Safety by Design - Strategies for Electrical Contractors
Continuing Education Credits

NECA has been accredited as an Authorized Provider by the International Association for Continuing Education and Training (IACET) and is authorized to offer IACET CEUs for its programs that qualify under the ANSI/IACET Standard.

This session is eligible for 0.1 IACET CEUs

To earn these credits you must:
• Have your badge scanned in and out at the door
• Attend 90% of this presentation
• Fill out the online evaluation for this session
Learning Objectives

Following this session, participants will be able to:

1. Discuss the role that design can play in eliminating or reducing electrical hazards

2. Explain that overcurrent protective device (OCPD) time-current characteristics are an important consideration in regard to arc flash hazards

3. Identify equipment/options that eliminate/reduce electrical hazards

4. Identify safety design layout methods that can enhance electrical safety
Safety by Design Strategies for Electrical Contractors

Presenters
• Vince Saporita 636-527-1608, VinceSaporitia@Eaton.com
• Tim Crnko 636-527-1384, TimMCrnko@Eaton.com

Special thanks to NJATC
• Some of this material is from the NJATC Electrical Safety-Related Work Practices
  Palmer Hickman, Director Codes and Standards
Safety By Design: new or existing installations

Objectives

1. **Discuss the role that design can play in eliminating or reducing electrical hazards**

2. Explain that overcurrent protective device (OCPD) time-current characteristics are an important consideration in regard to arc flash hazards

3. Identify equipment/options that eliminate/reduce electrical hazards

4. Identify safety design layout methods that can enhance electrical safety
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
Which is more important?

- Safe work practices
- Worker training and workers demonstrating competencies related to safe work practices
- Designing for electrical safety
Safety By Design

Categories or Groupings

- Eliminate hazard
- Mitigate/reduce hazard
- Reduce probability of hazard
- Alter work practices

How to Achieve

- Design layout
- Equipment chosen
- Equipment options selected
NFPA 70E Informative Annex O
Safety-Related Design Requirements

• Compare design options per requirements of 130.3(B)(1)

• 130.3(B) Working Within the Limited Approach Boundary of Exposed Electrical Conductors or Circuit Parts That Are or Might Become Energized.

(1) Electrical Hazard Analysis.

• Designer:
  • develop design options
  • conduct and compare shock and arc flash hazard analysis
  • Use as consideration
Design for Safety Considerations

Design practices that enhance personnel electrical safety:

- Choosing OCPDs for maximum current limitation
- Equipping circuit breakers with ARMs (arc reduction maintenance switch)
- 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 for Safety 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
- Main in separate enclosure
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
Safety By Design: new or existing installations

Objectives

1. Discuss the role that design can play in eliminating or reducing electrical hazards

2. Explain that overcurrent protective device (OCPD) time-current characteristics are an important consideration in regard to arc flash hazards

3. Identify equipment/options that eliminate/reduce electrical hazards

4. Identify safety design layout methods that can enhance electrical safety
Work Involving Electrical Hazards

Bolted Fault
Systems must be designed and are tested for worst case bolted fault conditions.

Arcing Fault
Systems not typically tested for arc fault conditions.

The amount of thermal energy released is based on the magnitude of arcing current and time.
Arcing Fault Basics

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

2. Arc in air results in additional resistance

3. Result: arcing fault current is lower than bolted fault current
Arcing fault approximately 13kA amperes with 22.6kA available 3Ø bolted short-circuit current @ 480V

47 in.  
5.8 cal/cm²  
640 amp non current-limiting OCPD  
6 cycles opening time

22 in.  
1.6 cal/cm²  
KRP-C-601SP  
601 amp current-limiting Class L Fuse

6 in.  
0.25 cal/cm²  
LPS-RK-30SP  
30 amp current-limiting Class RK1 Fuse

Determined by IEEE 1584 Methods

Click photos for videos
Current-Limitation: Arc Energy Reduction

Non-Current Limiting (Clearing in time-current curve region)

Test 4

Test 3

Reduced Fault Current via Current-Limitation

Test 1

KRP-C-601SP Fuse

LPS-RK-30SPSP Fuse
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

If arcing fault current here
**Electronic Sensing Circuit Breaker Adjustment**

**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
Electronic Sensing Circuit Breaker Adjustment

Short Time Delay
- Trip Curve Of Breaker Utilizing Short Time Delay
- Max Clearing Time T1 For Arcing Current $I_a = \sim 0.9$ Seconds

