Safety By Design

Strategies for Electrical Contractors
Introduction

• Engineering and system design significantly impact worker safety

• System design provides opportunity to eliminate/minimize workers’ exposure to electrical hazards
  – Before worker has a chance to be exposed
Design Considerations

Design practices that enhance personnel electrical safety:

- Choosing OCPDs for maximum current limitation
- Selecting rejection-style (Class J, R, T, L) fuses
- Selecting shunt-trip option for switches of 800+ amps
- Choosing Type 2 protection for motor controllers
- Installing finger-safe products, covers, insulating barriers
- Install HP-Rated Disconnects within Sight of Every Motor or Driven Machine
- Installing selectively coordinated OCPDs
- Selecting impedance-grounded systems
- Installing cable limiters
- Installing windows for infrared viewing
- Marking equipment with NEC® and NFPA 70E compliant arc-flash labels
Design Considerations (Continued)

Design practices that enhance personnel electrical safety:

- Installing main overcurrent protection
- Breaking larger loads/feeders into smaller ones
- Lowering adjustable instantaneous trip settings
- Properly utilizing short-time delay
- Utilizing zone-selective interlocking
- Utilizing arc reducing maintenance switches
- Utilizing differential relaying
- Utilizing arc-flash relays
- Utilizing crowbar devices for arc-flash mitigation
- Installing remote monitoring
- Selecting arc-resistant switchgear
- Installing remote racking of power circuit breakers
- Installing remote opening and closing of switches, circuit breakers
Upgrade Considerations

Upgrade practices that enhance personnel electrical safety:

- Upgrading fuses for greater current limitation
- Upgrading circuit breakers for greater current limitation
- Cutting in current limiting fuses, current limiting CBs, current limiting cable limiters
- Lowering adjustable instantaneous trip settings
- Adjusting short-time delay settings
- Marking equipment with NEC® and NFPA 70E compliant arc-flash labels
- Installing arc-flash relays with primary side disconnecting means
- Installing crowbar devices for arc-flash mitigation
- Evaluate existing interrupting ratings and rectify if required
- Sizing Under-Utilized Circuits with Lower Ampere Rated Current-Limiting Fuses or CBs
Arcing Fault Basics

1. Equations:
   
   Bolted I = V/R_{Bolted}
   
   Arcing I = V/(R_{Bolted} + R_{Arc})

2. Arc in air results in additional resistance

3. Result: arcing fault current is lower than bolted fault current
Arc Flash Statistics

Results of an electrical industry 10-year study of 120,000 workers

• 125 Injuries per year
• 77% electrical arc injuries
• 21% permanent disabilities
• 2.4% fatalities

Based on ED France data, IEEE Presentation from M. Capelli-Schellpfeffer, M.D. Electrical Trauma Research Program (University of Chicago)
Exposed skin has a limited ability to protect the body from the high temperatures of electrical arcs.
NFPA 70E & AWARENESS OF ARCFLASH
(Article 130 - Work Involving Electrical Hazards)

NFPA 70E Put Arc Flash Dangers On The Safety Map -
Many Studies Have Been Commissioned In This area
Light & Heat is Evident
Plasma & Debris Can Be Seen
More Light – Heat – Plasma & Debris
The Event Engulfs Those Within The Zone
The Event Can Reach Those Standing Near
**Results**

**T1**
- > 225°C / 437°F
- > 2160 lbs/sq.ft

**T2**
- > 225°C / 437°F

**T3**
- 50°C / 122°F

**P1**
- > Indicates Meter Pegged

**Sound**
- 141.5 db @ 2 ft.
Why is an Arc a Hazard?

- 35,000 °F
- Molten Metal
- Pressure Waves
- Sound Waves
- Shrapnel
- Hot Air-Rapid Expansion
- Intense Light

Copper Vapor: Solid to Vapor Expands by 67,000 times
Work Involving Electrical Hazards

Bolted Fault

Systems must be designed and are tested for worst case conditions.

