Arc Flash Hazard Calculations – What does it all mean?

Robert E. Fuhr, P.E.
PowerStudies, Inc.
Why are Arc Flash Hazard Studies Needed?

- To Increase Electrical Safety at your facility!
- Required by National Electric Code (NEC) and OSHA
- To Protect You!
2000 HELMET
Highest Ballistic Integrity in the World. Tested and Defeated Fragments Over 2000 FPS

VISOR
705 M/S 2315 FPS

FRONT
VO (No Penetration)
1667 M/S 5471 FPS (Includes Chest/Groin Plates)

ARMS
563 M/S 1850 FPS

LEGS
563 M/S 1850 FPS
OSHA Requirements

- Standard 29 CFR 1910 Subpart S, 1910 to 1910.335
- Must **identify** all hazards above 50 Volts
- Must put **safeguards** in place for these hazards
- Must **train** employees on safe work practices
- OSHA will fine you if you do not use NFPA 70E and there is an injury investigation.
Employers must provide workers with appropriate PPE as per the OSHA 29 1910.132 (h)(1) PPE payment requirement, i.e., (PPE) used to comply with this part, shall be provided by the employer at no cost to employees. Paragraph (h) became effective February 13, 2008, and employers must implement the PPE payment requirements no later than May 15, 2008.
110.16(A) General - Electrical equipment, such as switchboards, switchgear, panelboards, industrial control panels, meter socket enclosures, and motor control centers, that is in other than dwelling units, and is likely to require examination, adjustment, servicing, or maintenance while energized,
NEC 110.16 (continued)

shall be field or factory marked to warn qualified persons of potential electric arc flash hazards.
NEC 110.16 (continued)

The marking shall meet the requirements in 110.21(B) and shall be located so as to be clearly visible to qualified persons before examination, adjustment, servicing, or maintenance of the equipment.
(B) - In other than dwelling units, in addition to the requirements in (A), a permanent label shall be field or factory applied to service equipment rated 1200 amps or more. The label shall meet the requirements of 110.21(B) and contain the following information:
NEC 110.16 (continued)

(1) Nominal system voltage
(2) Available fault current at the service overcurrent protective devices
(3) The clearing time of service overcurrent protective devices based on the available fault current at the service
(4) The date the label was applied

Exception: Service equipment labeling shall not be required if an arc flash label is applied in accordance with acceptable industry practice.
NEC 110.16 (continued)

Informational Notes No. 1 & 3 Point to NFPA-70E for guidance as to how to determine the values & information to put on the labels.
130.5(A) General. An arc flash risk assessment shall be performed:
- (1) To identify arc flash hazards
- (2) To estimate the likelihood of occurrence of injury or damage to health and the potential severity of injury or damage to health
- (3) To determine if additional protective measures are required, including the use of PPE
130.5(F) Arc Flash PPE. One of the following methods shall be used for the selection of arc flash PPE:

- (1) The incident energy analysis method in accordance with 130.5(G)
- (2) The arc flash PPE category method in accordance with 130.7(C)(15)*

* - Use with extreme caution!!!
NFPA Approach to Electrical Safety

How to...

BUILD it safely

WORK on it safely

Upgrade/replace latest NEC applies

Maintain/repair latest 70E applies

MAINTAIN it properly
Arc Flash Hazard Analysis Key Steps

- Use NFPA 70E* Tables, IEEE 1584, Arc Pro, or Lee Equations to Determine
  - Incident energy levels
  - Arc Flash hazard boundary

* Use with extreme caution!
Arc Flash Hazard Analysis Key Steps

- **Use**
  - Calculated Incident Energy
  - NFPA 70E Table 130.5(G)
  - to determine

- **Required PPE**
**130.5(H) 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 marked with a label containing all the following information:
Start here.

