protected
- Improper coordination can lead to higher arc flash energy or nuisance tripping
Comparing the Two

**IEEE**
- Requires complete electrical system data collection
- Results in the creation of an updated single line diagram

**NFPA**
- Looks at pieces of equipment individually

### Table 130.7(C)(15)(A)(b) Arc-Flash Hazard PPE Categories for Alternating Current (ac) Systems

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Arc Flash PPE Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panelboards or other equipment rated 240 V and below</td>
<td>1</td>
</tr>
<tr>
<td>Parameters: Maximum of 25 kA short-circuit current available; maximum of 0.03 sec (2 cycles) fault clearing time; working distance 455 mm (18 in.)</td>
<td></td>
</tr>
</tbody>
</table>
Conclusion – Recommendation on Method

Overall the best practice option = the incident energy analysis method

• Based on actual electrical distribution system based from data collection

• Deliverables should include all the input data and calculations results (record keeping), as well as an updated SLD for your facility.

• Employees are accurately protected
What Should Be Included in an Arc Flash Risk Assessment?

- Data Collection
- Power System Modeling
- Fault Current Study
- Equipment Evaluation
- Coordination Study
- Arc Flash Calculations
- General Observations
- Report and Documentation
- Label Creation and Installation
Data Collection

- Typically is about 53% of total project time and spent on site.
- Requires Field engineer to put on his PPE, open panels, control cabinets, disconnects, etc (anything that needs to get labeled)...and collects data.
- They are looking at breakers and fuses (manufacturer, type, ratings, settings), as well as wire size and wire length.
- This data is used to build the system model
Process

Power System Modeling

- This where a third party software would be used to take all the data we collected and draw a single line diagram.
- The single line drawing is "smart" and contains inputs for the data we collected. On paper it just looks like a schematic diagram, but it's a living/breathing model.
Process  Power System Modeling
Fault Current Study

• Performed to determine the maximum current that could flow through an electrical distribution system after a “fault” or abnormal condition occurs. i.e. panels switches…

• The available fault current at each point in the system is one of the main factors that drives the arc flash potential.

• The results of the fault current study are used in the arc flash calculations.