Arcing Fault

Most equipment is not tested for arcing faults.

The Amount of Energy Released Is Based on The Amount of Current and Time
Choosing OCPDs for maximum current limitation

Designs using current-limiting ability of OCPDs can enhance electrical safety

- One of the most important decisions impacting arc flash hazards
- Energy released during arcing fault depends upon:
  - Magnitude of the arcing current that flows
  - Time duration the arcing current flows

- Current-limiting OCPDs can reduce the energy released during arcing fault
- OCPDs can either be current-limiting type or non-current-limiting type
Current Limitation of OCPDs

Non Current-Limiting

- Renewable & Class H Fuses
- Typical MCCB
- ICCB
- LVPCB

Current-Limiting

- CL MCCB
- MCCB w/Limiter Oversized
- Class RK5 Fuses

Medium Degree of Current Limitation

Best Current-Limitation

Class RK1
Class J
Class CC
Class L
Class T
Fuses

MCCB: Molded Case Circuit Breaker
ICCB: Insulated Case Circuit Breaker
LVPCB: LV Power Circuit Breaker
CL: Current-Limiting
Current Limitation of OCPDs

Non-current-limiting OCPDs

- Renewable, Class H fuses: outdated, not current-limiting, not recommended
- Typical molded case circuit breakers, insulated case circuit breakers, low-voltage power circuit breakers not listed and marked as current-limiting
  - May not significantly reduce level of short-circuit currents
  - Take longer to open
  - For arcing faults in instantaneous trip region, the higher the fault current, the greater the incident energy
Current Limitation of OCPDs

• Current-limiting OCPDs
  – Different types of current-limiting devices provide different degrees of protection
  – For the same ampere rating, the fault current at which they become current-limiting varies based on the type
  – Typically, once in the current-limiting range of an OCPD, the arc flash incident energy does not significantly increase as fault current increases
Current Limitation of OCPDs

• CL MCCBs are a better choice than standard MCCBs
• MCCB with fused limiters: size the limiter as low as practical
  – Limiters typically oversized
  – Not as good as fuse (in switch) sized properly for load
• Class RK5 fuses offer good arc flash mitigation
• The best current-limitation
  – Class RK1 fuses
  – Class J fuses
  – Class CF
  – Class CC fuses
  – Class L fuses
  – Class T fuses
Current Limitation of OCPDs

Table 4.1: UL Standard Limits for OCPDs

<table>
<thead>
<tr>
<th>Device Ampere Rating</th>
<th>Class J 600 Volts</th>
<th>Class RK1 600 Volts</th>
<th>Class RK5 600 Volts</th>
<th>Current-Limiting Molded Case Circuit Breaker</th>
<th>Standard Molded Case Circuit Breaker</th>
</tr>
</thead>
<tbody>
<tr>
<td>600 ampere</td>
<td>2,500,000</td>
<td>3,000,000</td>
<td>10,000,000</td>
<td>20,750,000</td>
<td>No limit</td>
</tr>
<tr>
<td>400 ampere</td>
<td>1,000,000</td>
<td>1,200,000</td>
<td>5,200,000</td>
<td>20,750,000</td>
<td>No limit</td>
</tr>
<tr>
<td>200 ampere</td>
<td>200,000</td>
<td>400,000</td>
<td>1,600,000</td>
<td>20,750,000</td>
<td>No limit</td>
</tr>
</tbody>
</table>

- Illustrates potential benefits of using the most current-limiting overcurrent protective devices
  - $I^2t$ values are maximums that UL Standards allow for these products
  - Commercially available products may have lower values
- Arc flash incident energy generally directly proportional to $I^2t$ let-thru
- The lower the $I^2t$ let-thru by an OCPD, the lower the arc flash incident energy
Current Limitation of OCPDs 200A