Electronic Sensing
- Offers more adjustability to time-current characteristic curves
Arc Flash Reduction Maintenance Switch

• ALWAYS WORK DE-ENERGIZED
• Manually or automatically enables analog instantaneous pickup
• Protects all downstream equipment / personnel
• Limits energy available during maintenance
• ARM technology implemented differently for various CBs (it matters)
Arc Flash Reduction Maintenance Switch

- High Avail Fault Current
- Digitrip 610 & Arcflash Reduction Maintenance Switch
- Normal settings: $10.7 \text{ cal/cm}^2$
- With Arc flash reduction Maintenance Switch: $2.2 \text{ cal/cm}^2$
- ARM's speed vary greatly based on technology
Arc Reduction Maintenance Switch Example

480V

- $I_{SCA} = 17 \text{ kA}$
- $I_{ARC} = 10.3 \text{ kA}$

CB w STD
- I.E. @ 18” 7.6 cal/cm²
- AFB 55 inches

CB w ARM
- 1.4 cal/cm²
- 19.5 inches
Arc Flash Maintenance Reduction Switch

- Clearing times are much faster than normal short time delay setting (red)
- Clearing times can be faster than standard INST
- Digitrip 610 & arc flash reduction maintenance switch (blue)
- Analog technology

Ref: Incident energy calculated using IEEE STD 1584TM-2002 method for a 480 Vac system, working distance of 24 inches, Grounding type = solid grounded and Equipment type = Switchgear, 40kA available short-circuit current.
Utilizing Zone-Selective Interlocking (ZSI)

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.
Utilizing Zone-Selective Interlocking (ZSI)

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 rather holding to its short-time delay setting (speed varies by technology).
Utilizing Zone-Selective Interlocking (ZSI)

When fault is between CB1 and CB2, CB2 and CB3 do not send restraint to CB1, so CB1 opens as fast as it can rather holding to its short-time delay setting.
Utilizing Zone-Selective Interlocking (ZSI)

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

With ZSI = 0.08 S:
7.0 Cal/cm²

STD = 0.5S

35kA fault current

DANGER!
Fuse TCCs

Example: 400A Fuses
- 480V, MCC, 18” working distance
- 10.9 kA $I_{SCA}$
- 7.1 KA 100% $I_{ARC}$
- 6.0 KA 85% $I_{ARC}$

Results
- RK5: 2.05 cal/cm²
- RK1: 0.36 cal/cm²
- J (TD): 0.19 cal/cm²
- J (NTD): 0.19 cal/cm²

Ref: Incident energy calculated using IEEE STD 1584TM-2002 method for a 480 Vac system, working distance of 18 inches, Grounding type = solid grounded and Equipment type = MCC 10.9kA available short-circuit current.
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
Which Fuses Best Suited for Arc Flash Protection

Arc flash protection provided by fuses dependent on:

- Fuse time-current characteristics (TCCs)
- Degree of current-limitation

- Class RK5 Fuses
- Class CF
- Class J
- Class T
- Class RK1
- Class CC
- Class L

Non Current-Limiting

Current-Limiting

Renewable & Class H Fuses
Why OCPDs are so important

Fault currents can cause tremendous damage in a brief time

Fault Occurs At this Time

Normal current
Current-Limiting

Available fault current

Peak current limited

Forced to zero

Normal current

Fault initiated

Total clearing

Time to clear

1

2

3

4
Current-Limitation Benefit

90 Feet 2/0 conductor
Test current flow 26,000 A sym. rms
• 1 cycle clearing
• Non-current-limiting

Same test as above with LPJ-200SP fuse protecting (200A Class J Fuse):
Fuse was current-limiting:
• Cleared in less than ½ cycle
• Max. mech. force let-thru 1/25th
• Thermal energy let-thru 1/100th
Current-Limiting

LO 2

- LPJ-100SP Current Limiting

- UL I_p Limits for 200-A Rating
  - 115,000 Peak Amps
  - 32,000
  - 18,000
  - 16,000
  - 50,000 Sym. Amps Available

- E125C High Performance Current Limiting Circuit Breaker
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 Fuses
200A vs. 400A