Process
## Process Fault Current Study

<table>
<thead>
<tr>
<th>BUS NAME</th>
<th>VOLTAGE L-L</th>
<th>AVAILABLE 3 PHASE</th>
<th>FAULT CURRENT X/R LINE/GND</th>
<th>X/R</th>
</tr>
</thead>
<tbody>
<tr>
<td>BUS-CF1</td>
<td>480.</td>
<td>3999.0</td>
<td>3327.88</td>
<td>0.4</td>
</tr>
<tr>
<td>BUS-H1</td>
<td>480.</td>
<td>24862.6</td>
<td>27405.06</td>
<td>4.6</td>
</tr>
<tr>
<td>BUS-P1</td>
<td>208.</td>
<td>2909.6</td>
<td>2826.06</td>
<td>0.7</td>
</tr>
<tr>
<td>BUS-PNL-DP</td>
<td>480.</td>
<td>24974.5</td>
<td>27608.99</td>
<td>4.8</td>
</tr>
<tr>
<td>BUS-PZ</td>
<td>480.</td>
<td>3744.7</td>
<td>3035.63</td>
<td>0.4</td>
</tr>
<tr>
<td>BUS-SL1</td>
<td>480.</td>
<td>21819.3</td>
<td>22327.57</td>
<td>2.7</td>
</tr>
<tr>
<td>BUS-SWBD-A</td>
<td>480.</td>
<td>25825.9</td>
<td>29250.39</td>
<td>5.7</td>
</tr>
<tr>
<td>BUS-SWBD-B</td>
<td>480.</td>
<td>25919.2</td>
<td>29435.20</td>
<td>5.9</td>
</tr>
<tr>
<td>BUS-SWBD-C</td>
<td>480.</td>
<td>25796.5</td>
<td>29191.23</td>
<td>5.6</td>
</tr>
<tr>
<td>BUS-SWGR-A</td>
<td>480.</td>
<td>25989.1</td>
<td>29573.57</td>
<td>5.9</td>
</tr>
<tr>
<td>BUS-SWGR-B</td>
<td>480.</td>
<td>26056.8</td>
<td>29707.62</td>
<td>6.0</td>
</tr>
<tr>
<td>BUS-UTIL</td>
<td>480.</td>
<td>26984.0</td>
<td>31580.42</td>
<td>7.4</td>
</tr>
<tr>
<td>VFD 1</td>
<td>480.</td>
<td>25196.8</td>
<td>28075.34</td>
<td>4.6</td>
</tr>
<tr>
<td>VFD 2</td>
<td>480.</td>
<td>25287.2</td>
<td>28250.05</td>
<td>4.7</td>
</tr>
<tr>
<td>VFD 3</td>
<td>480.</td>
<td>25017.9</td>
<td>27740.10</td>
<td>4.8</td>
</tr>
<tr>
<td>VFD 4</td>
<td>480.</td>
<td>25106.8</td>
<td>27909.79</td>
<td>4.9</td>
</tr>
<tr>
<td>VFD 5</td>
<td>480.</td>
<td>24989.2</td>
<td>27684.05</td>
<td>4.7</td>
</tr>
<tr>
<td>VFD 6</td>
<td>480.</td>
<td>24989.2</td>
<td>27684.05</td>
<td>4.7</td>
</tr>
<tr>
<td>VFD 7</td>
<td>480.</td>
<td>25017.9</td>
<td>27740.10</td>
<td>4.8</td>
</tr>
<tr>
<td>VFD 8</td>
<td>480.</td>
<td>25106.8</td>
<td>27909.79</td>
<td>4.9</td>
</tr>
</tbody>
</table>
Process

Equipment Evaluation

- Compares the results of our fault current study to the actual ratings of the equipment (we gathered the actual ratings during data collection) and then let the owner know if we find any insufficient ratings.
- Every circuit breaker and fuse has an interrupting rating or a withstand rating.
- Basically, they are manufactured in such a way that if a fault occurs, the breaker should trip or the fuse should "blow" safely.
- When an electrical system is designed, the engineers do a fault current study and specify fuses/breakers with the appropriate interrupting ratings so things trip and "blow".
- If a breaker or fuse is rated improperly, then instead of tripping the breaker sees a fault current greater than what it's rated, it could fail catastrophically.
What can happen if Device fails Catastrophically?

•.
Process Equipment Evaluation

<table>
<thead>
<tr>
<th>Bus Name</th>
<th>Lowest Rated Device</th>
<th>Device Description</th>
<th>Interrupting Capacity</th>
<th>Fault Current Available</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel 1</td>
<td>20/3</td>
<td>Manufacturer / Type</td>
<td>14kA</td>
<td>9.99kA</td>
<td>(1)</td>
</tr>
<tr>
<td>Panel 2</td>
<td>30/3</td>
<td>Manufacturer / Type</td>
<td>14kA</td>
<td>9.99kA</td>
<td>(2)(3)</td>
</tr>
<tr>
<td>Panel 3</td>
<td>20/3</td>
<td>Manufacturer / Type</td>
<td>14kA</td>
<td>9.99kA</td>
<td>(1)(3)</td>
</tr>
</tbody>
</table>

Note (1):

The type 1 breakers found in this panel are not adequately rated for the potential fault current levels as calculated based on a fully rated system. A fully rated system is one in which all of the overcurrent protective devices have an individual interrupting rating equal to or greater than the available fault current at the line terminals. However, NEC Article 240.86 allows for fuses or circuit breakers to protect downstream circuit breakers where the available short-circuit current exceeds the downstream circuit breaker’s interrupting rating. This is referred to as a series rated combination. In order to be allowed by code, the series rated combinations shall be tested, listed and marked for use with specific panelboards and switchboards. Per manufacturer Information Manual 1C96944H02, the series equipment rating is 35kA due to the type FD main device, which results in the branch breaker being considered as having an adequate interrupting capacity.