- Dotted line represents the available fault current that could flow with 50,000A available fault current
- Shown are the maximum $I_p$ let-through permitted by the UL product standards for various types of OCPDs
- The lower the value the better for protection
Current Limitation of OCPDs
200A vs. 400A

Illustrates Different Levels of Protection
UL Ip Limits for 200A Rating

- Peak Amps
  - 115,000
  - 32,000
  - 18,000
  - 16,000

- Time
- 50,000 Sym. Amps Available

Illustrates Different Levels of Protection
UL Ip Limits for 400A Rating

- Peak Amps
  - 115,000
  - 50,000
  - 33,000
  - 25,000

- Time
- 50,000 Sym. Amps Available

Non-Current Limiting Circuit Breaker

Class RK5 200A
Class RK1 200A Fuse
Class J 200A Fuse

Class RK5 400A
Class RK1 400A Fuse
Class J 400A Fuse
Design of OCPD Important Time Current Characteristics

• Fuses and CBs have different profiles for incident energy versus fault current
• Under arcing fault conditions, overcurrent protective devices operate based on arcing current
• OCPD characteristics and arcing current magnitude determine incident energy:
  – For standard non-current limiting circuit breakers, when the arcing current is in their instantaneous trip region, as the arcing current increases, the incident energy increases
  – With current-limiting OCPDs in their current-limiting range, as the arcing current increases, the incident energy generally does not increase
  – Arcing currents, if self sustaining, in the long time region of an OCPD’s characteristics will typically result in higher incident energies
How to read this information
1. If the available three phase bolted short-circuit current is known (10,000A),
2. Under arcing fault conditions, the arcing current then would be the value shown by the
3. Which then causes the circuit breaker to operate at the yellow dot on CB time-current curve. (always use the maximum or total clear time)
4. This results in this specific arcing current releasing thermal energy measured at a specific distance from the arc fault source:
How to read this information

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3. Which then causes the circuit breaker to operate at the yellow dot on CB time-current curve. (always use the maximum or total clear time)
4. This results in this specific arcing current releasing thermal energy measured at a specific distance from the arc fault source:
This illustrates that the incident energy can be high when the arcing current is less than the instantaneous trip, if arcing fault can self-sustain.
This illustrates that the incident energy is lowest when the arcing current is just above the instantaneous trip setting.
This illustrates for higher arcing currents in the circuit breaker’s instantaneous trip region, the incident energy increases. This is applicable for non-current-limiting circuit breakers.
Incident Energy vs Arcing Current – Various Type Circuit Breakers

1. When the arcing current is less than the instantaneous trip of any circuit breaker (yellow)
2. CBs with short-time delay permit the highest incident energy (red)
3. When non-current limiting circuit breakers operating in their instantaneous trip region (blue)
4. Incident energy curve when arcing current is in instantaneous trip region for current-limiting circuit breaker (green)
Incident Energy vs Arcing Current – Circuit Breakers

This illustrates for circuit breakers with short-time delay (no instantaneous trip), the incident energy is much higher and increases as the fault current increases.
Incident Energy vs Arcing Current – Current-Limiting Fuses

- Next four slides cover current-limiting fuses
- Shown is incident energies for two different Class fuses
This illustrates that the incident energy can be highest when the arcing current is lower than the current-limiting range, if arcing fault can self-sustain.
Incident Energy vs Arcing Current – Current-Limiting Fuses

This illustrates as arcing current increases, the fuse clears faster (compared to previous slide) and results in reduced incident energy.
Incident Energy vs Arcing Current – Current-Limiting Fuses

- This illustrates when arcing current is in the current-limiting range of a fuse, the fuse clears in less than ½ cycle and resulting incident energy is low even for higher faults (incident energy curve is flat).
- Arcing currents beyond current-limiting threshold of fuse do not show increased arc flash level.
Incident Energy vs Arcing Current – Current-Limiting Fuses

• This illustrates comparison of Class RK1 fuses vs Class RK5 fuses
• Class RK1 fuses are more current-limiting and provide better arc flash protection for a lower range of arcing faults
Selecting rejection-style (Class J, R, T, L) fuses