Robert E Fuhr, 3/22/2018
NFPA 70E – Arc Flash Labeling

(1) Nominal system voltage
(2) Arc flash boundary
(3) At least one of the following:
   a. Available incident energy and the corresponding working distance, or the arc flash PPE category in Table 130.7(C)(15)(a) or Table 130.7(C)(15)(b) for the equipment, but not both.
   b. Minimum arc rating of clothing
   c. Site-specific level of PPE
NFPA 70E – Arc Flash Labeling

- The data shall be reviewed for accuracy at intervals not to exceed 5 years.
  - (Arc Flash Refresher Study)
- The owner of the electrical equipment shall be responsible for the documentation, installation, and maintenance of the marked label.
WARNING

Arc Flash and Shock Hazard

11 Ft 5 In  Flash Hazard Boundary
33.0  cal/cm² Flash Hazard at 1 Ft 6 In
Arc Rated Clothing Required (See NFPA 70E-2018 Table 130.5(G) for additional PPE)
208 VAC  Shock Hazard when cover is removed
00  Glove Class
3 Ft 6 In  Limited Approach (Fixed Circuit)
1 Ft 0 In  Restricted Approach

11/15/2018  IEEE 1584-2018 & NFPA 70E-2018
Equipment: SWBD MSB2
Device: MSB2MAIN

Scenario 2 - 50% UTILITY  Max Fault Current: 20.0 kA
Study Performed By PowerStudies, Inc. (253) 639-8535
Informative Label

DANGER

Arc Flash and Shock Hazard

14 Ft 1 In  Flash Hazard Boundary
47.0   cal/cm² Flash Hazard at 1 Ft 6 In
No PPE Exists - Do Not Work on Equipment while Energized!

208 VAC  Shock Hazard when cover is removed
00      Glove Class
3 Ft 6 In  Limited Approach (Fixed Circuit)
1 Ft 0 In  Restricted Approach


Equipment:  PNL-DB1 (PANEL DB1)
Device:  2-TO T-DB1
Line Side:  4-DB1 MAIN
Scenario  1 - UTIL MAX AFC-MOTORS ON        Max Fault Current: 20.9 kA

Study Performed By PowerStudies, Inc. (253) 639-8535
Obtain Equipment Nameplate Data & Settings

Coordination (PDC) Study

Short Circuit Fault Study

Arc Flash Study

Device Operating Time

Arcing Fault Current

3 Phase Bolted Fault Current

Arc Flash Label

Energy Level @ Working Distance

AF & Shock Boundaries

Required PPE
Arc Flash Hazard Analysis Key Steps

- **Determine:**
  - **Bolted Fault Currents** (Short Circuit Study)
  - **Arcing Fault (AF) Current**
  - **Upstream Protective Device Clearing Times** (PDC Study) using AF
Arc Flash Hazard Analysis Key Steps

- Calculate Arc Flash Energy
- Use NFPA 70E Tables to determine:
  - Glove Rating Class
  - Limited Approach Boundary
  - Restricted Approach Boundary
  - Required PPE
Arc Flash Hazard Analysis Key
Steps

- Arc Flash Warning Labels showing the details.
Informative Label

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11/15/2018  IEEE 1584.2018 & NFPA 70E-2018

Equipment: SWBD MSB2
Device: MSB2 MAIN

Scenario 2 - 50% UTILITY
Max Fault Current: 20.0 kA

Study Performed By Power Studies, Inc. (253) 639-8535
How a Short Circuit Study is Performed

- Obtain distribution system nameplate data for:
  - Transformers
  - Motors
  - Circuit breakers, fuses, relays
  - Switchgear
  - Motor Control Centers
  - Conductor sizes and lengths
How a Short Circuit Study is Performed

- **Enter data** into the computer program.
- **Simulate** short circuit at each location and **calculate** the fault current.
- **Compare** calculated fault current to equipment short circuit rating.
What is Protective Device Coordination (PDC) Study?

- Determines:
  - fuse sizes
  - *Settings* for relays and circuit breakers
  - Device *operating time*

- The study has 2 conflicting goals
Goal #1 - Maximum Selective Coordination Between Equipment

- Correct fuse sizes and settings will allow the device closest to a fault to trip.
- If the first device fails to operate, then the next upstream device will trip.
- Longer device trip delays = increased device coordination = greater incident energy.
Selective Coordination

1. 6-PNL-A MAIN
   PNL-A - 250 A

2. 5-Fdr to ATS-E
   SWBD
   3-MSWBD MAIN

3. XFMR-UTILS
   2- XFMR-UTILS
   ATS 260 Amp
Goal #2 - Maximum Equipment Protection and Reduction in Arc Flash Energy

- Correct fuse sizes and device settings will quickly interrupt the fault current for a short circuit downstream.