Note (2):

The type 2 breakers found in this panel are not adequately rated for the potential fault current levels as calculated based on a fully rated system. A fully rated system is one in which all of the overcurrent protective devices have an individual interrupting rating equal to or greater than the available fault current at the line terminals. However, NEC Article 240.86 allows for fuses or circuit breakers to protect downstream circuit breakers where the available short-circuit current exceeds the downstream circuit breaker’s interrupting rating. This is referred to as a series rated combination. In order to be allowed by code, the series rated combinations shall be tested, listed and marked for use with specific panelboards and switchboards. Per manufacturer Information Manual 1C96944H02, the series equipment rating is 22kA due to the type KD main device, which results in the branch breaker being considered as having an adequate interrupting capacity.

Note (3):

According to NEC Article 240.86(C), “Series ratings shall not be used where motors are connected on the load side of the higher rated overcurrent device and on the line side of the lower-rated overcurrent device,
Process

Coordination Study

• Looks at the trip curves of overcurrent protective devices to make sure they don't overlap, and to ensure the breaker settings are correct.

• If there's an issue, you want 1 breaker to trip. We look at breakers and settings and let clients know if there are issues and make recommendations to fix them if possible.

Coordination Study Results:
During the field survey of the BSC1 facility, it was found that only 1 circuit breaker had adjustable trip settings. The SKM TCC plot containing the 400 ampere main circuit breaker for panel HB can be found in Appendix C. This plot depicts the circuit breaker settings as per the existing conditions.

Coordination Study Recommendations:
Recommendations:
1. The TCC plot shows that there is an overlap between the 400A/3-pole main circuit breaker in panel 2 and the 1500A fuses located in the service disconnect. By adjusting the instantaneous trip setting of the 400A/3-pole main circuit breaker in panel 2, the overall incident energy can be reduced and system coordination for this series can be maintained. Brady recommends that the instantaneous trip setting be adjusted to a value of 5.
Process
Coordination Study
Process

Arc Flash Calculations

- The software takes the results of the calculations already performed and applies them to the arc flash calculations.
- The software will generate a table with all the calculation results.
- These tables are used to create labels for application according to NFPA 70E
Process

General Observations
• During the walk through of the facility any obvious code or safety issues should be noted.
• Really common example would be panel clearance issues.
Process
Report and Documentation

Brady Safety Client 1
Arc Flash Risk Assessment Report

* This is a sample report
Process

Labels are printed and placed

• Labels are placed in a location that is clearly visible to qualified persons before they begin work.
• The key point is that the label should be easily noticeable by workers before they may be exposed to any potentially dangerous live parts.

... 

NFPA 70E \(\rightarrow\) 130.5(D) Equipment Labeling. Electrical equipment such as switchboards, panelboards, industrial control panels, meter socket enclosures, and motor control centers that are in other than dwelling units and that are likely to require examination, adjustment, servicing, or maintenance while energized shall be field-marked with a label containing all the following information:

110.4 (A)(1) Only qualified persons shall perform tasks such as testing, troubleshooting, and voltage measuring within the limited approach boundary of energized electrical conductors or circuit parts operating at 50 volts or more or where an electrical hazard exists.
130.2 (A)(3) Energized electrical conductors and circuit parts that operate at less than 50 volts shall not be required to be de-energized where the capacity of the source and any overcurrent protection between the energy source and the worker are considered and it is determined that there will be no increased exposure to electrical burns or to explosion due to electric arcs.
130.4 (D) No qualified person shall approach or take any conductive object closer to exposed energized electrical conductors or circuit parts operating at 50 volts or more than the restricted approach boundary set forth in Table 130.4(D)(a) and Table 130.4(D)(b)
Label Format