Rejection-style Class J, T, R, L fuses are physically size-rejecting

- Fuses of different class cannot be accidentally put into service - They won’t fit
- Can not install fuse with lower voltage ratings, lower interrupting ratings, lower current limiting ability

Class L
Class T
Class R
Class J
Selecting shunt-trip option for switches of 800+ amps

Switches that shunt trip to open all 3 poles when first fuse opens can reduce arc flash energy levels.
Choosing Type 2 protection for motor controllers

Type 1 Protection of Motor Starters

Before | During | After

Motor starters are susceptible to extensive damage if not specified to be protected by OCPDs that can provide Type 2 protection.

Illustrated above: sequence of photos of short-circuit current testing for motor starter with Type 1 protection.

Type 1 protection is itself a potential arc flash hazard if the fault occurs with a worker near and enclosure door open.
Choosing Type 2 protection for motor controllers

Type 2 Protection of Motor Starters

Before

During

After

- Motor starters specified to be protected by OCPDs that provide Type 2 protection increase electrical safety
- Illustrated above: sequence of photos of short-circuit current testing for motor starter with Type 2 “No Damage” Protection
Electrocutions were the fifth leading cause of death from 1980 through 1995.
Installing finger-safe products, covers, insulating barriers to Help Minimize Electrical Shock Hazard

Also, reduces probability of initiating an arcing fault
Fusible Finger-safe Panelboards for Improved Electrical Safety

- UL 98 disconnect with CUBEFuse branch circuits
- Service branch fuses without opening trim
- Fuse Rejection, Interlock, and Indication
Install HP-Rated Disconnects within Sight of Every Motor or Driven Machine

In-sight motor disconnect:
- More likely to be used to lockout equipment into electrically safe work condition prior to doing work
- Readily available as emergency disconnect
Installing selectively coordinated OCPDs

Selective coordination: act of isolating overcurrent condition from remainder of electrical system by opening only one overcurrent protective device ahead of the overcurrent

- Eliminates unnecessary power outages
- Enhances personnel safety because electrical worker is exposed only at problem circuit
Selective Coordination: Act of Isolating Faulted Circuit from Remainder of Electrical System

- Main
  - Feeder
    - Feeder
      - Branch
        - branch circuit fault only opens branch OCPD
        - upstream OCPDs do not open

Arc Flash Hazard
- 12.3 cal/cm²
- 6.7 cal/cm²
- 1.6 cal/cm²

Selective coordination:
- Faults isolated by *only* nearest upstream OCPD
- Eliminates unnecessary power outages upstream
- Typically arc flash hazard greater for larger circuits upstream
- Enhances personnel safety because electrical worker is exposed only at problem circuit
Selecting impedance-grounded systems
Impedance-Grounded Wye Systems Reduce Probability of Dangerous Arcing Faults Initiated Line to Ground

- Impedance between transformer Wye center point and ground
- First line to ground fault will not create high-level arc flash event
- However, a high incident energy arc flash can still be initiated between two phases or three phases
Impedance-Grounded Wye Systems Reduce Probability of Dangerous Arcing Faults Initiated Line to Ground

- First line to ground fault, restricted to low current
  - Does not cause dangerous arc flash (current too low)
  - Does not propagate to three phase arcing fault
  - Does not open OCPD (current too low)
Impedance-Grounded Wye Systems Reduce Probability of Dangerous Arcing Faults Initiated Line to Ground

Should troubleshoot and remove first fault before a second line to ground fault occurs: high current line to line fault results...
Installing cable limiters

- Often the only short-circuit protection for (unprotected) service conductors
- Utilized to provide short-circuit protection for tap conductors which are also “unprotected” (sometimes at 10X their rating)
Installing windows for infrared viewing

- Eliminates the need to open doors or remove covers
- No energized parts for accidental contact
- No accidental arc-flash incidents from opening/closing, loose screws, etc.
Marking equipment with NEC® and NFPA 70E compliant arc-flash labels