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

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

Peak Amps
- 150,000
- 32,000
- 18,000
- 16,000

Time
50,000 Sym. Amps Available

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

- Class RK5 400A
- Class RK1 400A Fuse
- Class J 400A Fuse

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

Time
50,000 Sym. Amps Available
Which Fuses Best Suited for Arc Flash Protection

Arc flash protection provided by fuses dependent on

- Fuse time-current characteristics TCCs
- Degree of current-limitation

Non Current-Limiting

Current-Limiting

Class RK5 Fuses

Renewable & Class H Fuses

Class CF
Class J
Class T
Class RK1
Class CC
Class L
Fuses
Incident Energy vs Arcing Current
Current-Limiting Fuses

- Class RK1 fuses are more current-limiting and provide better arc flash protection for a lower range of arcing faults
- Yellow curve better characteristic than red curve
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
Sizing Under-Utilized Circuits with Lower Ampere Rated Current-Limiting Fuses or CBs

Measure actual load current
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

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

Branch circuit fault only opens branch OCPD
Upstream OCPDs do not open
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
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)
Safety By Design: new or existing installations

Objectives

1. Discuss the role that design can play in eliminating or reducing electrical hazards

2. Explain that overcurrent protective device (OCPD) time-current characteristics are an important consideration in regard to arc flash hazards

3. Identify equipment/options that eliminate/reduce electrical hazards

4. Identify safety design layout methods that can enhance electrical safety
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
- Door-in-Door
Installing Finger-Safe Products, Covers, Insulating Barriers to Help Minimize Electrical Shock Hazard

Also, reduces probability of initiating an arcing fault
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

Physical Separation Of Individuals From Arc Flash Boundaries Place Individuals Outside Of Harms Way

VS.
Installing Remote Opening and Closing of Switches, Circuit Breakers (Large Amp Rating)

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
Why do MCC Accidents Occur?

- MCCs are worked on when energized more than any other electrical equipment
- Diagnostic/trouble shooting is necessary
- Measurements are taken daily
- Maintenance work is performed daily
- Units are worked on live in order to avoid downtime of critical equipment or processes
- Inserting and removing is done when energized to minimize downtime

There are MCCs designed for safety!
FlashGard MCC Solution – Insulated Bus

- Both the horizontal and vertical buses are insulated
- Prevents phase to phase fault propagation

Labyrinth Vertical Bus

Automatic Shutter
FlashGard MCC Solution – Dead Front

• The door is closed while stabbing operations are performed
• This establishes a dead-front between the user and the danger

Rack-in and rack-out
• Hand racking tool or
• Remote racking device (15 feet)
FlashGard MCC Solution
RotoTract Stab Assembly

• Located at the top of the unit
• Enables stabs to be retracted and engaged onto the vertical bus while the unit’s door is closed
• Includes easy to see shutter and stab position indicators

• **Green** = Shutters closed
  Stabs disconnected
• **Red** = Shutters open
  Stabs connected
FlashGard MCC Bucket Top

- Bucket Position: Connected/Disconnected
- RotoTract Insertion Point: 3/8" Square
- Internal Shutter Position: Open/Closed
- Breaker Operator
- Device Panel
FlashGard MCC Bucket Top Shown Upside Down

- Conductor from Stabs to Breaker
- Internal Shutter: Open/Closed
- Visible Stab Disconnect
- Vertical Ground Stabs
- Threaded Screw
- Shutter Position Indicator
- Bucket Position: Connected/Disconnected
- RotoTract Insertion Point 3/8” Square

© 2013 Eaton. All rights reserved
RotoTract Stab Assembly
How it Works

Stabs Extended  Stabs Withdrawn

Note: The shutters close and create a physical barrier between the stabs and the bus.

Loadside Load Stab Assembly

- Male side located in rear of unit
- Female side located in structure
- T-lead connections are landed in the vertical wireway
  - Provides one-time connection of T-leads
  - Prevents the need to disconnect them each time the unit is removed from the structure
The FlashGard features multiple safety interlocks that prevent the bucket from being pulled while power is applied.

Breaker cannot be turned on until this latch is in this position – locks unit in structure.

This latch locks the unit in the structure and also prevents the unit from being installed while the stabs are extended.