Arc Flash Boundaries

- **Exposed Conductor, or Circuit**
- **RESTRICTED Approach Boundary** (distance at which there is increased danger of shock)
- **LIMITED Approach Boundary** (distance at which employees could be exposed to a shock hazard)
- **ARC FLASH Boundary** (furthest established boundary from the energy source where heat generated could result in burns)

### WARNING
Arc Flash and Shock Hazard
Appropriate PPE Required

<table>
<thead>
<tr>
<th>FLASH PROTECTION</th>
<th>SHOCK PROTECTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incident Energy at:</td>
<td>Shock Risk When Cover is Removed</td>
</tr>
<tr>
<td>18 in</td>
<td>480 VAC</td>
</tr>
<tr>
<td>Min. Arc Rating:</td>
<td>Limited Approach</td>
</tr>
<tr>
<td>0.45 cal/cm²</td>
<td>42 in</td>
</tr>
<tr>
<td>Arc Flash Boundary:</td>
<td>Restricted Approach</td>
</tr>
<tr>
<td>10 in</td>
<td>12 in</td>
</tr>
<tr>
<td>Glove Class:</td>
<td></td>
</tr>
<tr>
<td>00</td>
<td></td>
</tr>
</tbody>
</table>

PPE:
- **Shirt & pants or coverall**: Nonmetallic (ASTM F1506) or Unfilamented Fiber + hard hat + safety glasses + hearing protection

The label cannot be handwritten.
Per the National Electric Code (NEC) aka NFPA 70 - Article 110.24(B)(32)

**SHOCK HAZARD APPROACH BOUNDARIES**

VOLTAGE
Who Should Perform Your Arc Flash Risk Assessment?

To PE or not to PE, that is the question…

- The person doing the study must be “qualified”
  - Performed similar studies in the past
  - Has received training to become a “qualified” person capable of working on exposed/energized circuits
  - Thorough understanding of electrical distributions systems, both design and installation
Arc Flash Program Common Mistakes

• Label calculations being entered incorrectly 100 inches becomes 100 feet on label.
• Labels put on the wrong panels
• Arc Flash Assessment not being reviewed every 5 years
• Employee Training
• Using the NFPA Table vs. the IEEE analysis
• Not including Arc Flash in your change management system
• Not having Arc Flash Approved fall protection
Arc Flash Program Common Mistakes

- Assuming a piece of equipment fed from a panel with a classification of Zero will also have a classification of Zero
- Not taking into account your maximum fault current available
- Arc Flash Assessment does not cover Bus below 240 Volts
Arc Flash Program Analysis

- Evaluation of: current arc flash labeling,
- Accuracy of previous arc flash hazard assessment input data
- Electrical equipment condition
- Personal protective equipment (PPE)
- Review of electrical safety documents to verify that the principles and procedures of the electrical safety program are in compliance with NFPA 70E
- Limited interviews with electrical workers regarding field work procedures and training
Proposed Changes to NFPA70E 2018

• The layout of Article 120 Establishing an Electrically Safe Work Condition would be reorganized to better address the logical sequence of events. LO moved to first section and verification to the last section.

• A second change is to place further emphasis on the risk assessment and put the hierarchy of controls into mandatory language. PPE is last method of control.

• The third changes clarifies how the standard should have always been used when justified energized work is to be conducted. The change is that Table 130.7(C)(15)(A)(a) [that many call the task table] has become a new table applicable to both the PPE category method or the incident energy analysis method. It no longer determines whether PPE is required but whether or not there is a likelihood of an arc flash occurrence. The user conducts a risk assessment and determines the protection scheme to be employed to protect the worker using the hierarchy of controls (same as in the past editions).

• The equipment must still meet the applicable standards but the verification process has been changed to one of a conformity assessment where the PPE manufacturer should be able to provide assurance that the applicable standard has been met by one of three methods. Current does not require verification.