Marking/labeling electrical equipment with arc flash hazard or warning can reduce occurrence of serious injury or death

Various requirements and options

• NEC Section 110.16
• 2012 NFPA 70E 130.5 (C)
Arc Flash Hazard Warning Labels
New Installations

• *NEC Section 110.16* (since 2002 NEC) requires field marking with *arc flash warning label* on certain new equipment installations
  – Not required to include specific arc flash hazard detailed information

![Arc Flash and Shock Hazards
Appropriate PPE Required
Failure to Comply Can Result in Death or Injury
Refer to NFPA 70E](image)
Marking New Equipment with Arc Flash Hazard

• *2012 NFPA 70E* Section 130.5(C) requires marking equipment with incident energy or level of PPE when arc flash hazard analysis is performed
  – Benefit: qualified worker can readily know the hazard
  – Other important information can also be included on label such as shock hazard info
  – See example on next slide
Marking New Equipment with Arc Flash Hazard

WARNING

Arc Flash and Shock Hazard
Appropriate PPE Required

QUALIFIED PERSONS ONLY - REVIEW SAFE WORK PRACTICES PRIOR TO WORK

57 inches  Arc Flash Hazard Boundary
7.9 cal/cm²  Arc Flash Energy at Working Distance of: 18 inches

NOTE: Lack of proper maintenance, changes in settings, or changes in system layout could invalidate the calculated arc Flash Energy values and PPE shown on this label.

Recommended (minimum) PPE:
To assist workers in complying with company safety procedures, some companies include a listing of the required PPE for the hazards of the specific equipment labeled in this space. Personal protective equipment marked in this space should be in accordance with OSHA, NFPA 70E, and the employer’s electrical safety program.

<table>
<thead>
<tr>
<th>Voltage (VAC)</th>
<th>Hazard</th>
<th>Minimum PPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>480</td>
<td>Shock</td>
<td>42 inches</td>
</tr>
<tr>
<td>12</td>
<td>Restricted</td>
<td>12 inches</td>
</tr>
<tr>
<td>1</td>
<td>Prohibited</td>
<td>1 inches</td>
</tr>
</tbody>
</table>

LOCATION:  L3B
PREPARED:  11/17/08

COOPER Bussmann
Job#: 2008-05-14-01-CB1
Installing main overcurrent protection

Main provides shaded zone:
1. Disconnect to lockout
2. Overcurrent protection

No main leaves shaded area at greater risk to worker:
1. No disconnect to lockout
2. No premises overcurrent protection

Service Entrance Main Design

Service Entrance Six Disconnect Rule No Main Design
Breaking larger loads/feeders into smaller ones

28,000A Available Short Circuit Current

22.71 Cal/cm² @ 18” Incident Energy

28,000A Available Short Circuit Current

1.22 Cal/cm² @ 18” Incident Energy
Lowering adjustable instantaneous trip settings

Some circuit breakers have adjustable instantaneous trip (IT) settings

- Adjusting to lower instantaneous trip may lower arc flash incident energy
- If set too low, may incur nuisance tripping
- Lowering IT setting may negatively affect selective coordination
Properly utilizing short-time delay

Short-time delay (STD) mechanisms can be set to provide selective coordination and provide arc-flash protection at the same time

– Arc flash hazard increases with length of time current is permitted to flow
– Exception: if zone selective interlocking, arc reducing maintenance switch, differential relaying, or equivalent are used (see next six topics)
Properly utilizing short-time delay

**NO Short Time Delay**
- Trip Curve Of Breaker **NOT** Utilizing Short Time Delay
- Max Clearing Time $T_2$ For Arcing Current $I_a = \sim 15$ Sec
Properly utilizing short-time delay

**Short Time Delay**
- Trip Curve Of Breaker Utilizing Short Time Delay
- Max Clearing Time $T_1$ For Arcing Current $I_a = \sim .9$ Seconds
Utilizing zone-selective interlocking