- Shorter device delays = decreased equipment damage = less Incident Energy
Maximum Equipment Protection

(No Selective Coordination)
Must **balance** these **two** conflicting goals based upon the type of facility.
PDC Vocabulary

- Time Current Curve (TCC)
- Log-log graph of time versus current
- Every breaker, fuse, and relay has a time current characteristic curve.
PDC Vocabulary

- Selective Device Coordination
  - The devices plotted on the time current curves are coordinated for all levels of fault current and time.
This Fuse is Current Limiting – Clearing time is 0.004 seconds.
Thermal Magnetic Trip Unit

- Thermal Unit is Fixed
- Instantaneous
  - Fixed
  - Adjustable
Thermal Magnetic Breaker

Diagram showing current in amperes on the y-axis and time in seconds on the x-axis. Key points:

- 20-50 Sec
- 4 kA
- 0.01-0.025 Sec
- 20 kA

Legend:
- 1 - MAIN
Solid State Trip Unit

- SQ D NW 40H
- 4000 Amp
- Micrologic
Solid State Trip Unit

- Varies for each Trip Unit!
- Some Functions are Not Adjustable!
Solid State Trip

- SQ D NW 40H
- 40000 Amp
- Micrologic

```
<table>
<thead>
<tr>
<th>Current (kA)</th>
<th>Time (Sec)</th>
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<tr>
<td>30</td>
<td>0.08-0.12</td>
</tr>
<tr>
<td>100</td>
<td>0.01-0.06</td>
</tr>
<tr>
<td>1000</td>
<td>170-210</td>
</tr>
</tbody>
</table>
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Graph: Current in Amperes vs. Time in Seconds

- 3 Phase/400 Volt Main
- 6 kA
- 0.08-0.12 Sec
- 30 kA
- 0.01-0.06 Sec
- 100 kA
An example of a TCC with Coordinated Devices
Arc Flash Energy Calculations

- Incident Energy Levels are dependent on:
  - Level of arcing fault current
  - Upstream device clearing time.
- Multiple Sources
Typical Assumptions for an Analysis

- Trip time is determined by the upstream protective device settings.
- Worker is stationary.
- The maximum time that a worker will be exposed to the arc flash is 2.0 seconds. (Depends upon location!!!)
Fault Current vs. Incident Energy
(Time Constant @ 0.025 Sec)
Time vs. Incident Energy
(Fault Current Constant @ 30 kA)
Distance vs. Incident Energy
(Time Constant @ 0.5 Sec & Fault = 60 kA)
Arc Flash Warning Labels

What does it mean?
Informative Label

WARNING

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11/15/2018 IEEE 1584-2018 & NFPA 70E-2018

Equipment: SWBD MSB2
Device:      MSB2MAIN

Scenario 2 - 50% UTILITY Max Fault Current: 20.0 kA
Study Performed By Power Studies, Inc. (253) 639-8635
Limited Approach Boundary:

- An approach limit at a distance from an exposed energized electrical conductor or circuit part within which a shock hazard exists.
- This value is determined by NFPA 70E Table 130.4(D)(a).
- Qualified Persons
- Unqualified if accompanied by a Qualified Persons
Restricted Approach Boundary

- An approach limit at a distance from an exposed energized electrical conductor or circuit part within which there is an increased likelihood of electric shock, due to electrical arc-over combined with inadvertent movement.
- Determined by NFPA 70E Table 130.4(D)(a)
Arc Flash Label Installation

- Always clean the surface with detergent to remove all grease and dirt. Wipe surface dry before applying the label.
- Some locations will have a Line Side Label. They should be installed at locations where maintenance staff could be exposed to energized parts on the line side of a fuse or circuit breaker. Examples of this are Main Breakers in Switchboards and Switchgear.
Arc Flash Label Installation

- Transformer Labels are for small distribution transformers (480/208 V) where both the 480 and 208 Volts terminals are exposed.

- Locations where the label will be exposed to direct sun light should be brought to the attention of PowerStudies, Inc. We will provide labels with a special UV protective covering to protect the label from fading.
Need more Information

- www.powerstudies.com
  - Articles
  - Links
  - Specifications for Power System Studies
    - Short Circuit
    - Protective Device Coordination
    - Arc Flash Hazard

- Phone: 253-639-8535
- Email: fuhr@powerstudies.com or Quotes@powerstudies.com
Thank you for your time!

Questions??????