Breaker cannot be turned on until a stud (present on unit’s door) makes contact with this interlock.
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
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.
Choosing Type 2 Protection for Motor Controllers

Type 1 Protection of Motor Starters

• 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.
Type 2 Protection of Motor Starters

• 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
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
During the studies and tests conducted by Eaton, 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.
Selecting Arc-Resistant Switchgear

Highest pressure at first ½ cycle of arcing fault

Illustration of a three-phase internal arc fault.
A) Short circuit current    B) Arc Voltage    C) Dynamic pressure inside the cell
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.
Evaluate Interrupting Ratings
New & Existing Installations

- **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 the system
Interrupting Rating Misapplication (videos)

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

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

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 Interrupting Ratings
New & Existing Installations

- New installations
  - Ensure adequate circuit breaker and fuse interrupting ratings
  - Plan for future increased available short-circuit current
- Existing installations
  - Electrical system changes may result in higher available short-circuit currents
  - Existing circuit breakers and fuses 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
Selecting rejection-style (Class J, R, T, L) fuses

Rejection-style Class J, CF 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
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.
Safety By Design: new or existing installations

Objectives

1. Discuss the role that design can play in eliminating or reducing electrical hazards

2. Explain that overcurrent protective device (OCPD) time-current characteristics are an important consideration in regard to arc flash hazards

3. Identify equipment/options that eliminate/reduce electrical hazards

4. Identify safety design layout methods that can enhance electrical safety
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 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
If work needs to be performed in feeder equipment:

1. Open and lock out 2000A Main
2. Complete procedures to put feeder equipment in electrical safe work condition

Result: feeder equipment has no arc flash hazard or shock hazard
Divide Larger Loads/Feeders into Smaller Ones

28,000A Available Short Circuit Current

22.71 Cal/cm² @ 18” Incident Energy

MCC

M M M M M M

1600A

800A

MCC

M M M

M M M

M M M

28,000A Available Short Circuit Current

1.22 Cal/cm² @ 18” Incident Energy

MCC

M M M

M M M

M M M

© 2013 Eaton. All rights reserved
• 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

Resistor Keeps Arcing Current Low: 5 Amps or So

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

High magnitude L-L or L-L-L arcing faults can still occur (resistor now not in fault current path)
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.
Safety By Design: Summary

What can the contractor do to achieve safety by design?
Safety By Design: Summary

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

- Key factors to reduce arc-flash injuries
  - Equipment options to reduce or prevent occurrence
  - Reduced arcing time
  - Limiting arcing current
  - Increased working distance
  - Easily accessible disconnecting means (lockout/tagout)

- Key factor to reducing shock and electrocution
  - Finger safe construction, covers, barriers
  - Increased working distance
  - Easily Accessible Disconnecting Means
QUESTIONS?
Question: LO 1

Q1: By implementing design for safety it may be possible to design a system where a hazard can be eliminated or significantly lessened.
   a. ____ True
   b. ____ False

Q2: NFPA 70E Informative Annex O Safety-Related Design Requirements recommends the designer compare various design options for the effect to the ____________ and then use this data for consideration in the system design.
   a. ____ system stability
   b. ____ protection of components
   c. ____ shock hazard and arc flash hazard
Question: LO 2

Q1: What technologies may mitigate arc flash hazards to lower levels when using circuit breakers.

a. _____ Zone selective interlocking (ZSI)
b. _____ Arc reduction maintenance switch (ARM)
c. _____ Slash voltage rating

Q2: Which is not common practices for fuses when considering arc flash hazards.

a. _____ For new and existing installations use fuses with low interrupting ratings because they let-through low levels of arc flash energy.
b. _____ For new installations, the selection of the fuses based on it’s current ability may mitigate the arc flash hazard to much lower levels

c. _____ For existing fusible systems, upgrading to newer versions of current-limiting may mitigate the arc flash hazard to lower levels.
Question: LO 3

Q1: The following equipment/options may help eliminate or reduce electrical hazards a worker must face: remote racking of circuit breakers, remote MCC buck insertion/extraction, arc resistance switchgear, finger-safe products, overcurrent protective devices with the proper interrupting ratings, and IR scanning windows

a. ____ True
b. _____ False

Q2: Remote monitoring is an good design for safety feature because a manager can get access to the various measured electrical parameters without being exposed to electrical hazards while a worker is doing the diagnostic or troubleshooting on energized equipment with the doors opened.

a. ____ True
b. _____ False
Question: LO 4

Q1: Design for safety includes considering various alternatives for laying out the system and evaluating these alternatives for electrical hazards. It might include considering main overcurrent protective devices rather than the six disconnect rule and putting the service disconnect and overcurrent protective device in a separate enclosure from the feeder devices.

a. _____ True
b. _____ False