Circuit breakers with zone selective interlocking have current sensing elements that communicate. With fault on load side of CB 3, CB3 sends restraint signal to CB2 and CB1. Time current curves are as depicted.
When fault is between CB2 and CB3, CB3 does not send a restraint to CB2, CB2 sends a restraint to CB1, and CB2 opens as fast as it can (instantaneous trip) rather holding to its short-time delay setting.
When fault is between CB1 and CB2, CB2 and CB3 do not send restraint to CB1, so CB1 opens as fast as it can (instantaneous trip) rather holding to its short-time delay setting.
Zone Selective Interlocking

Without ZSI = 0.5 S:
43.7 Cal/cm²
DANGER!

With ZSI = 0.08 S:
7.0 Cal/cm²
FR Shirt & Pants

35kA fault current
Utilizing arc reducing maintenance switches - Reduces Exposure Levels for Workers

Control switch turns off short-time delay function while working in arc flash protection boundary

• Where short-time delay is utilized
• Option allows circuit breaker to trip without intentional delay if arc flash started while worker is in arc flash protection boundary
Utilizing arc reducing maintenance switches

Normally CB 1 trips by short-time delay setting.

When arc flash reducing maintenance switch is utilized, CB 1 trip setting is adjusted to instantaneous.
Utilizing arc reducing maintenance switches

Arc Flash Reduction Maintenance Switch

- High Avail Fault Current
- Digitrip 610 & Arcflash Reduction Maintenance Switch
- Normal settings –10.7 cal
- With Arcflash Reduction Maintenance Switch –2.2 cal
Utilizing differential relaying

The CTs and relay are configured to sum the currents entering and subtracting the sum of the currents exiting via the normal conducting paths. If a fault occurs on the bus with a current magnitude greater than the relay set point, the relay signals the disconnects to interrupt.
Utilizing arc-flash relays

Arc Flash Relay processes signals from Light Sensor Inputs and Current Sensor Inputs. If an arcing fault occurs in the LV switchgear, (1) a Light Sensor sees the light and communicates to the Arc Flash Relay, (2) a Current Unit Sensor sees uncharacteristic current flow and communicates with the Arc Flash Relay. An and-gate checks for signals from both the Light Sensor and the Current Sensor and then sends a signal to trip the primary side circuit breaker or vacuum interrupter.
Utilizing crowbar devices for arc-flash mitigation

• Several types of crowbar devices intentionally create bolted faults or arcing faults in parallel with the accidental arcing fault
• Lower impedance than an accidental arcing fault
• Available arcing fault current takes path of least impedance
• Quick enough to divert the harmful arcing fault energy away from the worker
Installing remote monitoring

Remote Monitoring: Enables Troubleshooting, Diagnostics without Opening Enclosures

Remote monitoring of voltage, current levels reduces exposure to electrical hazards

- Displays on enclosure exteriors or computer port on exterior or networked
Selecting arc-resistant switchgear

Arc-Resistant (Arc Diverting) Switchgear
Withstands Internal Arcing Faults

Arc by-products vented via louvers

- Arc-resistant equipment is designed with features that divert hot gases, pressures from internal arcing fault
- If indoors, typically requires duct work
- Only applicable when doors closed and latched
Selecting arc-resistant switchgear

During the studies and tests conducted by Eaton Electrical, it was found that the internal arcing phenomenon consists of two stages: A dynamic phase and a thermal phase.
Selecting arc-resistant switchgear

The Dynamic Phase

- Within 10 milliseconds of arc inception, the pressure inside a switchgear enclosure could reach a level as high as 4232 lb./square-foot. With this rate of rise, containment cannot be accomplished.

- Actual testing is the only way to prove an arc-resistant design. Arc resistant switchgear includes a pressure-relief vent to allow the dynamic phase to dissipate.
Selecting arc-resistant switchgear

The Thermal Phase

- While the arc is burning and expanding, copper bus bar will vaporize, insulation will disintegrate and paint will burn. If the fault persists beyond 30 cycles, the arc can burn through steel.
- Arc Resistant Switchgear does not protect personnel from:
  - Toxic gases which are vented due to internal faults
  - Inappropriate location of the equipment within a building
  - The loud noise that result from an internal fault
  - Damage resulting from doors being open or panels being removed.
The diagram above shows the dynamic pressure is at its highest point in the first cycle after the fault occurs.
Installing remote racking of power circuit breakers

• Important to move workers outside the arc-flash boundary—further from potential arc source for hazardous operations:
  – Remote-controlled motorized racking devices
  – Extended length hand-operated racking tools
Installing remote racking of power circuit breakers

- Racking circuit breakers into energized circuit is a very hazardous task
- Remote racking permits worker to be outside of arc flash protection boundary and rack in/out a circuit breaker
Installing remote racking of power circuit breakers

Physical Separation Of Individuals From Arc Flash Boundaries Place Individuals Outside Of Harms Way
Installing remote opening and closing of switches, circuit breakers

Permits worker to control operation from safe distance (outside the arc flash protection boundary)
Installing remote opening and closing of switches, circuit breakers

- Without
- With

Physical Separation Of Individuals From Arc Flash Boundaries Place Individuals Outside Of Harms Way
Upgrading fuses for greater current limitation

• If existing electrical system is fusible, consider replacing older fuses or less current-limiting fuses with newer, more current-limiting fuses where possible
  – Over the decades, advancements in fuse capabilities: use the more recent and best
  – There may be different type fuses that fit in the same mountings that mitigate the arc flash hazard better: see next slide
The Upgrade & Consolidation to Class RK1 Fuses

- Renewables (Class H)
- One-Time (Class H)
- Dual Element Time Delay (Class RK1)
- Fast Acting (Class RK1)
- Dual Element Time Delay (Class RK5)
Upgrading circuit breakers for greater current limitation

- Non-Current Limiting
- Current Limiting

Legend:
- Short Time Delay – Circuit breaker with short time delay
- Instantaneous – Circuit breaker with instantaneous trips
- CLCB – Current-limiting circuit breaker
Cutting in current limiting fuses, current limiting CBs, current limiting cable limiters

- Locations with dangerous arc-flash energy levels
- Locations with medium to high available short-circuit currents
- Space and ownership are the big issues to overcome
Lowering adjustable instantaneous trip settings

Some circuit breakers have adjustable instantaneous trip (IT) settings

- Adjusting to lower instantaneous trip may lower arc flash incident energy
- If set too low, may incur nuisance tripping
- Lowering IT setting may negatively affect coordination
Adjusting short-time delay settings

- Review the settings and associated time-current curves
- It is often possible to adjust settings to pick up and open quicker on expected arcing fault current

**Short Time Delay**
- Trip Curve Of Breaker Utilizing Short Time Delay
- Max Clearing Time T1 For Arcing Current Ia = ~100 Seconds
Adjusting short-time delay settings

- In this case, time to trip was reduced from 100 seconds to \(\frac{1}{2}\) second, simply by adjusting the short time pickup.

**Short Time Delay**
- Trip Curve Of Breaker Utilizing Short Time Delay
- Max Clearing Time T2 For Arcing Current \(I_a = \sim 0.5\) Seconds
Marking equipment with NEC® and NFPA 70E compliant arc-flash labels

Many premise owners conduct arc flash hazard analysis & shock hazard analysis for entire premises and label the premise electrical equipment

- Facilitates more efficient operation
- Especially when qualified workers do routine tasks such as checking for the absence of voltage

Process for premise wide labeling:

- Accurate single-line diagram
- Short-circuit current study
- Arc flash hazard analysis
- Affix labels
Updating Arc Flash Hazard Information

• 130.5 requires an arc flash hazard analysis to be updated when a major change occurs or to periodically be reviewed, not to exceed five years

• Electrical system changes can affect available arc flash incident energy, required level of PPE for electrical equipment

• Electrical system changes may alter
  – Available short-circuit current
  – Time duration for fuses or circuit breakers to interrupt arcing current
Updating Arc Flash Hazard Information

Changes that may affect the available arc flash incident energy and required level of PPE

– Upstream transformer replaced with different % Z and/or greater KVA rating (changes available short-circuit current)

– A fuse or circuit breaker type, amp rating, or setting is changed (changes time to interrupt arc fault current)

– Circuit conductor size or length is changed (changes available short-circuit current)

– Alternate power sources added or deleted
Installing arc-flash relays with primary side disconnecting means

Arc Flash Relay processes signals from Light Sensor Inputs and Current Sensor Inputs. If an arcing fault occurs in the LV switchgear, (1) a Light Sensor sees the light and communicates to the Arc Flash Relay, (2) a Current Unit Sensor sees uncharacteristic current flow and communicates with the Arc Flash Relay. An and-gate checks for signals from both the Light Sensor and the Current Sensor and then sends a signal to trip the primary side circuit breaker or vacuum interrupter.
Installing crowbar devices for arc-flash mitigation

• Several types of crowbar devices intentionally create bolted faults or arcing faults in parallel with the accidental arcing fault
• Lower impedance than an accidental arcing fault
• Available arcing fault current takes path of least impedance
• Quick enough to divert the harmful arcing fault energy away from the worker
Evaluate existing interrupting ratings and rectify if required

• **Interrupting Rating**
  Maximum current that a circuit breaker or fuse can safely interrupt under standard test conditions.

• **Serious safety hazard when available short-circuit current exceeds an OCPD’s interrupting rating**

• **Adequate interrupting rating required per National Electric Code Section 110.9 and OSHA §1910.303(b)(4). This OSHA regulation is applicable no matter what the age of system**
Interrupting Rating
Misapplication (videos)

10,000A IR, 600V
Class H Fuse
50,000 Available

14,000A IR, 480V
Circuit Breaker
50,000A Available

Violates NEC® 110.9 and OSHA §1910.303 (b)(4)
Inadequate Interrupting Rating Fuse

Test (still photos)

10,000A IR, 600V Class H Fuse with 50,000 available short-circuit current @480V
Inadequate Interrupting Rating Circuit Breaker Test (still photos)

14,000A IR, 480V Circuit Breaker with 50,000 available short-circuit current @ 480V
Adequate Interrupting Rating
Fuse Test

300,000A IR, 600V Class J Fuse
with 50,000 available short-circuit current @480V

Before, during and after test

- Modern current-limiting fuses have interrupting ratings of 200kA and 300kA
- Circuit breakers are available in a wide range of interrupting ratings up through 200kA
Evaluate existing interrupting ratings and rectify if required

• Electrical system changes result in higher available short-circuit currents
  – Might exceed interrupting rating of existing OCPDs
  – Existing OCPDs must be reevaluated for sufficient interrupting rating
    • Conduct short-circuit current analysis of facility
    • Check to insure each OCPD’s interrupting rating is equal to or greater than the available short-circuit current at OCPD’s line terminals
    • Series rated systems may be an exception, but should be properly evaluated
Sizing Under-Utilized Circuits with Lower Ampere Rated Current-Limiting Fuses or CBs

Measure actual load current
Summary

Electrical systems can be designed or upgraded to eliminate or reduce electrical hazards for personnel

• Key factors to reduce arc-flash injuries
  – Reduced Arcing Time
  – Limited Arcing Current
  – Increased Working Distance
  – Easily Accessible Disconnecting Means

• Key factor to reducing shock and electrocution
  – Finger Safe Construction, Covers, Barriers
  – Increased Working Distance
  – Easily Accessible Disconnecting Means
Thank You!
Any Questions?
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